

**PRIME MINISTER'S SCIENCE, ENGINEERING AND
INNOVATION COUNCIL**

NINTH MEETING – 5 December 2002

AGENDA ITEM 5

BEYOND KYOTO - INNOVATION AND ADAPTATION

Executive Summary

Scientific studies show that levels of atmospheric greenhouse gases are rising as a result of economic growth and will lead to global warming and resultant climate change. Even with significant future global reductions of emissions it is expected that most of Australia will warm 0.4° to 2°C by 2030 and 1° to 6°C by 2070. These changes are likely to result in increased pressure on water resources, increased intensity of tropical storms, increased bushfire risk, damage to ecosystems and threats to human health.

A better understanding of climate change and climate change impacts are required to help Australia adapt to the impacts generated by the expected changes in climate.

Australia is responsible for approximately 1.5% of global emissions and cannot on its own influence the long term impact of climate change. However, as one of the world's highest per capita emitters of greenhouse gases and with a growing economy highly dependent on high quality, cost effective fossil fuels, there are strong local and international political incentives for Australia to seek to lower its greenhouse signature.

Stationary energy production and use is responsible for around 50% of Australia's emissions. While there are a number of current and future technologies which offer the prospect of low or zero emissions, in the foreseeable future there are no options which offer large scale emission reduction at a price comparable with current coal-based energy sources under current economic circumstances. However, there are some options that have the potential of dramatically reducing Greenhouse Gas (GHG) emissions for a modest increase in the cost of energy. Of these options the production of electricity using coal gasification and sequestration of CO₂ in geological structures appears to offer the best chance of large scale GHG mitigation. In addition, a mixture of low emission energy sources will be required to address a diverse range of changing energy needs. To accelerate the development and adoption of low emission technologies it will be necessary to increase the

focus of research on energy and provide incentives to adopt new technologies.

Australia's road transport sector is another major source of emissions producing about 14% of net national emissions. Petroleum will continue to be the principal transport fuel until at least 2025 and emissions will grow in line with economic growth. Reductions in emissions growth can be achieved through incremental changes to vehicle efficiency and improved transport management systems. There may also be some prospect for mitigation through the use of alternative fuels or retrofitted systems that recover energy on deceleration. The extent of mitigation in the transport sector will depend on many factors, including the rate of uptake of new technologies.

Australian agriculture and land management producing about 18% of net national emissions are the other major source. The natural complexity and diversity of agricultural systems make it difficult to clearly identify the cost and impact of possible abatement measures.

Recommendations – Adaptation

- Enhance Australia's ability to predict climate change at the national, regional and local level.
- Identify areas of industry, ecosystems, built environments and society where climate change is expected to have a significant disruptive or damaging impact.
- Assess the nature of climate change in high risk areas and where appropriate develop and implement adaptation strategies.

Recommendations – Reduction of Energy Emissions

- Establish a national program to scope, develop, demonstrate and implement near zero emissions coal based electricity generation.
- Identify energy options resulting in low greenhouse emissions as a national research priority.
- Provide incentives for the adoption of abatement measures along similar lines for the incentive for renewables.
- Accelerate the adoption by energy consumers of low energy use devices and processes and the use of cost-effective alternative energy sources.

Recommendations – Reduction of Transport Emissions

- Identify and evaluate options to accelerate the adoption in Australia of technologies to improve fuel efficiency.
- Promote and encourage reduction of emissions through the deployment of intelligent transport systems technology, in particular for management of central city congestion through pricing arrangements.
- Assess Australia's future transport fuel mix options and associated infrastructure requirements.

Recommendation – Reducing Agriculture and Land Management Emissions

- Develop and implement a research plan aimed at better understanding agricultural emissions and identifying opportunities for cost effective mitigation.

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2. TERMS OF REFERENCE & MEMBERSHIP OF THE WORKING GROUP

2.1 Terms of Reference

A Working Group be formed to provide the ninth meeting of PMSEIC with a strategic view of how science, engineering and technology can best be adapted or developed by Australia to:

1) As part of Australia's mitigation strategies identify opportunities to utilise and develop emission reduction technologies which build on and promote Australia's competitive advantage in the energy and other industry sectors which are major sources of greenhouse emissions. The identification of opportunities is likely to have three distinct themes as set out below.

- opportunities to reduce the emissions arising from existing carbon-cycle based activities;
- opportunities to utilise existing non carbon-cycle technologies as practical future energy sources;
- opportunities for research and development which can lead to new zero-emission energy sources capable of exploitation by Australian industry and energy consumers.

2) As part of Australia's adaptation strategies identify technology strategies and research activities which will assist Australian industries and communities to identify and adapt to the expected impacts of climate change.

In preparing this strategic view it is envisaged that the Working Group will undertake the following activities:

- assess the relevance to Australia of existing, emerging and future developments in science and technology in areas such as energy production, transport, climate change science, and agriculture;
- review the Australian situation in regards to the nature and trend of greenhouse gas emissions and the identification of any unique characteristics or problems;
- review the capabilities of the Australian science engineering and technology base in terms of its ability to adapt and develop identified opportunities for Australia;
- review opportunities for engagement with industry and for international collaboration and co-operation; and
- identify potential risks and barriers associated with the development and implementation of identified new technologies.

2.2 Membership

Chair	Professor Chris Fell
Members	Mr Stuart Beil, Universal Carbon Exchange/CSIRO Mr David Cain, Rio Tinto Ltd Dr Colin Grant, Bureau of Rural Sciences Professor Paul Greenfield, University of Queensland Dr John Wright, CSIRO

2.3 Technical and Secretariat Support

The Working Group acknowledges the invaluable administrative and technical support provided to the group by representatives of the Australian Greenhouse Office, the Bureau of Transport and Regional Economics, the Department of Agriculture, Fisheries and Forestry - Australia, the Department of Education, Science and Training, and the Department of Industry, Tourism and Resources.

The Working Group would also like to acknowledge and thank the many organisations which made formal presentations and / or provided information.

3. THE NEED TO REDUCE GREENHOUSE GAS EMISSIONS

Scientific studies show that levels of atmospheric greenhouse gases are rising and will lead to climate change. There is some debate about the causes of rising atmospheric greenhouse gas levels but scientific studies show that human activity, particularly the burning of fossil fuels and the consequent emission of large amounts of carbon dioxide (CO₂), is a major contributor.

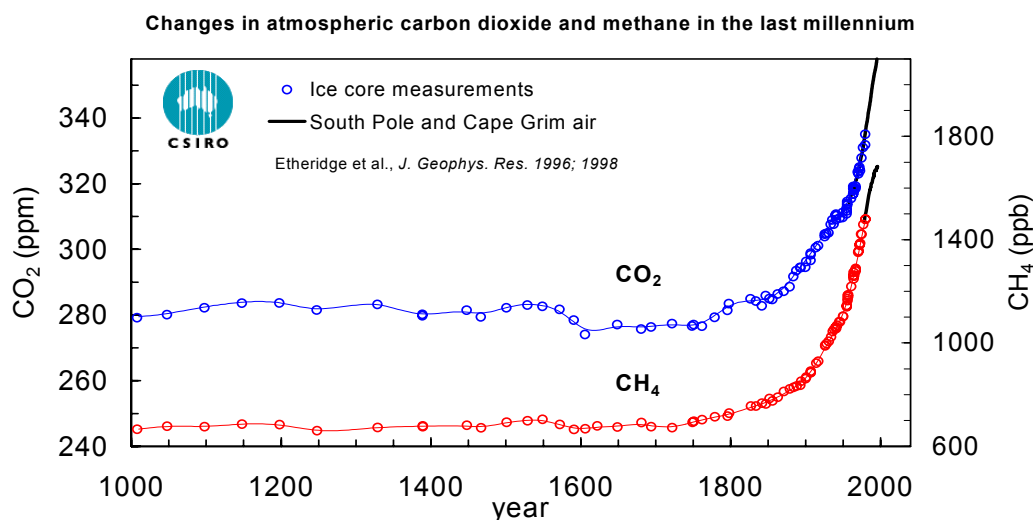


Figure 1. Changes in atmospheric carbon dioxide and methane over the last millennium

Predicting the degree of global warming and its impact on climate change is very difficult owing to the complexity of the systems involved. However, results from the Intergovernmental Panel on Climate Change (IPCC) Third Assessment Report¹ indicate that at a global level, averaged surface temperatures are projected to increase by between 1.4° and 5.8°C in the period 1990 to 2100. The latest CSIRO projections² indicate that most of Australia will warm 0.4° to 2°C by 2030 and 1° to 6°C by 2070. Assessments by the Australian Greenhouse Office (AGO)³ suggest these changes are expected to result in increased pressure on water resources, increased intensity of tropical storms, increased bushfire risk, damage to ecosystems and threats to human health.

In light of these predictions it is now generally accepted that global limits need to be placed on the concentration of greenhouse gases in the atmosphere. This is the objective of the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol.

¹ available online at http://www.grida.no/climate/ipcc_tar/

² available online at www.dar.csiro.au/publications/projections2001.pdf

³ available online at www.greenhouse.gov.au/international/third-comm/chapter6.html

3.1 Targets and Timetables for Emissions Reductions

Concerns about the potential impact of climate change arising from a rapid increase in the concentration of greenhouse gases in the atmosphere resulted in the widespread adoption in 1994 of the United Nations Framework Convention on Climate Change (UNFCCC)⁴. Arising from this Convention were short term goals such as the Kyoto Protocol which sought to achieve by around 2008-2012 a reduction in the greenhouse emissions of developed countries to levels 5% below their emissions in 1990.

However, looking beyond Kyoto, the ultimate goal of the UNFCCC is the “...stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.”

In practice, climate change science and the understanding of climate change impacts on ecological systems is not sufficiently well developed to determine what concentration of atmospheric greenhouse gases would result in “dangerous anthropogenic interference with the climate system”.

Nonetheless it is clear that atmospheric concentrations of greenhouse gases are growing in line with global economic growth and a continuation of this trend could lead to concentrations which are several times higher than pre-industrial levels over the next century. Scientific modelling suggests that concentrations of this level would have serious climate change implications. Accordingly, the scientific community has attempted to define a concentration level and time-frame to provide a reference point for emission reduction strategies. Although subject to considerable debate there is general acceptance that an appropriate reduction target is to seek to stabilise atmospheric concentrations at or below double the pre-industrial levels by early next century.

In adopting this target it needs to be recognised that a reduction in greenhouse gas emissions will not immediately lower overall atmospheric levels of greenhouse gases. The removal of CO₂ from the atmosphere by natural processes is very slow. Even with a progressive reduction in emission intensity over the next century, the combination of global economic growth and the long run stability of atmospheric CO₂ concentrations will ensure that significant global warming and as a consequence, climate change, will occur.

For example, a range of models indicate that overall global emissions in 2100 may need to be reduced to 50% of current levels to achieve long term stabilisation of CO₂ concentrations at twice pre-industrial levels. Although this level of reduction can be achieved with a net cumulative reduction in global emissions of less than 1% per annum the target is a major challenge for a

⁴ available at <http://unfccc.int/resource/convkp.html>

growing world economy. In practice, reductions in emissions are unlikely to be smooth and there will be a need for technological innovation to achieve major cost-effective reductions in the emission intensity of key human activities. Furthermore, given that much of the growth over the next century is expected to occur within developing economies, and it is unlikely that these countries will take part in the greenhouse gas reduction process under the present international mitigation circumstances, it follows that the bulk of the early reductions will need to be made by the large developed economies - at least in the initial decades of the century. Also, given the stability of atmospheric CO₂ and other greenhouse gases it is desirable to make an early start in appropriate enabling technologies is necessary.

