Options for moving towards a lower emission future

A report by AGL, Frontier Economics and WWF-Australia on the economic costs of different emission reduction pathways in the Australian electricity sector.

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Glossary

ABARE	Australian Bureau of Agricultural and Resource Economics
AGO	Australian Greenhouse Office
ASX	Australian Stock Exchange
BAU	Business as usual
CCG	Combined cycle gas
CH_4	Methane
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
EE	Energy efficiency
ETS	Emissions trading scheme
EU	European Union
G8	Group of Eight Nations
GDP	Gross domestic product
GJ	Gigajoule
GWh	Gigawatt hour
GWP	Global warming potential
IGCC	Integrated gasification combined cycle
IPCC	Intergovernmental Panel on Climate Change
kg	Kilogram
kWh	Kilowatt hour
LETDF	Low Emission Technology Development Fund
LPG	Liquefied petroleum gas
MRET	Mandatory Renewable Energy Target
Mt	Million tonnes
MW	Megawatt
MWh	Megawatt hour
N_2O	Nitrous oxide
NEM	National Electricity Market
NEMMCO	National Electricity Market Management Company
NPV	Net present value
NZX	New Zealand Stock Exchange
OCG	Open cycle gas
PJ	Petajoule
PNG	Papua New Guinea
ppm	Parts per million
REDI	Renewable Energy Development Initiative
SF_6	Sulphur hexaflouride
t/MWh	tonnes per MWh
TWh	Terawatt hour
UNFCCC	United Nations Framework Convention on Climate Change
WHIRLYGIG	The model of the National Electricity Market used for this study

1. Introduction

In 2005, the National Science Academies of the G8, China, India and Brazil stated, "There is now strong evidence that significant global warming is occurring. It is likely that most of the warming in recent decades can be attributed to human activities. This warming has already led to changes in the world's climate. We urge all nations, in line with the United Nations Framework Convention on Climate Change, to take prompt action to reduce the cause of climate change, adapt to its impacts and ensure that the issue is included in all relevant national and international strategies."[1]

The inexpensive sources of energy which have powered economic growth since the Industrial Revolution are the main source of human induced greenhouse gas emissions. If emissions are to be reduced, there is likely to be a cost in the short term as new methods of providing energy services are deployed.

However, the costs of not reducing emissions are likely to be far greater. A prosperous society is dependent upon a relatively stable climate. Once the costs associated with more extreme climatic conditions are considered, the investment in reducing emissions now is likely to be cost effective. In this context, many companies are already beginning to factor climate change into forward planning, both in terms of a carbon price and in terms of climatic impacts on their business operations.

This report does not analyse the indirect costs to the economy of not curbing greenhouse gas emissions, or the indirect economic benefits of investing in climate solutions. Furthermore, it does not attempt to comment on the long-term emission reductions that are necessary to prevent dangerous levels of climate change. Instead, it provides evidence on the direct costs of adopting different possible emission reduction pathways in the Australian electricity sector over the next 24 years to 2030. It is important to note that the economic modelling used in this report does not speculate on new technology development. The direct costs are based on existing technology. By completing the study in this way, policy makers should be able to use this information to assist in designing appropriate emission reduction policies.

The report is structured as follows:

- Section 2 provides a brief overview of climate science and how the Australian electricity sector may be required to reduce emissions in the future.
- Section 3 outlines how the Australian energy market operates and describes the economic model used in this study, the study assumptions and scenarios modelled. The model used is one capable of capturing regulatory requirements in relation to greenhouse gas emissions. An important feature of this report is that it presents evidence on the basis of existing costs in the electricity sector: new technology development is not assumed.
- Section 4 provides an analysis of the results of the economic modelling described in Section 3. This includes information about energy prices, the types of electricity generation technologies deployed and the total cost to society of different emission reduction pathways.
- A brief conclusion is outlined in Section 5. This includes discussion about the implication of this report for policy design.

