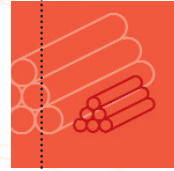


AUSTRALIA'S POLLUTING POWER

Coal-fired electricity and its impact on global warming



By Dr Mark Diesendorfⁱ
Reviewed by Dr Hugh Saddlerⁱⁱ

Twenty-four coal power stations are the largest source of greenhouse gas emissions in Australia, pumping out 170 million tonnes of carbon dioxide (CO₂) every year.

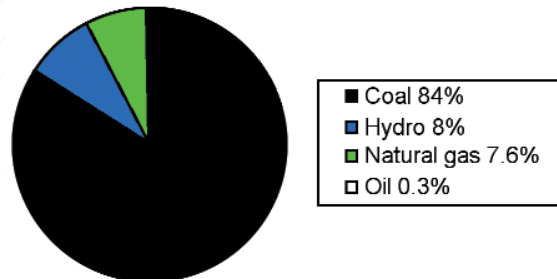
The pollution from these power stations is our main contribution to the problem of global warming. Coal is the main fuel for generating electricity in Australia – in 2000 84% of our electricity came from burning coal, making us one of the top coal-burning countries in the world.

If we are to slow global warming and the impact it has on our climate, we first need to tackle the biggest source of the pollution that is creating a blanket around the earth. The electricity sector is by far the biggest source of the pollution problem both here and globally.ⁱⁱⁱ

In Australia there are no legal requirements on coal fired power stations to prevent their greenhouse gas pollution going into the atmosphere and contributing to global warming. There are also no disincentives against building new coal-fired power stations, yet decisions today can affect Australia's greenhouse pollution levels for many years to come. A 1,000 megawatt black coal power station built today would over its 40-year lifetime emit a total of approximately 260 million tonnes of CO₂ – equivalent to about half of Australia's total annual emissions.

Australia is one of the biggest polluters of greenhouse gas emissions per person in the world. If Australia is to cut its greenhouse gas emissions and help to slow global warming we need to institute a major change to our dependence on coal-fired power.

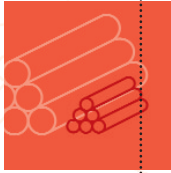
Figure 1:
Dependent on coal for electricity
Electricity generation by fuel use, Australia, FY 2000/01,
Electricity Supply Association Australia data



CLIMATE CHANGE



Geoffrey Heard



AUSTRALIA'S POLLUTING POWER

CLIMATE CHANGE

COAL: THE HIDDEN POLLUTION PROBLEM

Research suggests that the Australian public is unaware of the significant role of coal fired power in our greenhouse pollution problem. Opinion polls and focus groups reveal that most people do not realise the central role of coal in the production of our electricity, nor its major role in causing global warming.

In a recent survey by the Sustainable Energy Development Authority (SEDA), only 33% of people surveyed knew that coal is the main fuel for producing electricity. The source most nominated was hydro.

Another survey of Australians undertaken in 2000 by the International Environmental Monitor, showed that only 4% of respondents thought that the electricity industry is primarily responsible for causing any long term changes to the world's climate. Most people nominated industry sectors that have a far smaller contribution to global warming than the power sector.

The following graphs (Figure 2 and Figure 3) show the large gap between people's perception of the impact of electricity power stations, and the reality of the large contribution that they make to Australia's greenhouse gas emissions.

Figure 2:
The Australian public's perception of which industry sector is primarily responsible for global warming

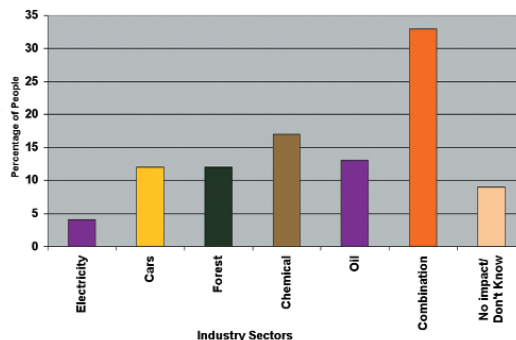
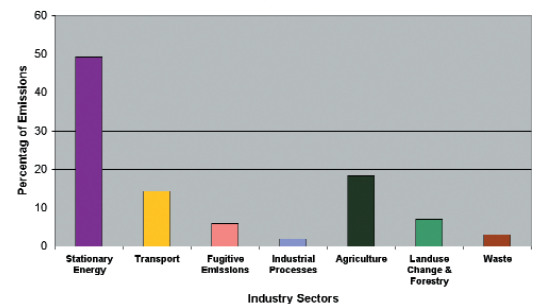


Figure 3:
The reality - Industry sectors and their impact on global warming (NGGI, 2000)



COAL: BIGGEST CAUSE OF GREENHOUSE POLLUTION

In Australia in 2000 the use of coal was responsible for the emission of 186 million tonnes (Mt) of CO₂, the most significant greenhouse gas in causing global warming. Coal use is by far the largest contribution to Australia's total greenhouse gas emissions. The majority of the coal emissions come from electricity generation, which produces one-third of Australia's total greenhouse emissions.

About 97% of the electricity industry's greenhouse gas emissions comes from 24 coal-fired power stations. This relatively small number of power stations produce an amount of greenhouse pollution equivalent to the annual emissions from about 40 million cars, four times Australia's actual car fleet.