4. GLOBAL GREENHOUSE EMISSIONS - SOURCES AND TRENDS

The collection and analyses of emissions data is subject to much uncertainty. Emissions from sectors such as electricity generation can be estimated with some accuracy owing to the relatively simple relationships between energy outputs and emissions. On the other hand, the complex biological, chemical and physical processes which influence the nature and rate of emissions from sectors such as agriculture and waste management preclude simple and accurate estimation.

Nonetheless, the reporting framework of the UNFCCC does provide a comprehensive picture of the distribution of global emissions and the relative mix of sources. This framework indicates that the major industrialised nations of Western Europe, the USA, and the former Soviet Union and Eastern Europe currently account for around 65% of greenhouse emissions. However, the dominant role of these economies as greenhouse emitters is expected to diminish as the economies of large developing countries expand. Australia with around 1.5% of global emissions is not a significant generator of emissions in a global context - however, consistent with its status as a developed, energy intensive economy, it does exhibit high levels of emissions on a per capita basis.

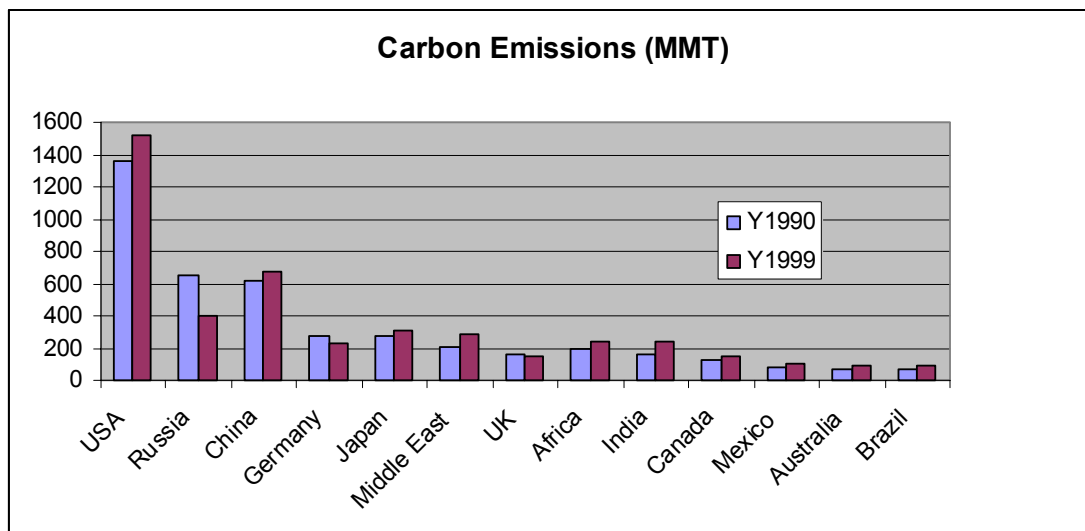


Figure 2. International carbon emission trends between 1990 and 1999

On the basis of volume, CO₂ from the burning of fossil fuels for energy accounts for around 56% of global emissions of greenhouse gases. The other major contributor is agriculture and land use which comprises around 29% of global emissions. Currently oil provides around 41% of global energy needs while coal and natural gas provide around 27% and 22% respectively. Only 10% of energy needs are currently generated by non fossil sources.

The importance of energy production as a source of greenhouse emissions will steadily increase over the coming decades. According to the World Energy Council, global energy demand is expected to grow by 50% by 2020 or about 2% per annum on a compound basis - chiefly as a result of economic growth in the developing countries. Under current government policy settings, few cost effective alternative technologies are available making coal and natural gas the likely sources of energy to provide much of the world's growth in energy needs over the next few decades if not the remainder of the century.

5. AUSTRALIAN GREENHOUSE EMISSIONS – SOURCES, TRENDS AND ABATEMENT ACTIVITIES

Details of Australia's emissions of greenhouse gases are described in the 2000 National Greenhouse Gas Inventory (NGGI) published by the Australian Greenhouse Office⁵. Although working to well defined protocols, it is understood that the methodology for estimating and measuring emissions is still evolving. Accordingly, and in common with global estimates, it is likely that the estimates in sectors such as agriculture are subject to considerable uncertainty.

A summary of the NGGI indicates that Australia's net greenhouse emissions were around 535.3 million tonnes of CO₂ equivalents in 2000. A figure which represents 27.9 tonnes per capita or around 0.85 tonnes per \$1000 of GDP. Carbon dioxide accounts for over 70% of Australia's emissions. Methane and nitrous oxide generate around 22% and 5% of effective emissions respectively.

As shown in Figure 3, the NGGI data shows that energy is the principal source of Australia's greenhouse emissions and also exhibited the highest rate of growth in emissions for the period 1990 to 2000. The other major sources of emissions are the transport and agricultural sectors.

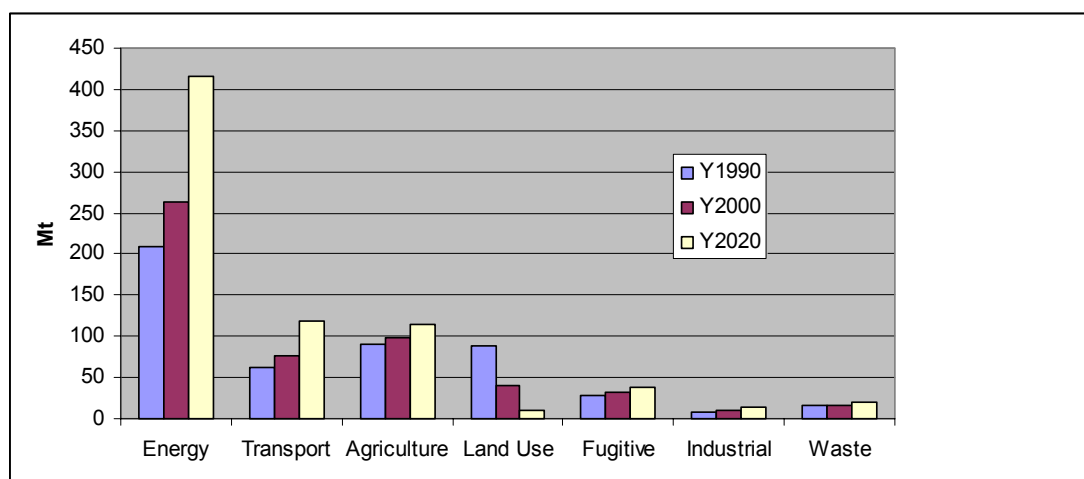


Figure 3. Past and future emissions (assuming 1990-2000 rates of emissions growth continue to 2020)⁶

⁵ Australian Greenhouse Office, Canberra, (2002), *National Greenhouse Gas Inventory Analysis of Trends and Greenhouse Indicators 2000*

⁶ Based on Australian Greenhouse Office, Canberra, (2002), *National Greenhouse Gas Inventory, Analysis of Trends and Greenhouse Indicators 2000*

Figure 3 also indicates the emission levels for the various sectors based on a continuation of the growth trends for the period 1990 to 2000. In practice, this extrapolation overestimates the growth in emissions. Consistent with world trends, and reflecting the impact of technological evolution and structural change, there has been a steady reduction in Australia's emission intensity. As shown in Figure 4, this is reflected in declining rates of greenhouse gas emissions per \$ of GDP. However, the emission intensity of the energy sector has remained reasonably constant.

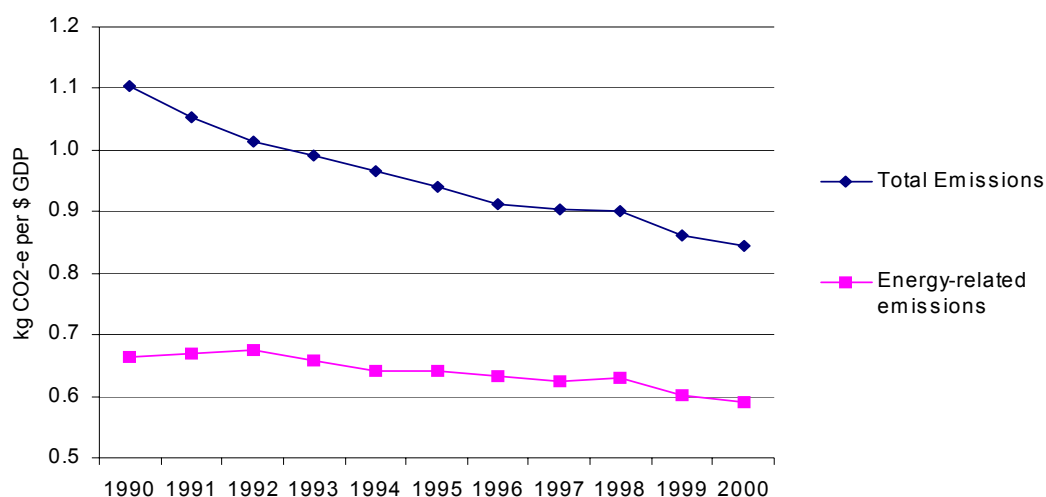


Figure 4. Greenhouse gas emissions per \$ of GDP⁷

5.1 Summary of Emissions Characteristics

Stationary Energy Sector (49.3%)

Stationary energy comprises electricity generation and other energy consumed in heating and manufacturing. Around 66% of energy emissions arise from the generation of electricity and involves a relatively small number of emission sources. The predominant fuel used in generation of electricity is coal.

Stationary energy emissions are predominantly CO₂. Emissions from energy grew by 2.3% in the period 1990 to 2000 and the Australian Bureau of Agricultural and Resource Economics (ABARE) estimates that demand for electricity in Australia will increase at more than 2.5% per annum to 2020.⁸

Transport Sector (14.3%)

Road transport vehicles produce over 90% of transport emissions. Most

⁷ Australian Greenhouse Office Canberra, (2002), *National Greenhouse Gas Inventory Analysis of Trends and Greenhouse Indicators 2000*

⁸ ABARE, Canberra (2001), *Australian Energy Projections*

emissions are predominantly CO₂ but include small amounts of nitrous oxide and methane. In the period 1990 to 2000 emissions from transport grew by 2.2% per annum.

The Bureau of Transport and Regional Economics (BTRE) anticipates that non-bulk freight transport in Australia will double by 2020 and that overall growth in transport demand will grow by around 30% in the same period. A factor influencing the growth in transport demand is the saturating demand for cars.

Agriculture (18.4%)

The principal source of emissions in agriculture arises from methane generated by the digestive processes of livestock and the loss of nitrous oxide from soils. The reliability of estimates for agricultural emissions is considered low owing to the complex biological, physical and chemical processes involved. Emissions were estimated to decline by 3.8% during the period 1990 to 2000 due to a 30.5% reduction in sheep numbers.