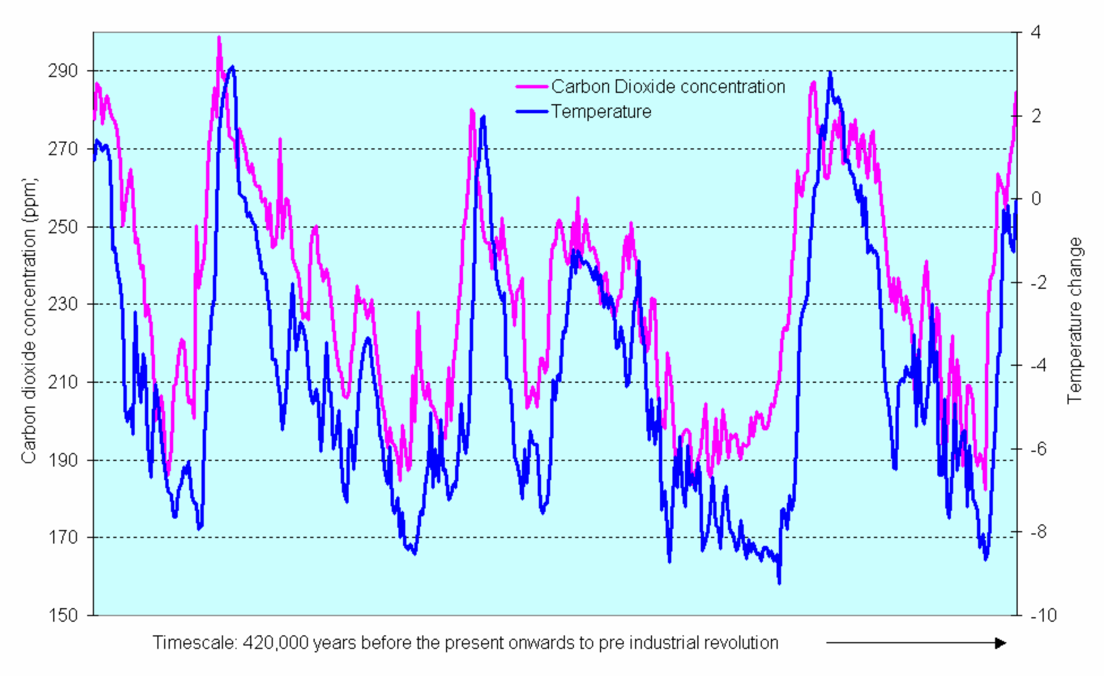
[1] The statement is available at http://nationalacademies.org/onpi/06072005.pdf.

2. Climate science – determining a target for the electricity sector

2.1 The greenhouse effect

Global climate is inherently complex. However, there is broad scientific consensus on a number of important processes. One such process is the greenhouse effect. Greenhouse gases act as a blanket in the atmosphere, trapping heat and warming the earth. There is a strong relationship between greenhouse gas emission concentrations and the earth's average temperature. In fact, without the greenhouse effect, the earth's temperature would be significantly lower than it is today and life on earth, as we know it, would not be possible. In the past, the world's climate has shifted significantly as a result of changes in greenhouse gas concentrations. This is shown in Figure 1.

Figure 1: Atmospheric concentration of carbon dioxide and temperature[2]



Since the Industrial Revolution, the concentration of all greenhouse gases in the atmosphere has risen dramatically from about 280 ppm to the current concentration of 381[3] ppm. It is well accepted that the increased concentrations of greenhouse gases in the atmosphere are largely due to emissions caused by human activities, such as the burning of fossil fuels to generate electricity. It is likely that current concentrations will continue to rise unless new energy technologies are deployed in both the developed and developing world.

[2] Derived from various journal articles published by Jouzel, J et al. Data is available at http://cdiac.esd.ornl.gov/trends/co2/contents.htm.
[3] Pearce, F, 'Atmospheric CO_2 Accumulating Faster than Ever', New Scientist, March 2006.

There are seven main greenhouse gases emitted as a result of human activity: water vapour, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons, perflurocarbons and sulphur hexafluoride (SF_6). The different greenhouse gases and their properties are outlined in Table 1.

Table 1: Greenhouse gases[4]

Gas	ppm in atmosphere	Increase since 1750	Heat trapping potential (carbon dioxide equivalents)	Main source of gas
Carbon dioxide	365	30%	1	Fossil fuels, land use change, cement
Methane	1.75	150%	23	Fossil fuels, agriculture, waste
Nitrous oxide	0.31	15%	296	Fertilisers, industry
Hydrofluoro-carbons	0.000014	N/A	12,000	Electronics, refrigerants
Perfluoro-carbons	0.00008	100%	5,700	Aluminium production
Sulphur hexafluoride	0.0000042	N/A	22,200	Dielectric fluid

While carbon dioxide traps less heat per unit than the other greenhouse gases, it is present in much greater quantities. Based upon the higher overall quantity of carbon dioxide, it is estimated to contribute around 60% of the anthropogenic (human caused) climate change. Methane and nitrous oxide are the second and third respectively, most significant greenhouse gases.