Australia's 24 coal power stations also produce more emissions than the total emissions from many entire countries, including Argentina, Belgium, Greece, Ireland, Israel, Malaysia, Pakistan, Portugal, Sweden, Switzerland, Thailand, Turkey, all eastern European countries apart from Russia and Poland, and all African countries apart from South Africa.

COAL-FIRED ELECTRICITY AND ITS IMPACT ON GLOBAL WARMING

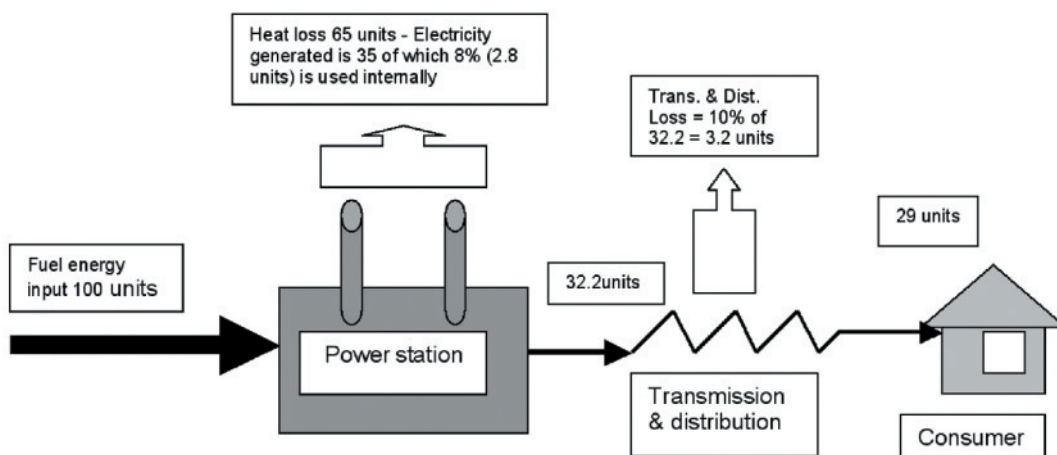
COAL: THE POLLUTING WAY TO GENERATE ELECTRICITY

Burning coal to generate electricity is an inherently inefficient process.

The burning fuel heats water in a boiler, turning it into steam, which spins a turbine, which in turn spins a generator, which produces the electricity. Only a fraction of the energy stored in the fuel (typically 25-36%) is actually turned into electricity. The rest is lost in the cooling water and in the exhaust gases that go up the smokestacks of the power station. About 8% of electricity generated is used to operate the power station and an additional 10% of electricity sent out from the power station is lost in transmission and distribution. (See Fig. 4)

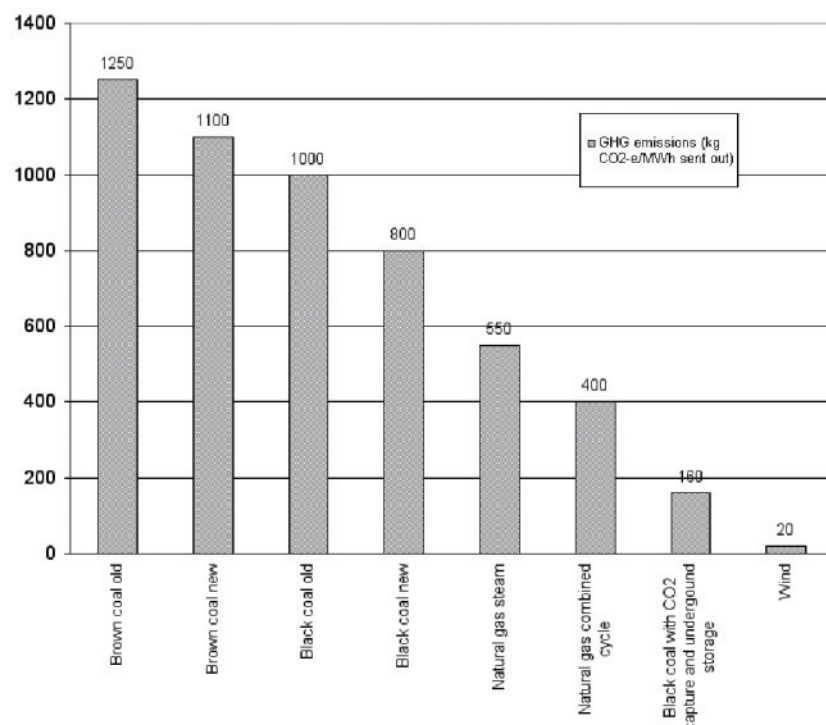
Figure 4: An inefficient way to make electricity

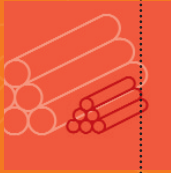
Energy losses in the generation of electricity by a black-coal power station - the fuel energy put in the power station is 100 (arbitrary units) but only about 29 units of energy reaches the consumer.



Brown coal power stations built in the 1990s are only about 29-30% efficient in converting fuel energy into electricity, while black coal power stations built in the 1990s are about 35-36% efficient. Brown coal or lignite contains large amounts of dirt and/or water and so is generally the most polluting type of coal in terms of CO₂ emitted per unit of electricity generated. Next in the ranking of pollutants comes black coal, then oil (which is only used in tiny quantities in large power stations) and then natural gas. (See Fig. 5.)