Land Use Change and Forestry (7.1%)

Activities in this sector lead to both sources and sinks of CO₂. Like the agricultural sector, the reliability of land use emissions estimates is considered low. In year 2000, forestry comprised a net sink of 4.4% and land clearing a net emission of 11.5% of national emissions respectively. Overall, emissions from land use and forestry have been estimated to have contracted by 7% per annum during the period 1990 to 2000.

Industrial Processes and Waste Management (5.0%)

Emissions from this sector involve a large number of different sources and emission processes. Waste emissions are principally methane arising from decomposition of organic material.

5.2 Principal Targets for the Reduction of Greenhouse Emissions

There are a number of factors which need to be considered when identifying appropriate targets for the reduction of greenhouse gases. The relative size and future growth prospects of different sectors are important considerations if major and ongoing reductions are to be achieved. On the other hand the relative cost and technical feasibility of abatement are important considerations. Although there is not sufficient information to properly assess abatement options across the various sectors it is clear that the principal targets are energy and transport. Both sectors are large sources of emissions, have high growth rates, and have technologies which are relatively uniform and well understood. In contrast, although the emissions from agriculture and land management are greater than those from transport, abatement of these emissions involve complex interactions which are not yet well understood. An important additional feature of the energy sector is the high concentration of emissions in a relatively few sources. A focus on

energy, transport and agriculture is also important in the Australian context owing to the critical role which these sectors play in underpinning the wealth and competitive advantage of the nation.

The emissions from agriculture could be considerably larger than currently thought due to the uncertainty of emissions estimation in this area. Furthermore there is strong evidence that a reduction in agricultural emissions would also deliver considerable productivity gains. On the other hand, the widely dispersed nature of the sources and the variability of conditions controlling emission levels are likely to complicate the development, cost and implementation of innovative technologies.

In light of the emissions characteristics of the various sources, the Working Group considers that stationary energy, transport and agriculture be the principal focus of mitigation activities – particularly those requiring a significant investment in technological innovation.

5.3 Current Greenhouse Gas Abatement Activities and Programs

Australia is undertaking a range of activities to reduce greenhouse gas emissions.

- The \$180 million climate change package, *Safeguarding the Future: Australia's Response to Climate Change*, committed by the Commonwealth Government in November 1997, contains programs aimed at promoting and enhancing renewable energy sources and energy market reform. The package also included strategies to decrease emissions from motor vehicles through fuel efficiencies, and investment in planting of trees to absorb carbon dioxide. Implementation has been principally through the Australian Greenhouse Office.
- The *Greenhouse Challenge* - a joint voluntary initiative between the Commonwealth Government and industry to abate greenhouse gas emissions - now has several hundred members. The challenge has also helped build the capacity of both government and industry to identify, monitor, manage and report greenhouse gas emissions.
- The *National Greenhouse Strategy*, released by the Commonwealth, State and Territory governments in 1998, provides a framework for action by all levels of government. Implementation plans have been prepared for this strategy which focuses action on three fronts—improving awareness and understanding of greenhouse issues; limiting greenhouse gas emissions; and developing adaptation responses.
- The Commonwealth Government's \$400 million *Greenhouse Gas Abatement Program* (2000), further assists Australia to meet its target of limiting greenhouse emissions to 108% of 1990 levels over the period 2008 -2012. The Program aims to deliver cost-effective and large-scale abatement across all sectors of the economy.

The Program is one of several major greenhouse initiatives included in the revised tax system package, *Measures for a Better Environment*. Other initiatives include renewable energy generation, alternative fuels use, and household energy reduction. The total funds for Australian greenhouse response actions amount to nearly \$1 billion.

6. ADAPTING TO CLIMATE CHANGE

Based on the assessment of a number of emissions scenarios from high fossil fuel use to a change to predominantly no fossil fuel use, the Intergovernmental Panel on Climate Change (IPCC)⁹ has projected that global average temperature increases of between 1.4 and 5.8 °C by 2100 are possible. Implications of these projections on a global scale are:

- sea level will rise by 9 to 88 cm relative to 1990;
- precipitation is likely to increase over the northern to mid high latitudes; increased extreme events (droughts, tropical cyclone intensity) are likely over some areas;
- significant changes to snow cover and ice extent;
- a weakening of the large-scale density driven circulation in the ocean could be evident.

Translation of these scenarios to Australia indicates this country is expected to experience overall warming of from 0.4°C to 2°C by 2030 and 1°C to 6°C by 2070.

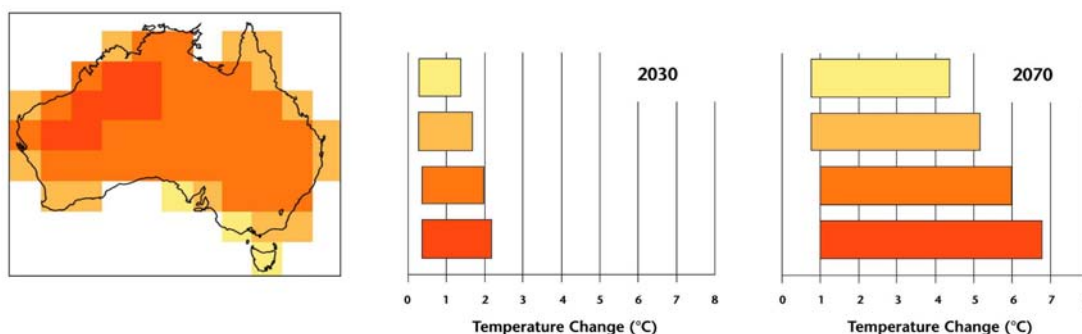


Figure 5. CSIRO estimates of average warming (°C) for around 2030 and 2070 relative to 1990. Coloured bars show changes for areas with corresponding colours on the map.¹⁰

These projections provide a starting point for most climate change impact studies undertaken in Australia. These studies indicate that climate change for Australia is inevitable and is expected to result in the following outcomes:

- more evaporation, more hot days and fewer cold days;
- rainfall decreasing in the south and east (mainly winter/spring);
- some inland and eastern coastal areas experiencing wetter summers; and
- extreme rainfall and tropical cyclones becoming more intense.

⁹ McCarthy JJ, Canziani OF, Leary NA, Dokken DJ & White KS. (2001), *Climate Change 2001 – Impacts, Adaptation and Vulnerability*. Intergovernmental Panel on Climate Change

¹⁰ Whetton, (2001), *CSIRO Climate Change Projections for Australia*.

Identifying the likely impacts on Australia's economic, environmental and social systems is an extremely complex problem – particularly given Australia's naturally occurring large climate variability.

6.1 Potential Climate Change Impacts

Identifying the likely impacts of climate change for regions and sectors of Australia is an extremely complicated task. There are two basic issues: a lack of ability to accurately predict climate change at a regional level; and a lack of understanding of the adaptive ability of the various ecosystems and economic activities involved. Furthermore, the impacts are likely to occur over a long time period, local factors will have a major influence on climate outcomes, the impact of climate change may be masked by natural variability, and technological innovation may moderate the impact of climate change. For example, advances in weather forecasting leading to increased predictability of rainfall on a regional basis may result in improvements in agricultural productivity even though there may be an overall reduction in rainfall. On the other hand, damage to ecosystems such as coral reefs may be inevitable and unavoidable.

However, even with a limited capability to predict the timing and extent of potential climate change impacts it is possible to identify a number of economic, environmental and social areas which appear to be highly sensitive to climate change impacts. A recent study by the Intergovernmental Panel on Climate Change identified a number of areas where Australia was vulnerable to climate change. The probability of impact in some of these cases was considered to be high.

Water Supply and Hydrology

Australia's water supply and hydrology systems are likely to be affected by the projected drying trends over much of the continent. The impact of this drying may have implications for the capacity of water storage systems and the increased incidence of drought on broad acre farming. Other potential impacts are increased soil salinity problems and possible contamination of water resources through eutrophication (for example, increased incidences of algae blooms).

Changes in water supply and hydrology will occur slowly and it is likely that appropriate responses can be assessed through better knowledge of the impacts and responses to normal rainfall variability.

Natural Ecosystems

Ecosystems that are particularly vulnerable to climate change include coral reefs, arid and semi-arid habitats in south-west and inland Australia and Australian alpine systems.

The principal issue concerning the impact on ecosystems will be the adaptive capacity of the systems and the species involved. Again, what if any response can be developed to address vulnerability can be assessed through increased knowledge of the impact on ecosystems of normal rainfall climatic variations.

Agriculture and Forestry

Predicting the likely impact of climate change on agriculture is complicated by a need to understand the interrelationships between declining rainfall and increasing temperature as well as other factors such as growth stimulation of increasing CO₂ levels, and the possibility of changes to the prevalence of pests and weeds. An assessment of agricultural impacts will need to be on a region by region basis.

Ocean Productivity and Fisheries

The productivity of Australia's ocean industries depends on the complex interaction of ocean currents and the distribution of Antarctic and other nutrient systems. It is expected that long term climate change will influence the behaviour of ocean currents and temperatures. Such changes could have a profound impact on fish stocks in Australasia. However, little is known about the nature of these changes and their impact on ocean productivity.

What, if any, response can be developed to address the vulnerability of ocean productivity can only be assessed through greater knowledge of the impact of climate change on ocean systems and of the relationship between ocean systems and Australia's ocean resources.

Settlements and the Built Environment

The impact of climate change on the built environment has a number of dimensions. The increased incidence of cyclones, flooding and bushfires all have implications for the integrity of structures and infrastructure, insurance and finance risk, and urban planning. On the other hand, warmer conditions can alter the nature and demand for energy, loss of snow in alpine areas and threaten unique biosystems with direct implications for the attractiveness of Australia as a tourist destination.

The impact of climate change on the built environment will occur slowly and it is likely that appropriate responses can be assessed and developed through better knowledge of the impacts and responses to normal climate variability.

Human Health

Climate change has the potential to impact on human health in a number of ways. Increased incidence of heatwaves, flooding and cyclones will increase injury and deaths. There is also a strong expectation that climate change will increase the potential for mosquito borne diseases.

In these circumstances it may be necessary to develop and implement major health programs based on detailed analyses of the problems and impacts.

6.2 Adapting to Climate Change Impacts

It seems inevitable that Australia will experience climate changes over the next century as a result of rising atmospheric greenhouse gas concentrations. Research also suggests that certain industries, ecosystems and indeed public health and infrastructure may be vulnerable to damage as a result of changed climatic conditions.

Factors which will determine what, if any, responses are appropriate to address these expected impacts are:

- capacity to identify vulnerable sectors in terms of economic, social or environmental implications;
- capacity to understand the underlying science linking climate change to climate change impacts; and
- capacity to define the timing and extent and rate of change of impacts.

In general, our understanding of climate and environmental systems is not adequate to confidently predict climate change impacts. Furthermore, any impacts will occur over a long period of time and will be superimposed on natural climatic variability. In these circumstances it is inadvisable to draw conclusions about climate change impacts and possible responses without a very clear and confident understanding of the issues.

On the other hand, it is likely that climate change impacts will have a range of economic, social and environmental impacts with the potential to cause significant economic and social disruption and environmental damage. A carefully structured adaptation strategy has the ability to minimise the impact of climate change by appropriate timely intervention.

Accordingly, it is recommended that adaptation be framed around a long term strategy based on increasing our understanding and increasing our ability to identify and understand areas vulnerable to climate change.

Recommendations

Enhance Australia's ability to predict climate change at the national, regional and local level.