As outlined in Table 1, many of the production techniques that underpin Australia's current standard of living produce greenhouse gases. The single largest contributor to human induced greenhouse gas emissions is the burning of fossil fuels to create energy. Carbon dioxide equivalent is the term used to group these greenhouse gases for measurement purposes.

2.2 Impact of increasing greenhouse gas concentrations

The Third Assessment Report (2001) of the Intergovernmental Panel on Climate Change (IPCC) states:[5]

- The global average surface temperature has increased by about 0.6^{O}C during the last century.
- Night-time daily minimum air temperatures over land increased by about 0.2^{O}C per decade between 1950 and 1993.
- The global average sea level has risen between 0.1 and 0.2 metres during the last century.

There have also been changes to the Australian climate. *Climate Change: An Australian Guide to the Science and Potential Impacts*, which draws upon the work of the IPCC, states[6]:

[4] Compiled from information obtained from the Intergovernmental Panel on Climate Change (http://www.ipcc.ch/).
[5] Watson, R T et al, Climate Change 2001: Synthesis Report. A Contribution of Working Groups I, II, and III to the Third Assessment Report of the Intergovernmental Panel on Climate Change, 2001.
[6] Pittock, B (ed), Climate Change - An Australian Guide to the Science and Potential Impacts, 2003.

- Australian average temperatures have risen by about 0.7^{O}C during the past century and there has been an increase in the frequency of very warm days and a decrease in the frequency of frost and very cold days.

- Higher temperatures are likely to have worsened the impact of droughts.

- Overall rainfall in Australia has increased by about 6% during the last century. However, there has been a reduction in winter rainfall on the south coast and an increase in summer rainfall in the north west.

2.3 The need to reduce emissions

The Third Assessment Report of the IPCC includes climate projections for the next 100 years. Because it uses a number of different economic scenarios to project future greenhouse gas emissions and resulting concentrations, the temperature projections range significantly. In each of the scenarios, a different level of emissions is assumed depending upon the actions to reduce emissions assumed to have been taken. For example, one scenario includes progressive new technology deployment.

By 2100, atmospheric carbon dioxide concentrations are projected to rise from current levels (381 ppm) to between 540 ppm and 970 ppm. As a result of these changes, the IPCC has anticipated the following climate impacts:[7]

- The average surface temperature is likely to increase by between 1.4^{O}C and 5.8^{O}C.

- The projected rate of warming is without precedent during the last 10,000 years.

- Sea surface temperatures in the tropical Pacific Ocean are likely to become more El-Nino like.

- Global average water vapour concentration and precipitation are projected to increase.

- Weather events such as extreme rainfall, droughts and cyclone wind intensity, are likely to increase in frequency and intensity.

Potential impacts on nature and society include the destruction of homes, buildings and other infrastructure as a consequence of sea-level rise and changes in the frequency and nature of extreme weather events and natural disasters.[8]

Climate change is likely to make conditions more favourable for certain vector mosquitoes, increasing the risk of mosquito-borne diseases such as Ross River virus, dengue fever, Australian encephalitis and Japanese encephalitis. The higher temperatures and increased rainfall variability are predicted to increase the intensity and frequency of food-borne and water-borne diseases.[9] By the year 2100, the Australian Medical Association and the Australian Conservation Foundation estimate that up to 15,000 Australians could die every year from heat-related illnesses.[10]

Climate change may lead to civil and political unrest internationally.[11]

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[7] Compiled from information obtained from the Intergovernmental Panel on Climate Change (http://www.ipcc.ch/).
[8] Australian Greenhouse Office, Climate Change Risk and Vulnerability Promoting an Efficient Adaptation Response in Australia, A Report by The Allen Consulting Group, March 2005, pp 77-80.
[9] Australian Greenhouse Office, Climate Change Risk and Vulnerability Promoting an Efficient Adaptation Response in Australia, A Report by The Allen Consulting Group, March 2005, p 75.
[10] Australian Medical Association and Australian Conservation Foundation, Climate Change Health Impacts in Australia: Effects of Dramatic CO_2 Emissions Reductions, 2005.
[11] Schwartz and Randall, An Abrupt Climate Change Scenario and Its Implications for United States National Security, A report by the Global Business Network for the United States Department of Defense, 2004; Brauch, H G, Threats, Challenges, Vulnerabilites and Risks in Environmental and Human Security, in: Studies Of University: Research, Counsel, Education, 1 - 2005, publication series of UN University's Institute of Environment and Human Security; Bonn, October 2005.