Figure 5:
Greenhouse emissions emitted from coal compared to other types of power stations
Source: industry data

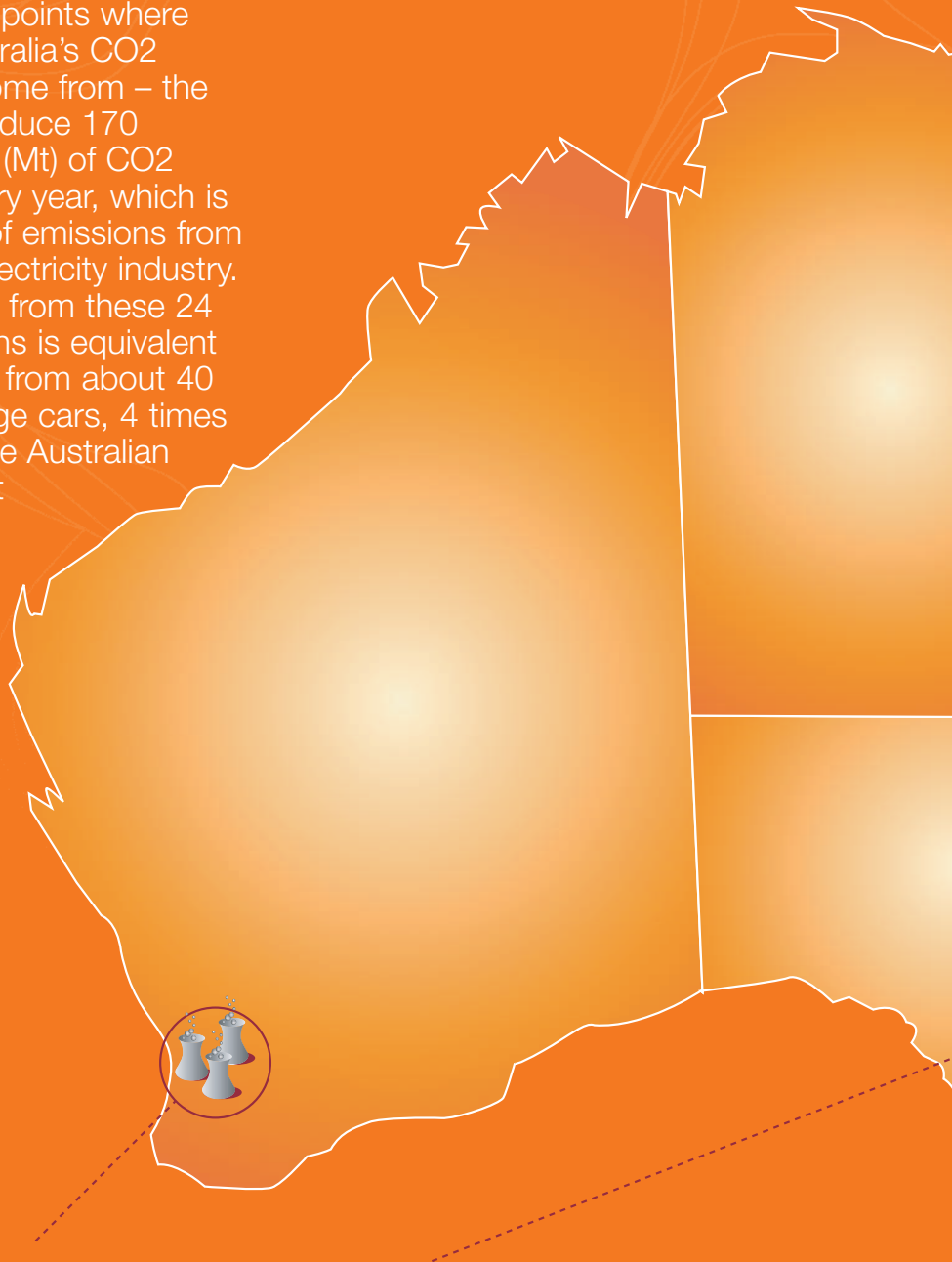




AUSTRALIA'S POLLUTING POWER

AUSTRALIA'S 'HOT SPOTS' OF GREENHOUSE GAS EMISSION FROM COAL-FIRED POWER STATIONS

This map pinpoints where most of Australia's CO₂ emissions come from – the hotspots produce 170 megatonnes (Mt) of CO₂ pollution every year, which is about 97% of emissions from Australia's electricity industry. The pollution from these 24 power stations is equivalent to emissions from about 40 million average cars, 4 times more than the Australian fleet of about 10 million.



South West Integrated System, W.A.

Power stations:

Muja
Kwinana
Collie

Total CO₂ emissions from power stations: About 10 megatonnes

Port Augusta, S.A.