Identify areas of industry, ecosystems, built environments and society where climate change is expected to have a significant disruptive or damaging impact.

Assess the nature of climate change in high risk areas and where appropriate develop and implement adaptation strategies.

7. REDUCING EMISSIONS IN THE ENERGY SECTOR

The principal driver of emissions in the energy sector has been economic growth. According to ABARE¹¹ a 1% increase in GDP increases energy consumption by around 0.5%. On the other hand the emission intensity of energy production has declined as a result of improvements in the efficiency of production and use of energy as well as the growing use of lower emission sources such as natural gas and renewables.

Emissions in the stationary energy sector are dominated by electricity production (47%). Other sources of emissions include the use of natural gas and other fuels for heating and the combustion of a variety of fuels used to provide energy in a wide range of industry sectors other than transport.

Compared to electricity production, the other components of the energy sector are characterised by a large number of widely dispersed, generally small scale sources, which involve a range of different technologies. In these circumstances it is difficult to identify specific technologies where a process of innovation might be expected to achieve significant reductions in greenhouse emissions. On the other hand there are a number of general measures which could be applied across the non electricity sector to reduce emissions.

These measures would focus incentives to replace high with lower emission sources where possible and improve the efficiency of devices which consume energy. Obvious examples are the greater use of natural gas and solar heating devices and the use of energy rating schemes.

These measures alone however cannot respond to the inevitable increases in emissions which will arise from continuing economic growth. However, they will lessen the rate of emissions growth, they have the potential to improve economic efficiency and can promote an innovative sector of the energy industry.

7.1 Electricity Production

Electricity production supplies around 41% of Australia's energy needs and generates 32.7% of national greenhouse emissions. The bulk of Australia's electricity demand is met through a relatively small number of large-scale coal-fired power stations. This outcome reflects the cost-effectiveness of Australian coal and the relatively low cost of modern large scale coal based power stations. Given the wide number of variables it is difficult to make broad cost comparisons between the different sources of energy. However, comparison of data from several sources suggests that natural gas, hydro electricity, and wind power costs are around 1.6, 1.9 and 2.5 times that of black coal. Australian energy is at the low end of comparisons with other developed countries.

¹¹ ABARE, Canberra (2001), *Australian Energy Projections*

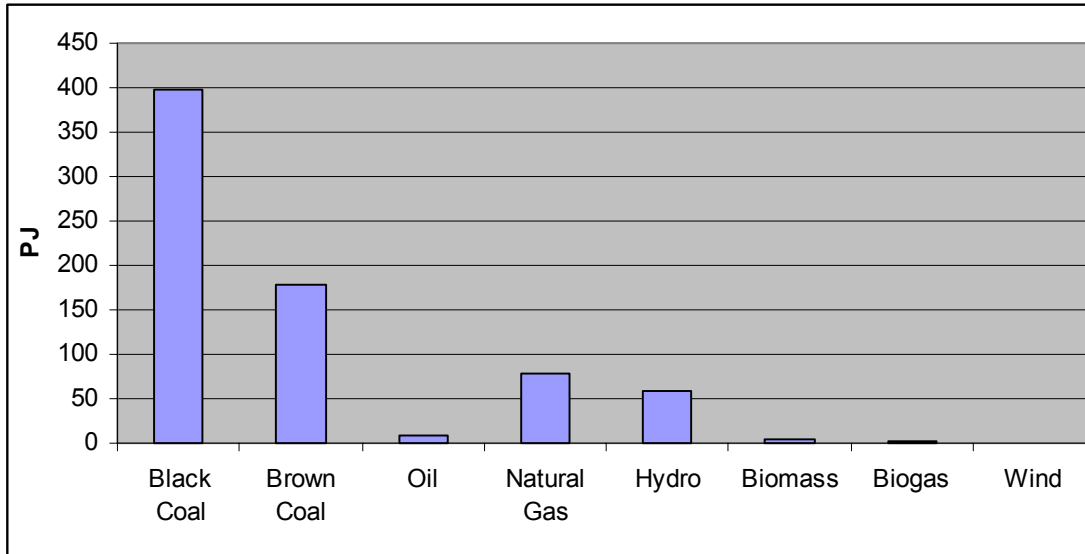


Figure 6. Australian electricity generation, by fuel 1998-99¹²

7.2 Future Demand for Electricity

A comparison of electricity demand forecasts by ABARE¹³ and an assessment of the life of existing generating plant¹⁴ indicate that Australia faces a growing supply gap in terms of generating capacity over the next three decades. The results of this comparison are shown in Figure 7.

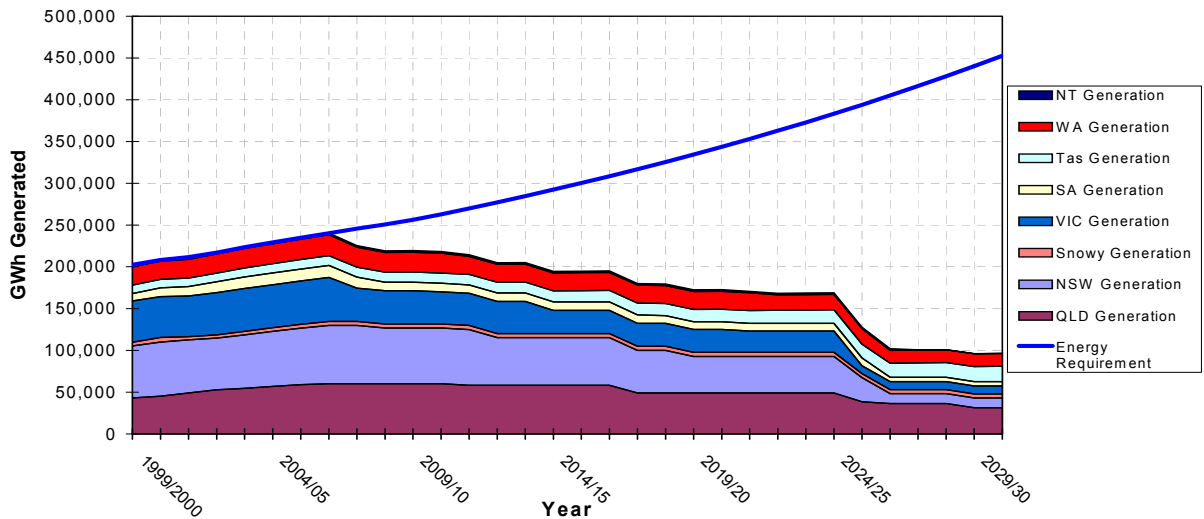


Figure 7. Comparison of Australian energy supply and demand

With power generation plant lives of up to 40 years, these results indicate that a major determinant of Australia’s greenhouse signature over the next century

¹² ABARE (2002) - *Australian Energy Outlook to 2019-20*

¹³ *ibid*

¹⁴ Roam Consulting unpublished data

will be the nature of the power generation equipment installed over the next few decades. This presents both an opportunity and a problem. The opportunity is to adopt an appropriate investment regime to achieve major and ongoing reductions in Australia's greenhouse signature. The problem is to achieve this goal without jeopardising Australia's cost competitiveness as an energy supplier. Ideally, the objective is to position Australia such that increasing international pressure on emissions reductions can be turned to Australia's advantage as a major primary energy supplier.

There are many potential options for reducing emissions. However, the process of significant emissions reductions will invariably involve increased cost and may require the solving of significant technical problems. In essence the options can be looked at in three time horizons: technologies which are currently available; technologies which could be commercialised within 10 to 20 years; and technologies which may be 50 or more years away.

7.3 Current Options – do now

Conventional Coal

Australia's current coal based plants use pulverised fuel technologies and achieve thermal efficiencies of around 33% (this includes both black and brown coal). The thermal efficiency of these plants is an important factor in establishing their greenhouse signature in that a 1% improvement in efficiency will deliver a 2% reduction in emissions. New generations of coal based plants are now offering thermal efficiencies of 42% with an increase up to 55% expected by 2020. In principle, such high efficiency plants offer reductions in emissions of 10-20% at similar cost to existing plants. However, there would appear to be some outstanding technical issues which may delay the development and introduction of these new technologies. Even if efficiency is increased from 42% to 55% this will only deliver a small part of our 50% reduction target by 2100.

Coal Gasification

The use of coal in the integrated gasification combined cycle (IGCC) process has the potential for thermal efficiencies in excess of 50% and the generation of synthesis gas, a mixture of hydrogen and carbon monoxide. Conversion of coal to synthesis gas allows a range of choices from power generation by combined cycle, production of various fuels (like hydrogen or liquid fuels) and / or a range of chemicals. It is possible to produce separate CO₂ and hydrogen streams. This opens up a number of future options including a reduction in pollutants, the possibility of sequestering of the CO₂ to produce a low to zero emissions outcome, and the first steps in the development of the hydrogen economy.

IGCC plants are in operation in a number of countries, but not yet in Australia, but it is understood that the process is approaching cost competitiveness with conventional coal technologies. At this stage there are no IGCC electricity generating plants operating in conjunction with geosequestration technologies

but opportunities for combining these technologies are being considered in the United States.

Near zero emissions technology results in major reductions in greenhouse emissions but for technical reasons does not equate to zero emission.

Natural Gas

The proportion of electricity generated by natural gas has been growing rapidly and is expected to generate over 18% of Australia's electricity by 2020. Natural gas used in sophisticated combined cycle plants is efficient and has the potential to provide significant emissions reductions compared to current coal plants. However, the cost of electricity generated by natural gas plants is up to 60% greater than that of a conventional coal plant. The cost difference is largely attributed to the cost of gas compared to coal. For reasons of relatively low capital cost and the advantages of quick start up times natural gas plants have tended to be used for peaking capacity, rather than base load, at time of high wholesale electricity prices. The potential to use gas in the emerging distributed energy technology offers the prospect of competitive power costs and significantly lower emissions per unit of power generated in situations where the otherwise waste heat is used (combined heat and power situations).

Nuclear

Current nuclear technology provides for zero emissions but suffers from costs of up to more than twice that of coal and contingent safeguard and waste storage problems. There is also a question on the degree of public acceptability in Australia over this form of technology. The Working Group notes from its research that a new generation of nuclear reactors is being developed which should go a long way to addressing the inherent safety concerns about the technology.

Renewable Energy

There are a range of renewable energy technologies including photovoltaics, solar thermal, wind, biomass, hydro, geothermal, and marine-based energy technologies. These technologies are expected to play an increasingly important niche role in Australia's energy mix over the next twenty years. However, their market penetration is currently restricted by cost which is likely to decrease as the technologies mature. Accordingly they are unlikely to be employed on a scale sufficient to achieve major cuts in greenhouse gas emissions in the near future. The cost of renewable energy is generally site specific although an indication of relative cost is shown in Figure 8¹⁵. Wind is a relatively low cost renewable energy technology but the availability of suitable sites with access to the grid will limit its contribution to Australia's electricity supply. The Working Group notes the report by the Australia

¹⁵ A variety of sources including Sinclair Knight Mertz 2000, Where is Renewable Energy Going and unpublished data from Roam Consulting.

Institute on renewable energy suggesting that Australia can get to 70% of its current total using wind and forests but this would involve over 600 massive wind farms and turning over much of our agriculture to forestry. Public acceptability of this direction is questionable.