The significant changes in temperature and rainfall patterns will affect the habitat of millions of animals and plants world wide, placing many – possibly as many as a million species[12] – at risk of extinction. Australian native animals and plants are particularly vulnerable to climate change, especially those already threatened or inhabiting areas likely to be severely affected by climate change such as the Wet Tropics, Kakadu, Australian Alps or Great Barrier Reef. [13]

The purpose of this report is not to engage in the debate surrounding climate change science. The focus of this report is to analyse the direct costs of reducing emissions in the Australian electricity sector. The work of the IPCC and the CSIRO has been used to inform our analysis about possible emission reduction paths and their relative merits.

2.4 What global emission reductions are necessary?

There is ongoing debate at the international and national level about what emission reductions are necessary during the next 50 years with a view to avoiding dangerous climate change. There is a growing consensus among the scientific community that global warming of $2^{O}C$ above the pre-Industrial Revolution average is dangerous. Beyond this point, the costs associated with the required mitigation and with climate impacts become prohibitive.[14] However, it is also likely that major threshold points could be crossed, causing so-called positive feedback, or processes which will lead to runaway climate change, with severe consequences. For example, it is unclear how much additional energy would be absorbed by the planet if the major ice caps melt and less sunlight is reflected back into the atmosphere.

EU

In March 2005, the EU stated that global average temperatures should not be allowed to increase by more than $2^{O}C$ above the pre-Industrial Revolution level.[15] If greenhouse gas *concentrations* are to be stablised, actual *emissions* need to fall. There are a number of views about what levels of greenhouse gas concentrations are necessary to achieve this goal. The EU has not set a ppm target but has noted that greenhouse gas concentrations need to be stabilised at levels well below 550 ppm to achieve the $2^{O}C$ goal.

Keeping this long-term temperature objective within reach would require greenhouse gas concentrations to peak within decades. This would need to be followed by substantial global reductions in the order of at least 15% and perhaps by as much as 50% by 2050 compared to 1990 levels.

The EU Heads of State Council concluded that "reduction pathways for the group of developed countries in the order of 15-30% by 2020, compared to the baseline envisaged in the Kyoto Protocol, and beyond, should be considered."[16]

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[12] Thomas, C et al, Feeling the Heat: Climate Change and Biodiversity Loss, Nature p 427, 145–148, 8 Jan 2004.
[13] Australian Greenhouse Office, Climate Change Risk and Vulnerability Promoting an Efficient Adaptation Response in Australia, A Report by The Allen Consulting Group, March 2005, pp 69-70; Pittock, B (ed), Climate Change - An Australian Guide to the Science and Potential Impacts, 2003.
[14] Watson, R T et al, Climate Change 2001: Synthesis Report. A Contribution of Working Groups I, II, and III to the Third Assessment Report of the Intergovernmental Panel on Climate Change, 2001.
[15] Council of the European Union Conclusions, 23 March 2005, p 15.
[16] Council of the European Union Conclusions, 23 March 2005, p 16.

Hadley Centre in the UK

The Hadley Centre in the UK has recently developed new techniques for analysing emission reduction pathways and their implications for global temperature. Specifically, the new techniques are designed to apply probabilistic methods to remove the uncertainty around a range of estimates.