Power station:
Northern

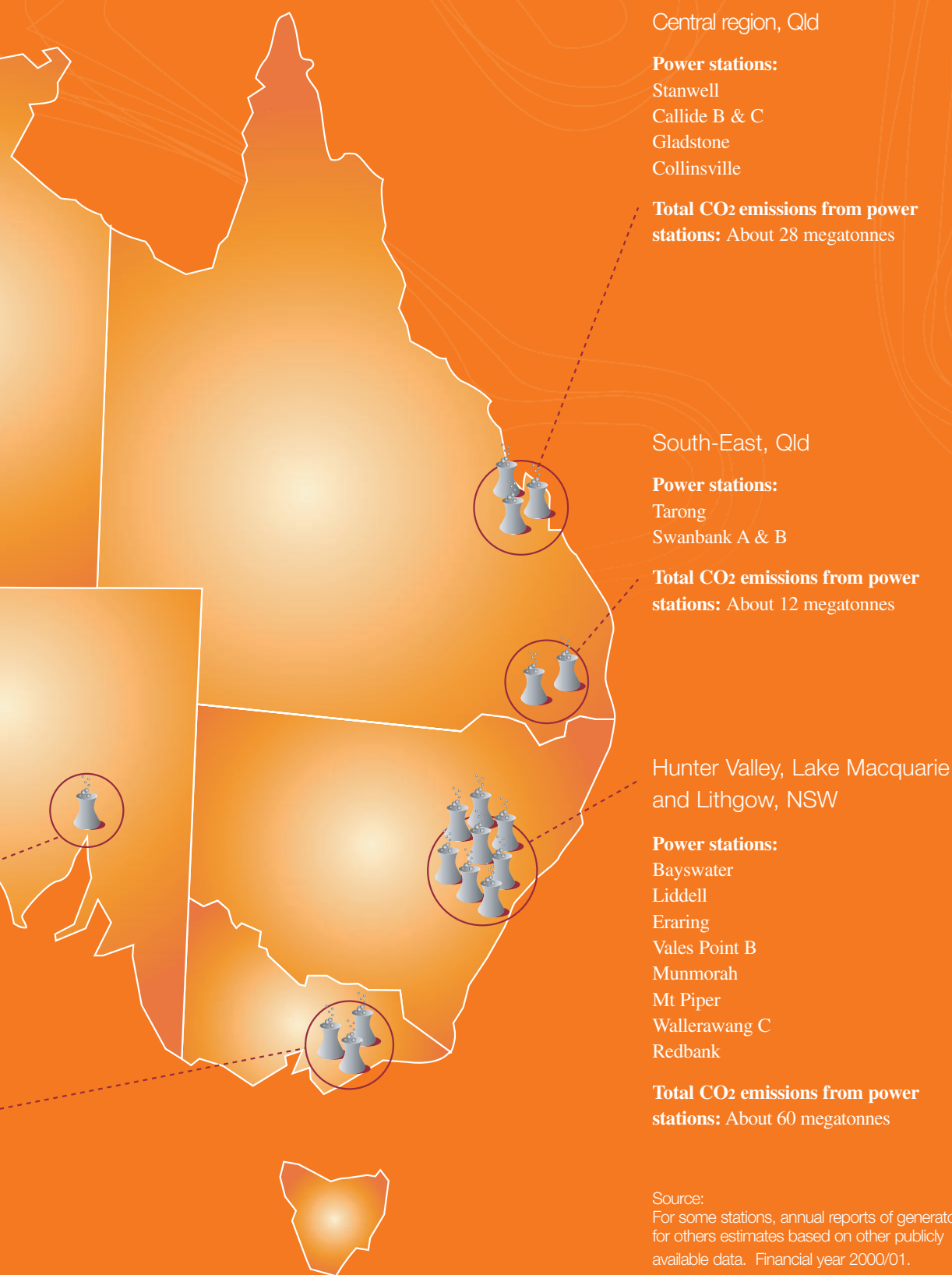
Total CO₂ emissions from power station: About 5 megatonnes

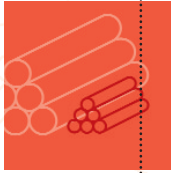
LaTrobe Valley, Vic.

Power stations:
Loy Yang A & B
Hazelwood
Yallourn W

Total CO₂ emissions from power stations: About 57 megatonnes

COAL-FIRED ELECTRICITY AND ITS IMPACT ON GLOBAL WARMING





AUSTRALIA'S POLLUTING POWER

CLIMATE CHANGE

AUSTRALIA'S DEPENDENCE ON COAL IS GLOBALLY SIGNIFICANT

Australia is one of only a few countries in the world that is highly dependent on coal for its electricity, after Poland and South Africa (see Table 1).

Coal is on average the leading source of electricity generation in both industrialised and developing countries. Nevertheless, many countries have a much more diverse mix of sources for their electricity and the contribution from natural gas is gradually increasing.

Table 1: Percentage of electricity generated from coal in selected countries

Country	Year	Percent of electricity from coal	Trend since 1990
Poland	2000	96	Steady at saturation
South Africa	2000	about 92	rising slightly towards saturation
Australia	2000	78	Steady
PR China	1999	75	small increase over the decade
India	1999	75	small increase
Czech Republic	2000	73	Steady
Germany	2000	53	fallen slightly
USA	2000	52	Steady
Denmark	2000	47	big decline as gas and wind increase
Korea	2000	42	big increase
UK	2001	37	big decline since 1986
Japan	2000	22	big increase
Thailand	1999	18	small decrease
Vietnam	1999	12	big decrease

Source: International Energy Agency

Countries that are not so dependent on coal include the UK and Thailand where there is a strong use of gas fired generation; in USA there is coal, gas, nuclear, hydro and geothermal; in Denmark 18% of electricity was generated by wind power in 2002 and a significant percentage was also obtained from biomass. Some countries, such as Belgium, France and Sweden have a high percentage of electricity from nuclear energy, although nowadays there is little growth in nuclear energy in developed countries.