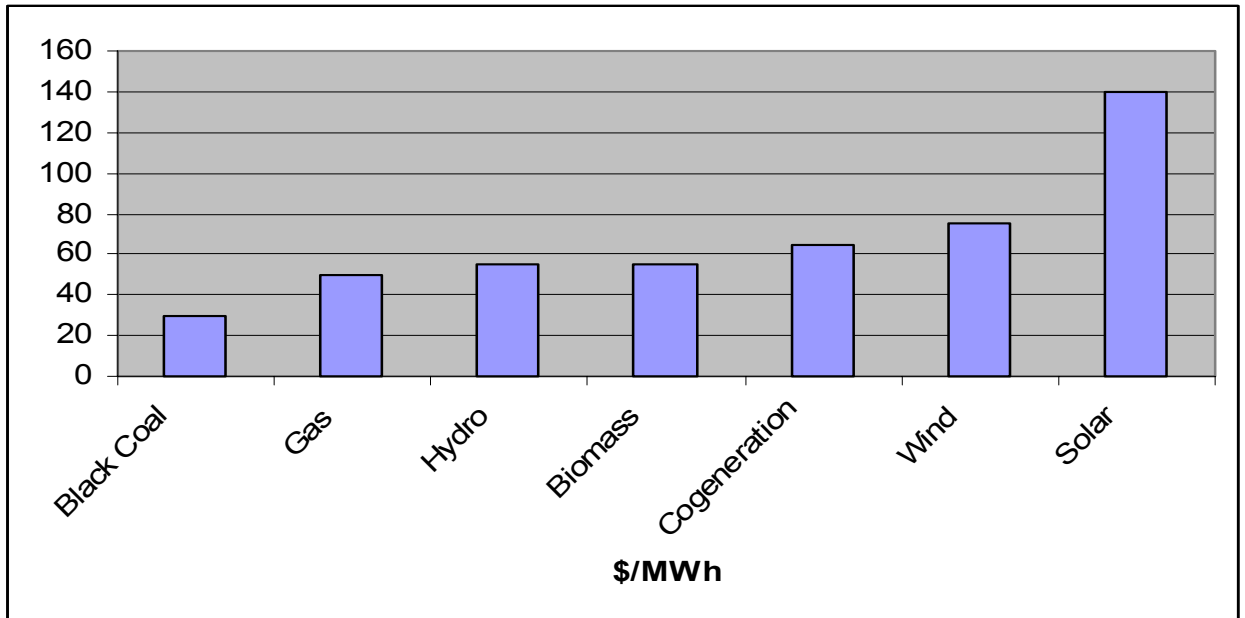


Figure 8. Comparative cost (\$/MWh) of various energy sources

Particular problems with renewable energy sources are their generally low power density and efficiency. These shortcomings result in relatively high costs and restricts the technologies to application in niche markets, particularly in remote areas where the cost of long-distance transmission of centrally generated energy is high. A number of research and development activities are attempting to enhance the efficiency of natural energy collection and conversion processes and reducing costs through innovation and scale. Successful results of this work could create a greater role for renewables in the energy mix. Materials science aimed at reducing weight, increasing conversion efficiency and reducing cost is a critical area of research.

An interesting example of the developments in renewable energy is provided by the “Solar Tower” proposal of EnviroMission Ltd in which it is envisaged that a 90 km² area near Mildura be used to build a collector and a one km high tower to generate 200 MW of electricity.¹⁶

7.4 Emerging Options – will happen within 10 years

Sequestration of CO₂

Providing CO₂ from energy production can be economically captured and concentrated, it seems likely that large volumes of CO₂ can be stored (sequestered) at moderate cost in a range of environments and with low

¹⁶ CL Creations Pty Ltd, (2002), *Sustainable Energy Innovation a new era for Australia*

environmental impact. Possible sites include depleted oil and gas reservoirs, deep saline aquifers and unmineable coal seams. Some estimates of capacity suggest 1800 million years of capacity at current CO₂ production rates. Storage of CO₂ deep in the ocean has also been proposed but technical and environmental problems suggest that this approach is unlikely to be an option in the near future.

Sequestration of CO₂ is already used in the oil industry as a means of enhancing the recovery from oil fields and disposing of CO₂ generated through the extraction of oil and gas. Similarly nearly a million tonnes per year of CO₂ is being injected into a deep saline reservoir in the North Sea in conjunction with production from the Sleipner Vest gas field¹⁷.

In Australia, the potential for geological sequestration has been examined by the Australian Petroleum Cooperative Research Centre's GEODISC project. This program has identified 65 sites which are thought to be environmentally sustainable for CO₂ injection and have the capacity to meet the volume requirements of neighboring CO₂ sources¹⁸. Depending on the method of carbon dioxide capture and transport geosequestration costs have been estimated at from \$10¹⁹ to \$50²⁰ per tonne of carbon dioxide abated²¹. Such figures compare favorably with other options offering large reductions in emissions²².

The principal challenge for geosequestration is to develop cost effective methods of capturing carbon emissions and testing the geosequestration process on a large scale. All indications and trials to date in other countries indicate that sequestration will be technically feasible. The community will need to be satisfied of this feasibility.

Capture and concentration of CO₂ – conventional power stations

Exhaust gases from conventional fossil fuel based power stations contain only a small concentration of CO₂. For example, conventional coal and gas power station flue gases contain around 14% and 4% of CO₂ by volume respectively. There are a number of methods which can be used to generate a concentrated stream of CO₂ from flue gases including solvent extraction. However, these technologies are currently very expensive owing to low concentration and/or gas pressure. Some of the costs of capturing CO₂ from flue gases could be reduced if the concentration of CO₂ in the flue stream was increased. There are a number of ways that this might be achieved including the use of oxygen rather than air and recycling of flue gases with the fuel. Similarly, improvements in the capability and efficiency of membrane and

¹⁷ IEA Greenhouse Gas R&D Programme (2001) *Putting Carbon Back in the Ground*

¹⁸ J Bradshaw, B.E. Bradshaw, G Allinsson, A.J.Rigg, V. Nguyen & L. Spenser.(2002) *The Potential for Geological Sequestration in Australia: Preliminary findings and implications for new Gas Field Development*. APPEA Journal.

¹⁹ Roam Consulting 2002. Unpublished data [Roam changed to Roam – 22 April 2003]

²⁰ IEA Greenhouse Gas R&D Programme (2001) *Putting Carbon Back in the Ground*

²¹ The word “dioxide” was inserted in two places in this sentence on 15 October 2003.

²² Ibid

absorption technologies hold the promise of lower post combustion CO₂ capture in the future.

Combined work by Alstom and the Japanese Government has developed a concentrating device that will help lower capture costs.²³ However, the capture of carbon from flue gases is not considered to be a cost effective abatement option at this time.

Pre combustion capture and concentration of CO₂

Emerging coal-based technologies such as coal gasification offer the prospect of separating the various components of the production process into separate gas streams including a pure stream of CO₂ prior to combustion. A schematic illustration of a gasification and sequestration system is shown in Figure 9.

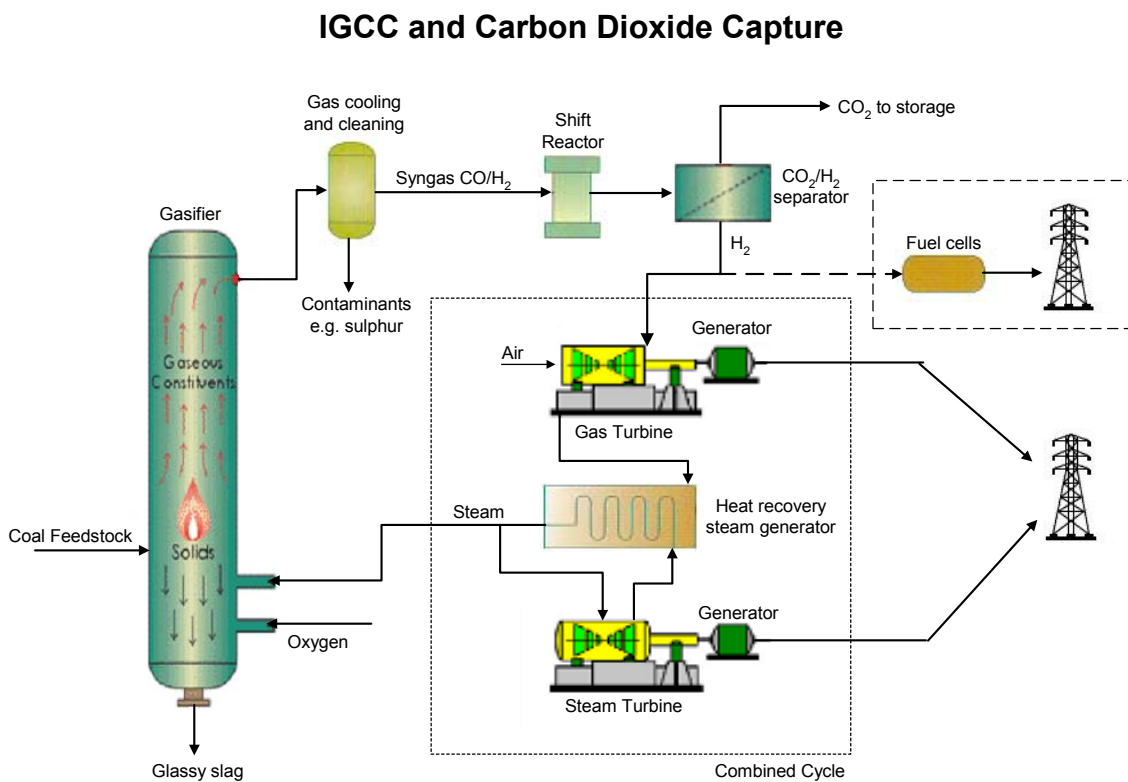


Figure 9. Schematic coal gasification and CO₂ geo-sequestration facility.

In this process the shift reactor produces a pressurised, relatively pure stream of CO₂ that is ideal for sequestration. Given that this process uses an established technology with a cost structure similar to that of conventional generating plants it offers the most cost effective means of carbon capture at this time.

As noted, earlier, coal gasification also offers the potential for the manufacture of liquid fuels and other chemicals as well as electricity.

²³ Y. Shimomura (Alstom) Fukuoka (Nov 2002) *Changes and NewBusinesses brought about by New Technology* Presentation to the 14th Conference of the Electric Power Supply Industry

Brown coal is also suitable for sequestration for this processing route. The higher reactivity of brown coal results in a somewhat cheaper gasification process but the higher moisture content requires more expensive front end processing. Cost reduction for brown coal gasification and CO₂ capture may be quite dramatic if the drying technology being developed by the CRC for Clean Power from Lignite is scaled up and commercialized.

Distributed energy systems

Distributed energy systems are an emerging technology option with the potential for significant emissions reductions, cost savings and the development of innovative modular generation packages. Principally based on natural gas, and applied to electricity generation, heat and cooling, these systems are intended to achieve efficiency savings through the use of otherwise wasted heat and reduced transmission losses. The avoidance of transmission losses and the full use of what would normally be waste heat can boost overall efficiency to more than 80%.