Initial estimates provided by the Centre indicate that to prevent warming beyond $2^{O}C$, carbon dioxide concentrations need to be stablised at between 490 and 670 ppm (5% and 95% confidence intervals).[17]

Swiss Federal Institute of Technology

The Swiss Federal Institute of Technology found that there is a 4:1 chance that temperatures could be limited to below 2% even if we exceed 400 ppm carbon dioxide concentrations provided emissions are reduced fast enough to peak at 475 ppm carbon dioxide equivalent (before sliding back to 400 ppm carbon dioxide equivalent).[18]

Australia

The former Australian Chief Scientist, Dr Robin Batterham stated before a Senate Inquiry in 2004, "We have to talk not about a few per cent reduction but about an 80% reduction by the end of this century or a 50% reduction by 2050."[18] The CSIRO has concluded that a 60% reduction by 2050 would be the minimum reduction required by developed countries if the world is to avoid dangerous climate change.[19] However, Australian governments, Federal and State, have not reached a consensus on the level of emission reductions necessary.

2.5 Australian contribution to global emission increases

When assessed on a global scale, Australia is not a significant emitter of greenhouse gases. Australia currently contributes about 1.5% of human induced greenhouse gas emissions. In total, Australian emissions are similar in magnitude to those of Italy and the UK which contribute 1.5% and 2% of global emissions respectively. However, on a per capita basis, Australia is one of the highest emitters in the world. Figures 2 and 3 show Australia's per capita and per economic output emission intensities relative to other nations. [20]

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[17] Jenkins, G et al, Stabilising Climate to Avoid Dangerous Climate Change – A Summary of Relevant Research at the Hadley Centre, 2005.
[18] Meinshausen, M et al, Can 2°C Warming be Avoided, Swiss Federal Institute of Technology, 2006.
[18] Quote available at http://www.abc.net.au/catalyst/stories/s1195633.htm.
[19] Preston, B L and Jones, R N, Climate Change Impacts on Australia and the Benefits of Early Action to Reduce Global Greenhouse Gas Emissions, CSIRO, 2006.
[20] International Energy Agency, Key World Energy Statistics, 2005.

Figure 2: Per capita greenhouse gas emissions

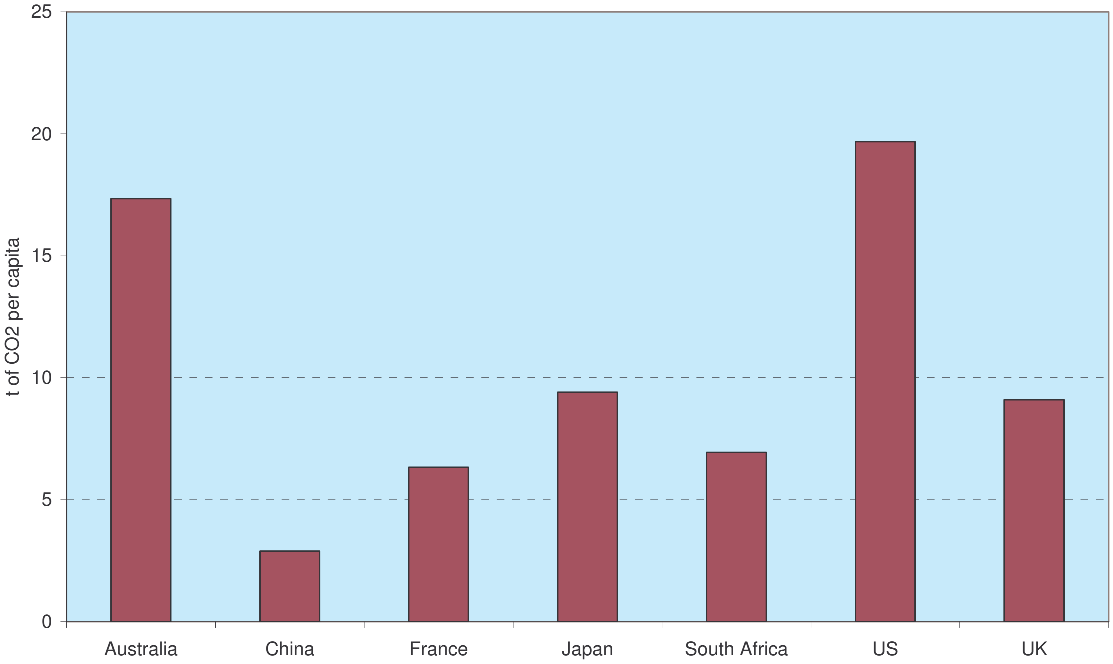
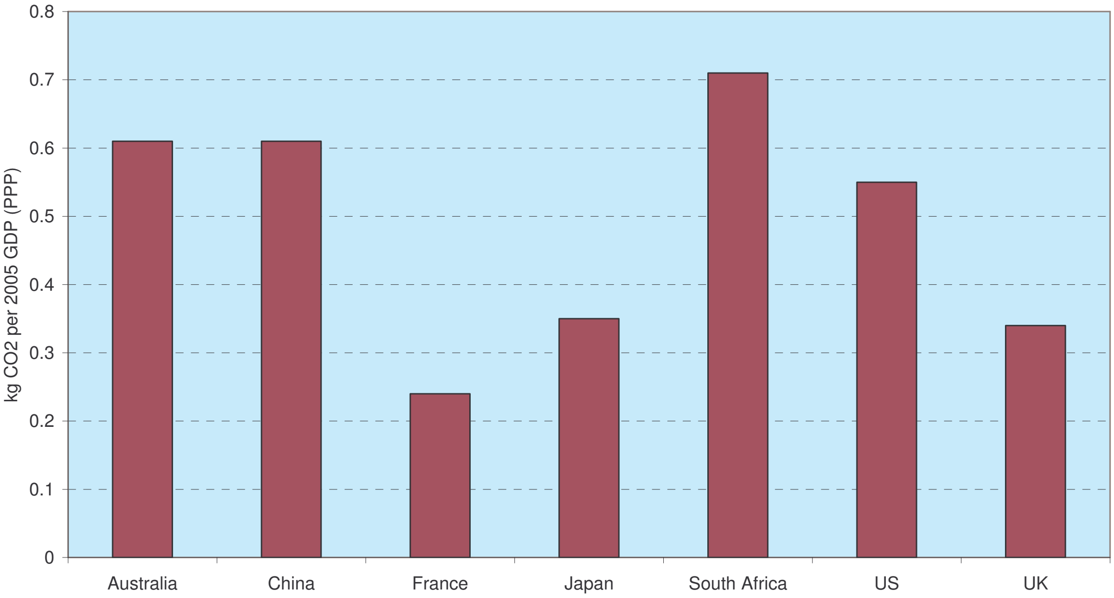