COAL-FIRED ELECTRICITY AND ITS IMPACT ON GLOBAL WARMING

AUSTRALIA'S COAL USE CLIMBS WHILE OTHER COUNTRIES SWITCH TO CLEANER POWER

Over the period 1990-1999, both greenhouse gas emissions (Fig. 6) and coal consumption (Fig. 7) increased in Australia. The trend of increasing coal use in Australia has been more dramatic than the industrialised country average (OECD) and more than in countries like the USA.

Coal consumption and emissions have decreased in Germany, following reunification and the closure of many inefficient power stations and industries, and in the UK, which has shifted dramatically from coal to natural gas and a much more substantial renewable energy target than Australia's. From 1996 onwards, China closed down many small, inefficient and highly polluting uses of coal and commenced substituting natural gas for coal in home heating. As a result, China's coal consumption and greenhouse gas emissions decreased despite a rapidly growing economy.

Figure 6:
Greenhouse gas
emissions
1990 – 1999

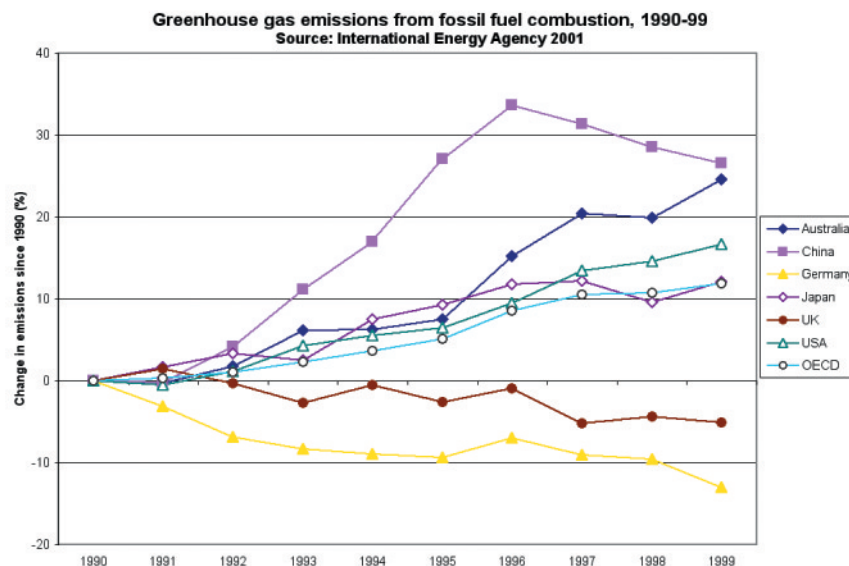
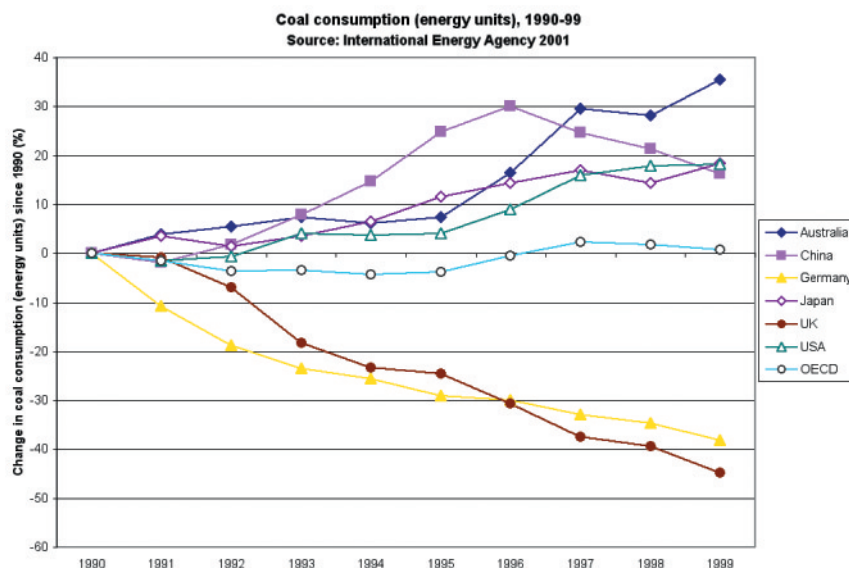
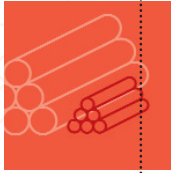


Figure 7:
Coal consumption
1990 – 1999





AUSTRALIA'S POLLUTING POWER

CLIMATE CHANGE

CAN COAL BE MADE 'CLEAN'? A REALITY CHECK

Australia's coal dependence has a large influence on Australian Governments' attitude to greenhouse gas reduction policies and laws. For example, it is perhaps the main reason why the Federal Government refuses to ratify the Kyoto Protocol treaty on preventing global warming.

Substantial government funding and policy support has been and continues to be put towards trying to clean up coal, rather than committing resources to cleaner sources of electricity. The Federal Government is funding three Cooperative Research Centres (CRCs) devoted to fossil fuel industries, and has just announced that one of these has been renamed the CRC for Greenhouse Gas Technologies and renewed for 7 years from 1 July 2003 with an additional \$21 million of government funding. Meanwhile the government has also announced that it will not renew funding for Australia's only Cooperative Research Centre devoted to renewable energy. It has also frozen the rebate scheme for encouraging the installation of solar electricity on residential rooftops.