Distributed energy systems allow remote communities to develop a flexible approach to energy built around an efficient mix of energy technologies. In the longer term it is possible that multiple distributed energy sources and loads can be integrated with large centrally-generated sources in a two way grid to maximise efficiency and reduce cost.

The core of the distributed energy systems is a new generation of new small-scale, efficient and environmentally friendly generation sources including improved reciprocating engines, micro-turbines, renewables and fuel cells. The efficiencies of micro-turbines are not particularly high however they do offer potentially low capital and maintenance costs because of the simplicity of the design, low combustion temperatures, suitability for small-scale local cogeneration and lower nitrogen oxide (NO_x) emissions per unit of power produced.

Successful implementation of distributed energy systems depends on further development in the efficiency of microturbines and other small-scale energy conversion devices particularly fuel cells. Upgrading the gas infrastructure network to permit widespread access to high pressure gas would also be required.

Fuel cells

Fuel cells have been in development for many years and offer the prospect of low emission mobile and static power generation provided hydrogen is used.

If fuel cells running off other primary fuels such as natural gas are commercialised there will be limited benefits as converter technology will need to be incorporated to convert the fuel source to hydrogen. Fuel technologies include low-temperature phosphoric acid fuel cells (PAFCs), proton exchange membrane fuel cells (PEMFCs), high-temperature molten carbonate fuel cells

(MFCs) and solid-oxide fuel cells (SOFCs). Their modular characteristics enable them to power individual motor vehicles or dwellings, or by stacking to power a suburb or a large industrial plant. Fuel cell surplus capacity, not needed for local use in vehicles, homes or businesses, can be fed into the grid, earning the owner income or energy credits.

The Working Group notes that commercialisation of fuel cells has been a slow process.

7.5 Future Options – 50 or more years away

There are a number of energy technologies which can be expected to contribute to the fuel mix in the longer term. Many of these technologies offer zero emission capabilities or significantly reduced greenhouse signatures depending on the feedstock for the fuel used. Many are in the early stage of development and it is difficult to accurately estimate energy costs and abatement potential.

Advanced Renewables

It is possible that renewable energy technologies will expand to become a major source of the world's energy. However, this result depends on achieving significant improvements in the efficiency and cost effectiveness of existing technologies and major research efforts in new areas of potential such as artificial photosynthesis. Important research areas include better energy storage devices, new photovoltaic materials, lighter and more efficient wind turbines and improved efficiency of bio-mass energy production.

Hot Dry Rocks

Geothermal resources associated with "hot dry rocks", located at depths of several kilometers, offer the potential of a huge emissions-free energy source - provided technical and cost issues can be overcome. The heat is extracted from these resources by circulating water through fissures in the deeply buried rocks.

Australia is well endowed with these geothermal resources and potential resources are sufficient to more than meet Australia's energy needs. However, the efficiency and cost of extraction are difficult to estimate.

Hydrogen economy

The 'Holy Grail' of global energy is to move to a hydrogen economy and to eliminate air pollution (other than water vapour) from all energy sources. The critical issue is the selection of the pathway by which this goal is attained. Widespread application of fuel cell technology for transport and for distributed generation will act as the spur for the development of a hydrogen production and distribution infrastructure. Hydrogen is likely to be produced from fossil fuels initially, and then finally through electrolysis of water using renewable or nuclear energy sources.

There is also active research on the possibility of hydrogen production from biological sources and there is also the possibility of direct production from sunlight and water.

7.6 Comparison of Energy Abatement Options

In the case of electricity production, which accounts for 43% of Australia’s energy needs, there are a range of alternative energy technologies with low or zero emission characteristics. However, as previously indicated in Figure 8, and with the possible exception of distributed energy, none can match the intrinsically low cost of coal based energy generation. Furthermore, owing to geography and energy intensity, existing renewable alternatives can only be expected to make up a small proportion of the total energy mix in the near future until the industries further mature.

Given that abatement is a necessary component of reducing future greenhouse emissions it then follows its focus should consider the most cost

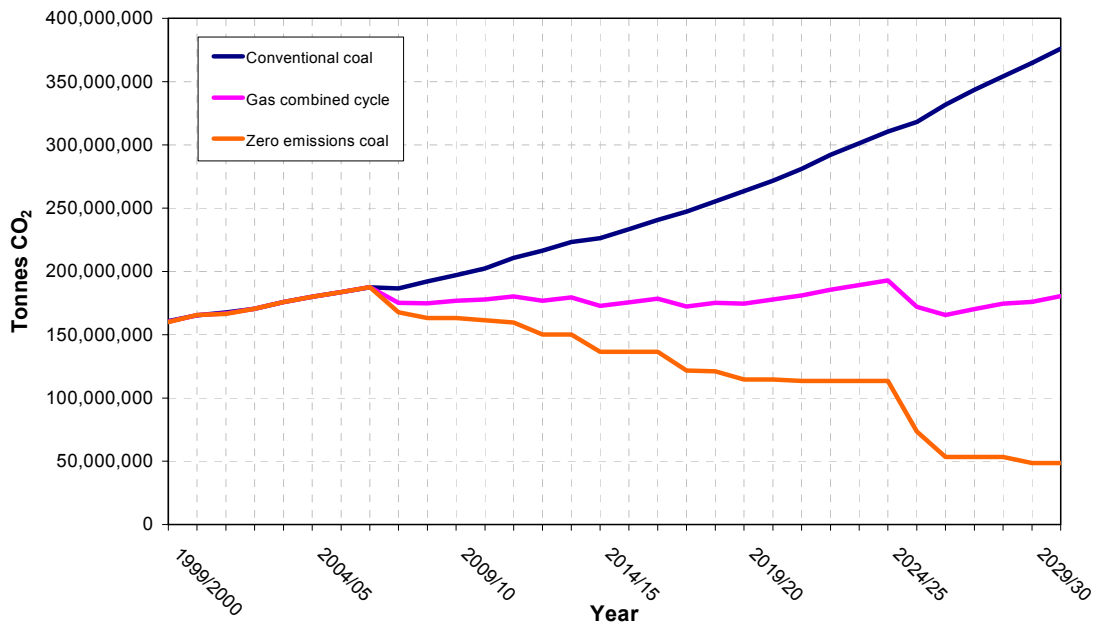


Figure 10. Abatement potential of electricity technology options²⁴

effective and practical options. In this case, cost effectiveness means that the technologies adopted are at least comparable in cost to alternative technologies and that the abatement can be achieved on a scale capable of making major reductions in emissions. With current technologies it is clear that abatement will add to the cost of energy production. The challenge is to adopt or develop abatement technologies which are low cost compared to the available alternatives.

²⁴ Roam Consulting. Unpublished data

A comparison of the abatement potential of the various technology options is shown in Figure 10. The chart shows emissions from electricity generation for cases where all future new generating capacity is either conventional coal, gas combined cycle or zero emissions coal (IGCC with geosequestration). Although these are extreme scenarios the chart indicates that within the foreseeable future only carbon capture and geosequestration has the potential to radically reduce Australia’s greenhouse signature. However, gas can clearly play a major role in developing an energy mix with a reduced greenhouse signature.

The attractiveness of the zero emissions coal option is further reinforced by the information shown in Figure 11 which compares the cost of electricity generated by the three technologies and a range of renewable technologies.

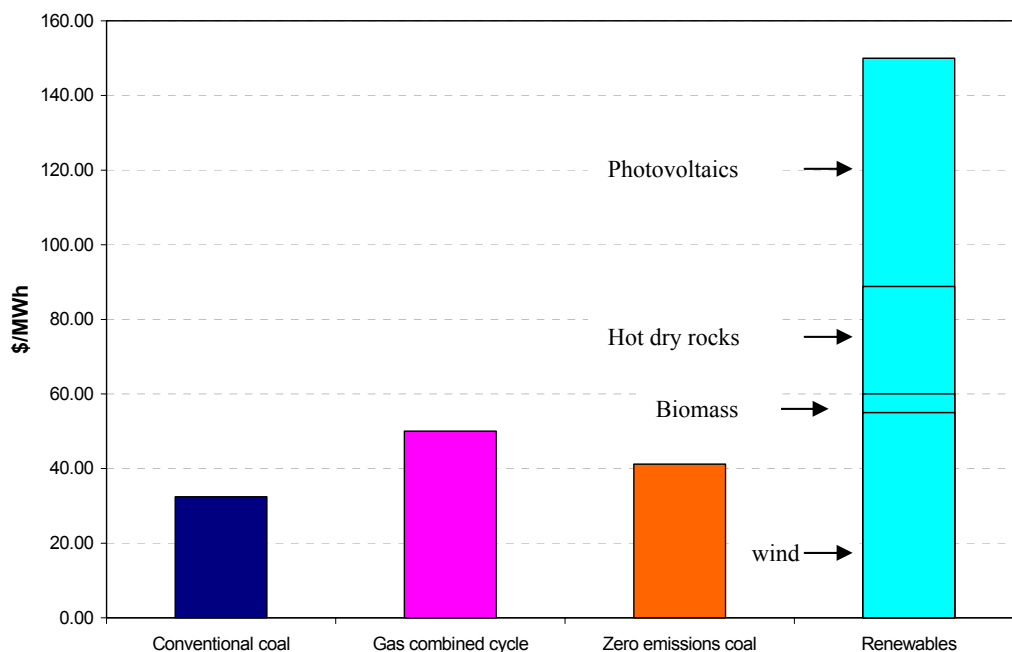


Figure 11. Electricity cost for a range of technologies²⁵

In a recent draft report to the Council of Australian Governments similar estimates for electricity generation costs have been published²⁶. Whilst the figures differ in detail, wind and photovoltaics are seen as significantly more expensive than other alternatives, as in our own analysis.

When these comparisons are put into the broader context of promoting our competitive advantage as a source of low cost coal for export and electricity generation, it is clear that near zero-emissions coal technology has the added advantage, compared to the higher cost alternatives, of assisting coal remain the major global energy source for the foreseeable future. Accordingly, within the context of growing international pressure for emissions reduction by

²⁵ Ibid

²⁶ Council of Australian Governments (2002) Draft Report *Towards a Truly National and Efficient Energy Market* pg135

Australia, the development of cost effective near zero emission coal technologies should be a national priority.

All of the components of near zero emission coal technology have been demonstrated at various sites around the world. However, the demonstration process has so far been disaggregated and at a relatively small scale. To accelerate the development of zero (coal) emission technology it is now necessary to establish an integrated demonstration facility to fully evaluate technical feasibility and costs. Australia's advanced knowledge of large sequestration sites close to major power stations points to Australia being an ideal location for a demonstration facility. Demonstrating the technology under Australian conditions would assist early adoption of the technology when appropriate.

This argument for a demonstration facility recognises that gasification and sequestration offers one of the most cost effective and practical means of reducing greenhouse emissions and that the successful implementation of the technology would provide strong support to Australia's role as a low cost energy supplier. However, it does not mean that this should be the sole initiative by Australia in regards to reducing energy emissions.

7.7 Energy as a Research Priority

It is likely that pressure to reduce cost and emissions will require a mix of technologies which provide targeted cost effective solutions in different situations. High energy intensity coal fired plants will continue to underpin major urban and industrial demand for electricity. However, small communities may be better served by distributed energy systems and the 53% of energy demand not met by electricity needs to be addressed in terms of reducing emissions from the whole of the energy sector. The diversity of the non-electricity sector provides a range of innovative opportunities using renewables and sophisticated gas and other technologies. The need to respond to pressure for cost and emission reductions throughout the energy sector, the unique nature of our geography and demographics, and the critical role that cost effective energy solutions will play in establishing the competitiveness of Australia demands that energy research be a priority.