Figure 3: Emissions per unit of economic output

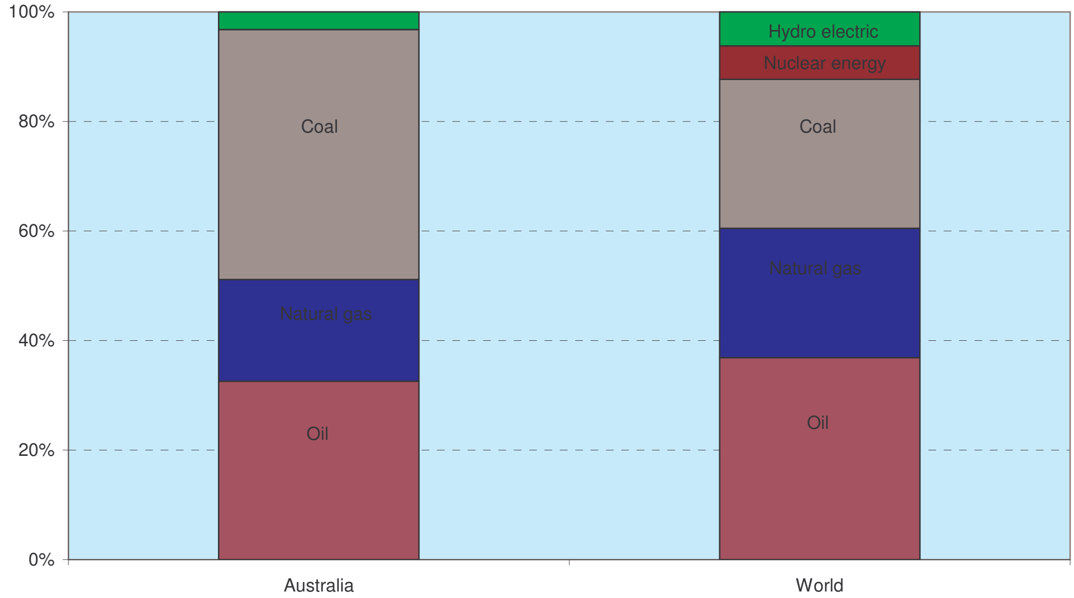


On a cumulative basis, Australian emissions are only 1% of global emissions. This is largely because Australia, as a relatively young industrial nation, has not been emitting for as long as other countries. In contrast, the EU is responsible for 16% of global emissions from fossil fuels but accounts for 27% of global cumulative emissions. In most cases, a country's historic share of global emissions is different from current emission levels.[21]

Australia's high emission levels are largely due to the country's abundant coal reserves which are used to produce electricity and other forms of energy. Figure 4 shows how Australian energy production relies more heavily on coal than the global average.