There are some practical measures that can be implemented to reduce the CO₂ pollution that comes from coal burning, for instance:

- Improving the quality of coal used. However, the pollutants and greenhouse gases produced by the processing itself are significant.
- Improving the efficiency of coal burning by using better technologies, such as fluidized bed combustion, integrated gasification combined cycle and supercritical boilers.
- Capturing pollutants from the exhaust gas and storing them securely for long periods of time.

Some of the above 'clean coal' technologies are commercially available, but these produce reductions in CO₂ emissions of only a few percent.

There are two proposed measures, which are not yet commercial, that promise much larger greenhouse gas emission reductions and so require closer examination. These are so-called 'ultra-clean coal' and the collection and storage of greenhouse gases (or CO₂ waste) from power stations.

'ULTRA-CLEAN COAL', A MISLEADING TERM

'Ultra-clean coal' (UCC) is a solid fuel made from coal, with very low ash content (less than 1%), for direct firing in gas turbines. Its development is being piloted in Australia by industry and CSIRO with support from the Federal and NSW Governments.

'Ultra-clean coal' is not a substitute for conventional coal in conventional power stations. Its major application is in areas where conventional coal cannot be used: as an alternative for heavy fuel oil and gas in a gas turbine. Promoting 'ultra-clean coal' as a means of continuing with coal-fired power stations is misleading. Furthermore, from the figures given by researchers, ultra-clean coal, even when burnt in an advanced combined-cycle power station, produces much more greenhouse gas emissions than natural gas.

CAN GREENHOUSE GAS POLLUTION (CO₂) BE COLLECTED AND SAFELY STORED?

Australia's large point sources of CO₂ – like power stations and industrial plants – were responsible for 72% of CO₂ emissions in 2000, while distributed sources – like transport, land use change and forestry – were responsible for 28%.

COAL-FIRED ELECTRICITY AND ITS IMPACT ON GLOBAL WARMING

Currently most of this CO₂ pollution goes into the atmosphere and contributes to the problem of global warming. There are currently two main potential methods of collecting CO₂ waste from power stations to prevent it from escaping into the atmosphere:

- A** *Collecting CO₂ after burning the coal.* The exhaust gas emitted by a standard coal-fired power station contains about 14% CO₂ with the remainder containing a range of other pollutants along with nitrogen and oxygen. All the gas has to be 'scrubbed' with chemical solution, then reheated to release high-purity CO₂. To do this large energy inputs are required. The technology is not commercial for power stations.
- B** *Collecting CO₂ before burning the coal.* Coal is made to react with oxygen and steam to form CO₂ (which is readily captured, because of its purity) and hydrogen. The hydrogen can then be used as an alternative fuel to generate electricity in a fuel cell or as fuel in a gas turbine. However the production of hydrogen in this way is not a clean process in greenhouse or local environmental terms. Neither of the two methods of converting hydrogen into electricity is commercial technology at this stage.

Other potential methods for separating CO₂ – such as cryogenics, membranes and absorption – require much more development, may not be suitable for large-sources, and are likely to be more expensive than the above methods.

If the CO₂ is collected it then needs to be compressed and transported in high-pressure pipelines to the long-term storage or 'sequestration' points. Tanker ships, similar to those used to transport LNG, could also be used, but these would be more expensive than pipelines. Three different types of storage are being researched:

- 1 *Underground storage (geosequestration),* the injection of captured CO₂ into underground geological formations, such as depleted oil and gas wells, saline aquifers, and deep unminable coal seams.
- 2 *Ocean sequestration,* the injection of captured CO₂ into deep and intermediate ocean waters and into geological formations under the sea-bed. There are concerns about the impact that this would have on ocean life.
- 3 *Conversion and reuse,* converting CO₂ into another chemical compound. This does not look commercially promising at present, because there is no market for such a large amount of converted CO₂.

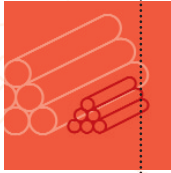
CO₂ IN THE UNDERWORLD

The type of long-term storage that is technically possible within the next decade is underground storage, because it can draw upon the geological and technical knowledge of the gas and oil industry.

The big question marks over all types of underground storage are the volumes of CO₂ that can be safely stored, whether the storage will be secure, the gaps in scientific knowledge about the potential stores, the economic costs, and the environmental impacts. Experience in injecting CO₂ into underground reservoirs is so far limited to a number of enhanced oil recovery projects, several enhanced coal bed methane projects, a single project that injects CO₂ into a saline aquifer under the sea-bed, and a number of other experiments.

In Australia, assessment of potential long-term geological storage sites is being carried out by the Australian Petroleum Cooperative Research Centre. It has found that the potential for CO₂ storage in deep unminable coal seams is very limited. Storage potential is also limited in Australian oil and gas fields, because they are not yet sufficiently depleted. This means that only saline aquifers, which are not well understood scientifically, appear feasible in terms of storage capacity for the next 30-40 years.