Encouraging Abatement

In dealing with innovation in the energy sector it is clear that the cost relative to the market price is the critical factor in determining the choice of technology by energy producers. Some recent analyses by the Australia Institute are suggesting abatement at no extra cost. We consider this unlikely and suggest that abatement will impose a cost. As such even the lowest cost abatement technologies will not be taken up without the appropriate pricing signals.

The recent draft report to the Council of Australian Governments recognizes this and suggests an emission trading scheme²⁷. We acknowledge the plausibility of this approach but suggest there are other alternatives that should be considered. One obvious direction is to keep the mandated renewables energy targets but to consider making emission reduction equivalent to renewables for any new generator.

We agree with the thrust of the draft report that the promotion of cost effective solutions should apply to a range of abatement technologies.

RECOMMENDATIONS

Establish a national program to scope, develop, demonstrate and implement near zero emissions coal based electricity generation.

Identify energy options resulting in low greenhouse emissions as a national research priority.

Provide incentives for the adoption of abatement measures along similar lines for the incentive for renewables.

Accelerate the adoption by energy consumers of low energy use devices and processes and the use of cost effective alternative energy sources.

²⁷ Council of Australian Governments (2002) Draft Report *Towards a Truly National and Efficient Energy Market* pg 33

8. REDUCING EMISSIONS IN THE TRANSPORT SECTOR

Australia's transport sector contributes around 14% of the nation's greenhouse gas emissions. Road transport is responsible for around 90% of emissions and dominates the emission profile of the sector. Some 60% of road based emissions are due to passenger vehicles which are mainly fuelled by petrol. Road freight is principally fuelled by diesel. Liquefied petroleum gas is used by 2.4% of the road transport fleet and is cost effective for high kilometre passenger vehicles. Compressed natural gas (0.2% of the road transport fleet, notably urban buses) has significant range and infrastructure problems. By OECD standards Australia's vehicle fleet is relatively old and as a consequence tends to lag in the adoption of vehicles incorporating state of the art technology.

By 2020, greenhouse gas emissions from Australian transport (under a 'business-as-usual' scenario) to be almost 70% above 1990 levels²⁸. The Bureau of Transport and Regional Economics business-as-usual scenario incorporates a continuation of present trends in fuel efficiency improvements for transport vehicles. Due to future technical innovation, average fuel intensity across the transport sector is assumed to fall by between 1 and 2% per annum. Within this aggregate forecast growth in domestic transport emissions over the next two decades (at about 1.7% per annum), aviation is projected to have the strongest rate of growth (averaging around 4% per annum), followed by commercial road vehicles (at slightly above 2% per annum). The passenger car fleet will remain the single largest contributor to total sector emissions, but is expected to exhibit a slower rate of growth (of around 1% per annum between 2000 and 2020).

The scale of these forecast increases points to the fact that Australian transport demand is highly dependent on underlying economic and population growth, where the annual rate of emissions growth is expected to be below the forecast rate of GDP growth (averaging about 3% per annum) and above that of population growth (averaging about 0.7% per annum).

Continuous improvements in engine technology over the years have resulted in significant improvements in fuel economy. However, gains have largely been offset by growing demand for larger vehicles with energy consuming accessories such as air conditioning. The technology underpinning Australia's transport system is essentially derived from and directed by the technology trajectories of Europe and North America.

Petroleum based fuels are expected to remain the principal road transport fuel until at least 2020. In the absence of major technological breakthroughs, such as the use of zero emissions hydrogen based fuel systems, there is little prospect of substantially reducing the greenhouse signature of Australia's transport system. The development of zero emissions systems is unlikely to

²⁸ Bureau of Transport and Regional Economics, Canberra, *Greenhouse Emissions from Transport: Australian Trends to 2020*, forthcoming publication

be realised before 2050. Accordingly, the level of transport emissions can be expected to continue to grow in response to increases in transport activity. However, modest reductions in the greenhouse intensity of the transport sector can be achieved through incremental changes to engine efficiency, intelligent traffic systems applications and perhaps the adoption of low carbon content alternative fuels.

8.1 Options for Improving Fuel Efficiency

Efficiency of Internal Combustion Engines

Projections indicate that internal combustion engine fuel efficiency will continue to improve at a rate of 1.5% annually²⁹. Technological advances expected over the next ten years include: continuously variable transmissions; infinitely variable engine-valve timing; direct fuel injection; cylinder deactivation; plasma ignition systems; turbo charging; and drive-by-wire technologies. It is estimated that that applications of these technologies can decrease CO₂ emissions by nearly 50% for diesel engines and around 40% for gasoline engines³⁰.

Hybrid Vehicles

Hybrid internal combustion/electric vehicles are being produced in small numbers and offer efficiency gains through storing energy at various stages. The vehicles use a small internal combustion engine in conjunction with electrical systems to store energy and to provide the drive train. These vehicles are currently significantly more expensive than traditional vehicles but are expected to become more cost competitive with time and scale of production. It is expected that emissions from hybrid vehicles can be up to 30% less than equivalent conventional vehicles.

Energy recovery

The Working Group is aware of a number of innovative vehicle energy recovery systems which have the potential to achieve quite substantial savings in fuel consumption. One of the more promising systems under development is that developed by Permo-Drive Technologies, a Queensland based company.

Permo-Drive Technologies has developed an innovative hydraulic regenerative braking and propulsion system suitable for most heavy vehicles and buses (in particular those vehicles operating in an urban driving cycle) aimed at delivering significant efficiency, economic, environmental and safety benefits. The potential benefits of regenerative braking are claimed to be quite substantial (eg as high as 40% savings in average fuel intensity while in

²⁹McKinsey Quarterly No3, (2002) *Tomorrows cars, today's engines*.

³⁰Ibid

stop/start modes with high deceleration/acceleration demands potential savings are understood to be significantly higher).

8.2 Alternative Fuels

There is scope for Australia to alter its fuel mix with a view to reducing vehicle emissions. Such a move could include a shift from petrol to diesel which offers potential reductions in emissions of up to 17% (although a more widespread use of diesel will require particulate emissions to be controlled, in view of potential adverse health implications). Other options include the use of non-petroleum based fuels including compressed natural gas, ethanol, liquid natural gas, methanol and hydrogen. However while the emission reduction benefits of diesel are well established there is less certainty about the overall environmental benefits of non-petroleum based fuels. The use of some alternative fuels may also poses problems in terms of the need for new infrastructure.

Compressed Natural Gas (CNG)

The interest in natural gas as an alternative fuel stems mainly from its clean burning qualities, its domestic resource base, and its commercial availability to end-users.

There is a divergence of opinions on the potential of CNG as a lower greenhouse emitter. Some research indicates that, among fossil fuels, CNG is the lowest emitter for highway cycle, and that greenhouse emissions are significantly lower than those for diesel fuel. Broadly, however, CNG-fuelled vehicles are currently less efficient at extracting the energy content of the fuel than comparable diesel fuelled vehicles, limiting the greenhouse gain that results from CNG's relatively low carbon emissions per unit of energy.

CNG also suffers from the absence of a suitable distribution infrastructure and the restrictions of limited range. In these circumstances it is likely that CNG will have restricted applications. It is not clear any strategy can overcome the limited range problem, due to the bulk of CNG.

Liquefied Petroleum Gas (LPG)

There is a divergence of opinion about the effectiveness of LPG as a low greenhouse emitter. Its emission advantages in comparison to diesel fuel are ranked from moderate to high. Some research ranks LPG as the lowest greenhouse gas emitter (of the fossil fuels) for the city cycle, outperforming even CNG.³¹

Major disadvantages of LPG are the lack of market penetration of dedicated heavy LPG vehicles and a comprehensive national distribution infrastructure and, in some States, a punitive excise on the fuel. LPG also has a lower

³¹ CSIRO, Canberra, (2000), *Life-cycle Emissions Analysis of Alternative Fuels for Heavy Vehicles*, pg xxi

energy content than petrol or diesel and, due to storage space requirements, is not generally suitable for smaller vehicles.

Ethanol

The energy content of ethanol is about 23 MJ/L. This compares to 38.6 MJ/L for diesel.

The life cycle emission costs of ethanol as a transport fuel are yet to be fully understood and will vary with the fuel source. Greenhouse benefits are most likely where ethanol is sourced from waste feedstock. In particular, it is possible that ethanol produced from lignocellulose could make a significant contribution to reduction in overall emissions. (Lignocellulose is the structural component of plant biomass and can be derived from trees, grasses, and from cereal and paper wastes.) However, the mass production of ethanol from lignocellulose is still largely in the research and development stage.

Other aspects also require further study, including the optimal use of ethanol in petrol engines and health impacts.

Hydrogen

Although currently under development, hydrogen fuel cells offer the possibility of significant potential improvements in greenhouse emissions. At the heart of a typical hydrogen fuel cell lies a proton-exchange-membrane that electrochemically converts hydrogen and air into electricity and water. This electricity directly powers the car's electric motors and accessories. Depending on how efficiently the hydrogen is produced, fuel cells not only are clean "at the tailpipe" but also tend to use fewer resources along the whole chain.

Despite the rapid development of fuel cells, they are still prohibitively expensive to produce, if the goal is to match the range and performance of conventionally powered cars. Depending on the manufacturer, current estimates for the cost of fuel cell prototypes range from \$500 to \$2,500 per kilowatt produced, which is not competitive with the internal-combustion engine's \$30 to \$35 per kilowatt.

The other problem is distribution infrastructure. Building hydrogen storage facilities at filling stations and manufacturing tankers to supply those stations will require billions of dollars in expenditure/investment.

There is extensive research on alternative storage via metal hydrides or chemical hydrides eg by Shell and Millennium Fuel Cell.

The generation of the vast quantities of hydrogen necessary to supply power to a large automobile market is also problematic. Hydrogen manufactured using natural gas is very energy intensive and lifecycle emissions are similar to those of diesel. Production of hydrogen by low-pressure water electrolysis would be an ecologically sustainable method of production provided that the

electricity used to undertake electrolysis is based on renewable energy. In the short to medium term, if coal gasification and CO₂ sequestration is developed at a reasonable rate, hydrogen could be available from coal. However, such infrastructure would need to be first developed in Australia with the means of distribution. It is possible that this could link in well with a strategy for increased gas reticulation infrastructure, particularly if the increased penetration of CNG was found to be warranted.

Alternative Clean Liquid Fuels

There is considerable interest in establishing gas to liquids plants in Australia based on the conversion of natural gas to low sulphur diesel. This could be combined with the geological sequestration of the CO₂ by-product. Alternatively, the production of synthetic gas from coal gasification could provide an alternate source for the production of liquid fuels, if and when prices changed to make the process commercially feasible. Liquid fuels are being generated from oil shale at a demonstration scale plant in Queensland.

There is a need to conduct comprehensive future transport fuel scenario modelling to understand the most prudent way forward for Australia to meet its future needs.