[21] Pew Center on Global Climate Change, Climate Data: Insights and Observations, 2004.

Figure 4: Proportion of energy production[22]



2.6 The intergovernmental response

All countries, including Australia and the US, have signed and ratified the United Nations Framework Convention on Climate Change (UNFCCC), the overall objective of which is to stabilise greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous human induced interference with the climate system.

The Kyoto Protocol came into force on 16 February 2005. The Protocol was ratified by 158 countries. Of these, 35 industrialised countries and the EU have obligations to reduce greenhouse gas emissions to prescribed levels by 2008-2012 (averaged over this period). The primary objective of the Protocol is to reduce the emissions of developed nations (Annex 1 nations) to 95% of 1990 levels. Australia and the US have not ratified the Kyoto Protocol.

Each country has a different obligation under the Protocol. For example, the overall EU target is for emissions to be no higher than 92% of 1990 levels. Australia on the other hand is permitted to increase emissions to 108% of 1990 levels. The Australian Government has stated that with actions taken to date, the target established under the Kyoto framework will be met.

Although the first Commitment Period of the Kyoto Protocol ends in 2012, ministers of signatory countries from both developed and developing countries agreed at the Montreal climate conference in early December 2005 to start the talks about deeper reductions for the second Commitment Period.[24]

In addition to the Kyoto Protocol, a number of countries have signed other agreements designed to address increasing greenhouse gas emissions. For example, on 12 January 2006 a new agreement was signed by ministers from the US, Australia, India, Republic of Korea, China and Japan: the Asia Pacific Climate Change Partnership (AP6). At the inaugural ministerial meeting in Sydney, governments agreed a charter, communique and work plan aimed at technology development and deployment in signatory countries.

[22] BP, Statistical Review of World Energy, 2005.
[24] Meeting details obtained from http://unfccc.int/meetings/cop_11/items/3394.php.

2.7 The Australian Government's response

In 1990, Australian greenhouse gas emissions were 543 million tonnes of carbon dioxide equivalent. The Australian Greenhouse Office has forecast that by 2012, emissions will be 585 million tonnes of carbon dioxide equivalent. This is equivalent to about 108% of 1990 emissions.

While Australia is on track to meet its Kyoto target, various sectors of the economy have experienced more significant increases and decreases in emissions since 1990. Figure 5 highlights how emissions have changed since 1990 in each of the sectors.