The study finds that the largest storage potential is in Western Australia, while the biggest point source emitters are in eastern Australia. There is no known suitable store near the huge emission hot spot spanning the Hunter Valley-Lithgow-Port Kembla region (see map), but there is one near the Victorian hot spot of the Latrobe Valley. The study concludes that Australia has the potential to store about 100-115 Mt CO₂ per year near large emitting sites. This is about 26 - 30% of Australia's total annual emissions.



AUSTRALIA'S POLLUTING POWER

CLIMATE CHANGE

ENVIRONMENTAL AND HEALTH IMPACTS OF UNDERGROUND STORAGE

The security of the storage site will depend upon a range of issues.

In the case of using old oil and gas wells, the security of the CO₂ will depend on whether it has been damaged by the number of wells drilled into it and by structural changes resulting from any extraction of oil or gas. Saline aquifers are not well understood scientifically and so the risk of escape may be substantial. In the case of coal mines, there has been one large trial conducted to date in the USA to use CO₂ in the enhanced recovery of coal bed methane gas. In this case the additional CO₂ caused swelling of the coal, however reports have not revealed whether this resulted in cracking of the store and release of both CO₂ and coal-bed methane.

The main danger of underground storage is the risk of large volumes of CO₂ escaping, leading to both global climatic and local environmental and health impacts. Since CO₂ is heavier than air, the sudden arrival of a large volume of CO₂ at a point on the Earth's surface could result in low-lying areas near the breach filling with CO₂ and people becoming asphyxiated. This kind of event could occur from breaching of either an underground store or an above-ground pipeline as a result of lack of knowledge of the store's capacity, mistakes in operations, earth tremors, or sabotage.

If the CO₂ did escape it would go into the atmosphere and contribute to global warming. Even before it reached the atmosphere, sudden escapes and slow leakage could impact on ground water, surface waterways, soils, subsoil and biodiversity. In water, CO₂ dissolves partially to form a weak acid, which could have a wide range of adverse impacts on living organisms that are not adapted to acid conditions. Impacts on soil microbes and soil ecosystems in general could be profound. Soil is a living thing containing complex ecosystems that are vulnerable to chemical and physical disturbance.

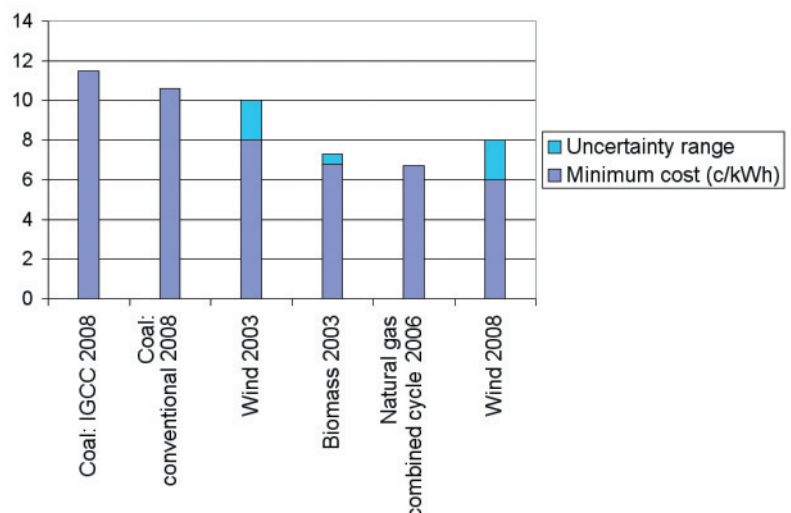
THE COST OF CAPTURE AND UNDERGROUND STORAGE

The International Energy Agency recently completed a study on the performance and cost of new power stations with the collection and storage of waste CO₂.

The study found that the process to collect and store the emissions reduces CO₂ emissions by about 80%. However, this also increases substantially the costs of the power stations, and reduces their thermal efficiency. The total cost of the cleaned up coal electricity becomes 11.3 cents per kilowatt-hour (c/kWh) for a coal-fired Integrated Gasification Combined Cycle power station; 10.7 c/kWh for a conventional coal-fired power station; and 6.7 c/kWh for a natural gas combined cycle power station (see Figure 8).

The International Energy Agency emphasizes in its report that these results are for new power stations and that the cost of cleaning up CO₂ waste from existing power stations would be higher. This is because older power stations are less efficient and so produce more CO₂ per kilowatt-hour sent out and have a shorter time to pay off the increased costs, and so increased annual charges are required.

Figure 8:
The estimated costs of generating CO₂-free electricity from various types of power stations (in cents per kilowatt-hour)



COAL-FIRED ELECTRICITY AND ITS IMPACT ON GLOBAL WARMING

Notes: These IEA estimates were originally made in US dollars which we converted to Australian dollars according to A\$1 = US\$0.60. We assumed that Australian black coal costs about A\$1/GJ and natural gas about \$3/GJ. The uncertainty ranges of the coal and gas options are unknown; those of renewables are the observed ranges, which depend upon location and scale of power plant. It is assumed that construction of all power stations commences in 2003 and that the coal stations start operating in 2008 and natural gas in 2006.

Figure 8 shows that the generation costs of electricity from several renewable energy sources are less than or equal to the cost estimates for cleaned up coal electricity). For example, electricity from large wind farms costs 8-10 c/kWh. By 2008 it is expected that windpower costs will have declined to 6-8 c/kWh. According to a study by the UK Department of Trade and Industry, the cost of generating electricity by burning some types of crop residue, waste and landfill gas is in the range 2.5-2.7 p/kWh (i.e. 6.8-7.3 c/kWh Australian), which is even cheaper than windpower.