8.3 Intelligent Transport Systems Applications

Implementing traffic management solutions such as congestion pricing (electronic road pricing) and traffic free-flow measures to reduce emissions is something that can be done immediately or in the short term for 'quick wins' at low cost. Optimal congestion pricing systems in Australian capital cities could deliver a reduction of 5 to 10% in total road transport GHG emissions as set-up costs are relatively low. Increasing the variable proportion of road user costs - and reducing the fixed proportion - will also have the effect of reducing travel and greenhouse emissions.

Vehicle Use Pricing

Many motoring costs vary according to where, when and how much one travels. Setting a fixed charge for these costs is akin to setting a fixed charge for groceries. Unless individuals face accurate price signals, they are not able to act in the interests of the wider community and will 'consume' too many groceries or too much motoring.

Recent advances in technology (in particular Global Positioning Systems (GPS)) have made it feasible to charge insurance and registration fees on a variable basis. Such a move could increase the variable cost of motoring by more than 70% (and reduce the fixed costs to offset this) and lead to a significant reduction in vehicle kilometres travelled. There are moves overseas to facilitate the penetration of Pay-As-You-Drive (PAYD) insurance and research is being undertaken in the US in shifting vehicle taxes and leasing payments to a variable charge reflecting vehicle usage.

The Australian Transport Council agreed in May 2002 to implement variable road pricing in place of registration fees within five to 10 years. In the US it has been necessary to introduce specific legislation to allow motor vehicle insurance to be charged on a PAYD basis.

Electronic Road Pricing (ERP)

ERP involves imposing a congestion tax, toll or road pricing charge on travellers in an intelligent selective fashion (eg for travel on some parts of a network at some times of the day). Electronic toll collection technology and associated intelligent traffic systems, including traffic monitoring capability, could offer a technical means to determine the relevant cost and charge motorists in real time.

ERP offers significant potential for reducing congestion and hence fuel use and greenhouse emissions. Current research indicates that optimal congestion charges may provide greenhouse gas emissions reductions of the order of 20 to 40% of morning peak hour emissions in Australian capital cities, depending on the pricing level and the form of implementation³². This could translate into a reduction in emissions of between 5-10% of total road-related transport emissions.

While ERP set up costs are quite small³³, a critical issue is how to achieve sufficient community support to enable it to become politically and socially acceptable. Determining the uses to which the additional revenue will be put is an important part. There is potential to implement ERP in a revenue-neutral manner, which is generally regarded as a precondition for community acceptance. Revenue generated could be delivered back to the public through, for example, reductions in vehicle taxes, fuel excise and/or local rates.³⁴

Well-designed trials can also be important in building support.

Other Traffic Management Opportunities

The application of well-established technologies could lead to significant reductions in greenhouse gas emissions from transport from, for example, better coordination of traffic lights.

To illustrate, in Modesto, California, the synchronisation of traffic lights reduced the number of stops at targeted intersections by around 50% during peak periods. This resulted in a 14% reduction in greenhouse gas emissions and fuel savings of almost US\$9.4m million.³⁵

Similarly, the reduction and/or rigorous enforcement of speed limits, using

³² Maunsell McIntyre, Adelaide, (2001), *Study of Intelligent Transport Systems (ITS) Impacts on Greenhouse Gas Emissions and Air Quality*, pg 119.

³³ Infrastructure options include overhead gantries and electronic tags attached to vehicles, or GPS receivers on vehicles.

³⁴ BTRE, Canberra, 2002, *Greenhouse Policy Options for Transport, Report 105*, pg 111

³⁵ See www.stancog.org/news_releases/release28.pdf.

advanced traffic management technology also has significant potential to reduce greenhouse gas emissions, since at 110 km/hr a car uses 25% more fuel than at 90 km/hr.

Australia has considerable capability in advanced traffic management and is a world leader in the development and deployment of some products and services. The Sydney Coordinated Adaptive Traffic Control System (SCATS), first introduced in 1978, is now installed in more than 40 cities and in over 9,000 intersections over the Asia-Pacific region.

The roll-out of advanced traffic management technology in areas not yet benefiting from traffic free-flow measures would result in 'quick wins' in terms of reduced greenhouse gas emissions. Furthermore, Australia's comparative advantage in specific areas could be further enhanced through well-directed R&D and wider deployment of currently available technologies.

Outcomes from other applications such as public transport priority systems, incident management systems, traveller information systems and freight management systems are not to be ignored but appear considerably less promising in terms of their impact on greenhouse.

8.4 Comparison of Transport Abatement Options

Emissions from Australia's transport sector will continue to grow as a result of economic growth. However, there are prospects for incremental changes through continuous improvement in vehicle efficiency, the possible shift of fuel mix toward low greenhouse fuels such as diesel, and the use of intelligent transport systems to reduce congestion and vehicle kilometres.

However, Australia will generally be a 'technology-taker' in regard to the transport sector. Our ability to utilise new engine technologies and alternative fuels will largely await the development of appropriate technologies in other countries and or the development of new infrastructure in Australia. The main issue for Australia in regards to these core technologies is how to promote the uptake of low-emission technologies in a timely and cost effective manner. Given that fuel costs are a relatively small component of vehicle operating costs there are few incentives for consumers to rapidly adopt more efficient vehicles.

On the other hand reduction of emissions through the implementation of intelligent transport systems may offer immediate and ongoing gains.

RECOMMENDATIONS

This paper was prepared by an independent working group for PMSEIC. Its views are those of the group, not necessarily those of the Commonwealth Government.

Identify and evaluate options to accelerate the adoption in Australia of technologies to improve fuel efficiency.

Promote and encourage reduction of emissions through the deployment of intelligent transport systems technology, in particular for management of central city congestion through pricing arrangements.

Assess Australia's future transport fuel mix options and associated infrastructure requirements.

9. REDUCING EMISSIONS FROM THE AGRICULTURE & LAND MANAGEMENT SECTOR

Agriculture and land management account for around 18% of Australia's greenhouse emissions. However, owing to the complex biological, chemical and physical processes involved in the generation of these emissions these estimates are subject to considerable uncertainty. Depending on the nature of the emission the AGO believes that the reliability of estimates can vary from 20% to 330%³⁶.

An important feature of agriculture is that NO_x and methane are the principal gases emitted. In terms of their greenhouse effects, these gases have global warming impacts which are 310 and 21 times greater than CO₂. Reflecting the strong role of agriculture in the economy the proportion of emissions from agriculture in Australia are up to three times higher than those of other developed countries.

Dealing with emission problems within the sector is complicated by the widely dispersed sources of emissions, variations in the underlying nature of agricultural practices, and the thousands of individual enterprises involved.

An important characteristic of agricultural emissions is the strong link between emission reduction and productivity. Emissions from agriculture are a loss of valuable resource from the production base. Accordingly, the cost-effective reduction of emissions has the potential to provide production, environmental and social benefits.

9.1 Options for reducing Emissions

The principal sources of agricultural emissions are methane from enteric fermentation in ruminant animals (62%) and nitrous oxide arising from the loss of nitrogen from soils during cultivation (18%) and the prescribed burning of savannas (16%). Agriculture is the dominant national source of methane and nitrous oxide. It should also be noted that agriculture and land management also has the capacity to contribute to the net lowering of emissions through the sequestration of carbon in soils and vegetation.

Methane Emissions from Enteric Fermentation

Enteric fermentation is a normal digestive process occurring in the rumen of sheep and cattle that produces methane as a waste product. Methane from enteric fermentation is the third largest single source of greenhouse gas emissions in Australia behind power generation and road transport.

The process of enteric fermentation is reasonably well understood and there are a number of ways in which emissions might be reduced. Reduction

³⁶ Australian Greenhouse Office (2002), *National Greenhouse Gas Inventory Analysis of Trends and Greenhouse Indicators 2000*

possibilities focus on modifying attributes of the animal population and attributes of the rumen.

Development work by CSIRO has led to a potential vaccine to inhibit production of methane by rumen organisms. Preliminary trials on sheep suggest that emission reductions of up to 20% and productivity gains of 5% may be possible. However, the cost-effectiveness and widespread application of the vaccine are yet to be demonstrated.

Other options which are being investigated include the use of additives in feed stocks, better control of pasture and pasture management, and the breeding of animals that may produce lower emissions without a decrease in product yield.

The development of measures to address enteric fermentation are largely in the development stage and it is difficult to predict the timing or impact of any cost-effective reduction technologies.

Nitrous Oxide from Soils

Nitrous Oxide is estimated to be the major greenhouse gas emitted from field crop production and its emission is enhanced by soil disturbance and the application of fertilisers.

The biophysical processes that lead to nitrous oxide emissions from soils are understood fairly well. However, there is a poor understanding of emission rates and how these might be influenced by various farming practices. Emissions can vary by several orders of magnitude in time and space depending on management practices and soil factors such as nutritional state, water content, temperature and texture. It is possible that nitrous oxide emissions are much higher than estimated and successful abatement could deliver significant productivity gains through the reduced use of fertilisers.

The key to reducing nitrous oxide emissions is to prevent the build-up of free nitrates in soils. Recognised techniques include:

- Improved efficiency of fertiliser use (eg timing and placement, improved drainage and irrigation efficiency).
- Improved soil management to improve porosity (no-till, controlled traffic, crop residue retention etc).
- Increased species diversity of improved pastures (this can also lead to major improvements against the two major threats to improved pastures – soil acidity and ground water accessions).
- Use fertiliser nitrification inhibitors (currently at the demonstration stage).

Development of successful abatement strategies requires better understanding of the nitrogen management process and its link to farming techniques.

Methane and Nitrous Oxides from Prescribed Savannah Burning

Tropical savannas cover almost one quarter of Australia and each year as much as one half is subject to controlled burns or wildfires.

It seems that better management practices have the potential to reduce emissions. For example, a Greenhouse Gas Abatement Program proposal on this issue showed that a switch to early dry season burns could be one of the most cost effective greenhouse gas reduction strategies available to Australia.

Development of successful abatement strategies needs to be based on a better understanding of seasonal changes in fuel loads and the development of optimal management approaches.

Carbon Sequestration

Carbon exchange between the atmosphere and farming systems is modified by the sequestering of carbon in soils and trees. In the case of soils, those in Australia are usually low in carbon and production systems which slow or reverse carbon loss – such as no till or sustainable grazing systems have the potential to generate positive production and greenhouse effects. Similarly, changed farming practices offer the potential to increase carbon sequestration in woody systems.

There is a need for an improved understanding of the scope and potential for carbon sequestration in farm and land management practices.

9.2 Comparison of Abatement Opportunities in Agriculture and Land Management

This sector is a significant generator of emissions. However, given the intrinsic complexity and a lack of understanding of the nature and prospects for abatement it is difficult to identify what if any current technologies could be used to make significant reductions in emissions. Clearly the relative size of enteric fermentation makes it an attractive target for abatement. Its downside as a target is the likely problem of finding a cost-effective solution. By comparison, the potential simplicity of changes to savannah burning may provide a low cost and relatively certain approach to achieving emissions.

Taking a broader view it is clear that the cost and impact of abatement in the agricultural and land management sector is unlikely to compare favourably with the opportunities established in the energy and perhaps transport sectors.

Accordingly, the principal focus on agriculture and land management should be to better understand the cost and impact of possible options.

RECOMMENDATION

Develop and implement a research plan aimed at better understanding agricultural emissions and identifying opportunities for cost effective mitigation.