CO₂ collection and underground storage will not be competitive with the cheaper cost of the renewable sources of electricity unless it receives either a large economic benefit from enhanced oil or gas recovery or large economic subsidies. The latter is possible because in Australia financial subsidies and incentives to the production and use of fossil fuels already amount to billions of dollars per year. At the same time there is small, declining government assistance for renewable energy.

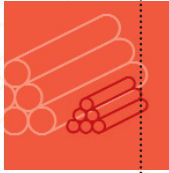
Australian decision-makers need to grasp the large number of uncertainties associated with these coal-based technologies before rushing headlong into making them the main greenhouse gas reduction strategy for Australia. It would be a mistake for Governments to continue to approve coal-fired power stations and to slow efforts to cut emissions in the hope that in a few years the most significant source of greenhouse gas pollution can be made completely benign.

SUMMARY:

Coal-fired power stations are the biggest greenhouse gas polluters in Australia and our major contribution to the problem of global warming. Australia is one of the most coal dependent nations in the world and coal is the most polluting way to produce electricity.

There may be potential for collecting CO₂ from power stations and storing it underground, however this technology is not available in the near term and will likely cost more than other power options. Australian decision-makers need to grasp the uncertainties associated with 'clean coal' technologies before making this a major focus of greenhouse gas reduction strategies. It would be a mistake for governments to continue to approve coal-fired power stations and to slow efforts to cut emissions in the hope that this major source of greenhouse pollution can be made clean easily and quickly.

It would be wise for Australia to diversify its electricity supply by increasing the use of renewable energy and super-efficient gas and by introducing much stronger energy saving regulations.



AUSTRALIA'S POLLUTING POWER

Coal-fired electricity and its impact on global warming

CLIMATE CHANGE

References

- Australian Greenhouse Office, 2002, National Greenhouse Gas Inventory 2000, Canberra: AGO; available on www.greenhouse.gov.au/ (go to Business & Industry page).
- Bradshaw J et al 2002, The potential for geological sequestration of CO₂ in Australia: preliminary findings and implications for new gas field development, *APPEA Journal*, 42 (1):25-46.
- Davison J, Freund P and Smith A, 2001, Putting carbon back in the ground, UK: IEA Greenhouse Gas R&D Programme, pp.20-22. (Downloadable from www.ieagreen.org.uk/; go to Capture & Storage of CO₂.)
- Electricity Supply Association of Australia, 2002, Electricity Australia 2002, ESAA.
- Ellis, M, 1997, Can coal be clean? A report for Aid/Watch, and Greenpeace Australia.
- Energy Information Administration of US Department of Energy, website: www.eia.doe.gov/emeu/; then go to International Energy Statistics or to Country Analysis Briefs.
- IPCC workshop on carbon dioxide capture and storage, Regina, Canada, November 2002. (This contains several important papers, including a more detailed IEA costing of geosequestration. Proceedings can be downloaded from www.climatepolicy.info/ipcc/index.html)
- International Energy Agency 2000, Energy Balances of Non-OECD Countries, 1998-1999, Paris Cedex: OECD/IEA.
- International Energy Agency 2001, Electricity Information, Paris Cedex: OECD/IEA.
- Lansbury, N, 2002, Up in smoke: Australian coal exports to South East Asia, Sydney: Greenpeace, Mineral Policy Institute and Climate Action Network Australia
- Riedy, C & Diesendorf, M, 2003, Financial subsidies to the Australian fossil fuel industry, *Energy Policy* 31:125-137.
- Tarlo K, 2002, Why brown coal should stay in the ground, Sydney: ISF, UTS.
- US Department of Energy, <http://www.netl.doe.gov/coalpower/sequestration/index.html>

Contact details

Copies of this paper can be downloaded from WWF Australia's website – www.wwf.org.au

This brochure is based on a consultancy by Dr Mark Diesendorf, Sustainability Centre, PO Box 221, Epping, Sydney NSW 1710, Australia. email: mark@sustainabilitycentre.com.au.

WWF-Australia's Climate Campaign Manager: Anna Reynolds areynolds@wwf.org.au

First published in 2003 by WWF Australia. © WWF Australia 2003. All Rights Reserved.

ISBN 1875941444

WWF Document number: Discussion Paper 03/02

Layout: Simon Swingler

Head Office – WWF Australia, GPO Box 528, Sydney NSW Australia Tel: +61-2-9281 5515 Fax: +61-2-92811060 enquiries@wwf.org.au

For a full list of WWF Australia publications on a wide range of conservation issues, please contact us on publications@wwf.org.au or call (02) 9281 5515

WWF is one of the world's largest and most experienced independent conservation organisations, with almost 5 million supporters and a global network active in more than 90 countries.

WWF Australia's mission is to conserve biodiversity in Australia and the Oceania Region. We have 180 active projects focusing on 5 priority areas that address current conservation challenges. For in-depth information on all our work, go on-line at www.wwf.org.au or call our toll free number 1800 032 551.

ⁱ Director, Sustainability Centre Pty Ltd. and Adjunct Professor, Murdoch University

ⁱⁱ Managing Director, Energy Strategies Pty Ltd.

ⁱⁱⁱ Public Electricity and Heat Production sector as used by the International Energy Agency