Figure 5: Australian greenhouse gas emissions

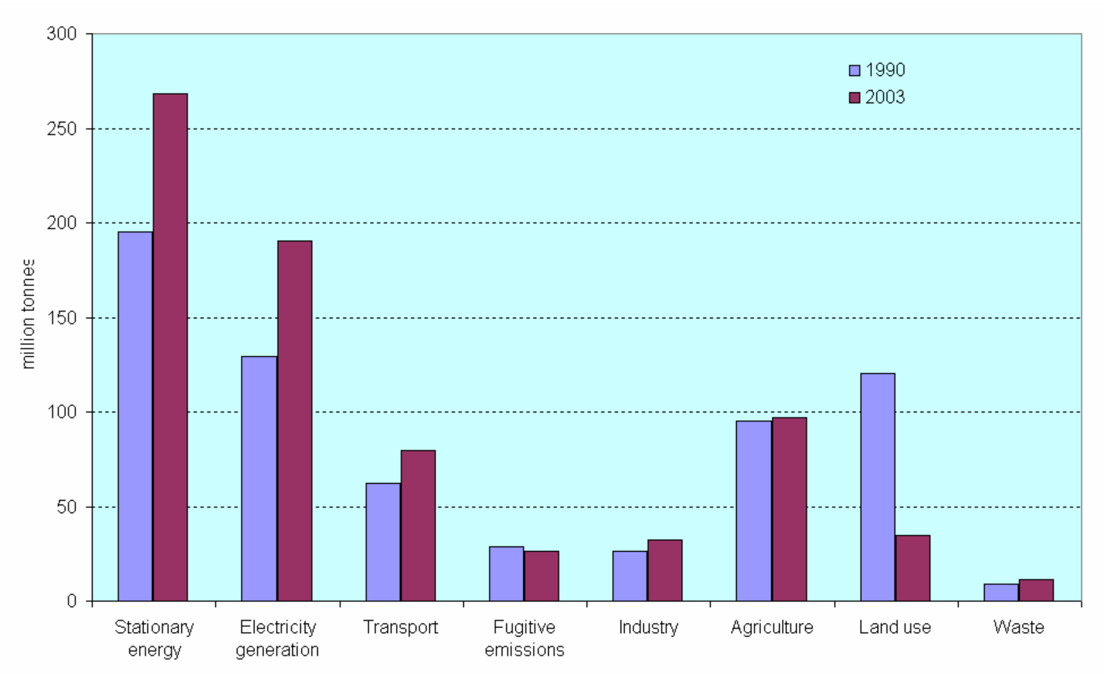


Figure 5 shows that the biggest changes in emissions since 1990 are in the energy and land use sectors. Emissions from changing land use are forecast to fall to 33% of 1990 levels by 2012. This is largely due to the cessation of land clearing in large parts of Queensland.

In the stationary energy sector, emissions have increased significantly since 1990. In 2003, stationary energy emissions were 268 million tonnes. This was already 38% higher than 1990 levels. In the electricity generation sector, emissions in 2003 were 190 million tonnes or 47% higher than 1990 levels.

Therefore, while Australia is on track to meet its overall Kyoto target of 108%, emissions from the stationary energy sector and more specifically the electricity generation sector are significantly higher now than in 1990.[24]

2.8 The business response

The global business community increasingly acknowledges that climate change presents enormous risks and opportunities for companies and investors. With the launch of the Kyoto Protocol and greenhouse gas regulation, power companies and other energy intensive businesses face growing 'carbon risk', in other words, risk as a result of the greenhouse intensity of their operations. Companies also face risks from direct physical impacts, including more intense and frequent storms, droughts, floods and sea-level rise.

[24] Australian Greenhouse Office, Tracking the Kyoto Target, 2005; Australian Greenhouse Office, State and Territory Greenhouse Gas Emission Inventories: An Overview, 2002.

In turn, forward-thinking companies that fine-tune their operations and develop new climate-friendly products can find new business opportunities.

A growing number of corporate leaders acknowledge that ultimately, effective corporate responses to climate change must be built on well-functioning environmental management systems and governance practices properly incorporating a focus on carbon management. They also acknowledge that investors and financial analysts will increasingly assign value to companies that prepare for and capitalise on business opportunities posed by climate change — whether from greenhouse gas regulations, direct physical impacts or changes in corporate reputation.

Corporate carbon risk is being investigated by the global investment community. In 2006, the Carbon Disclosure Project sent out its fourth annual questionnaire to the largest corporations around the world, including the ASX100 in Australia and NZX50 companies in New Zealand. The Carbon Disclosure Project is being supported by more than 200 leading institutional investors, which hold more than A$40 trillion of investments between them.

Other responses by the investment community include the Enhanced Analytics Initiative, an international collaboration between asset owners and managers, encouraging investment research that considers the impact of extra-financial issues, including greenhouse gas emissions on long-term company performance. The Equator Principles, designed to help financial institutions manage environmental and social risk in project financing, have now been adopted by 40 banks which arrange 75% of the world's project loans. In addition, the rise in shareholder activism and the growing debate on fiduciary responsibility, governance legislation and reporting requirements (such as the Global Reporting Initiative) indicate the mainstream incorporation of sustainability concerns.

The emergence of a patchwork of different forms of state-based carbon regulation and the need for certainty about the long-term policy framework have led a growing number of businesses around the world to call for tougher regulations and market mechanisms to curb the rise in greenhouse gases. In the US, Shell Oil, BP, Cinergy Corp, Intel, Alcan and others have endorsed the 'Agenda for Climate Action', calling for a combination of economy-wide mandatory emissions cuts.[26] Key messages from a global business conference on climate change coinciding with the G8 Summit included the need for a clearly mapped out long-term policy framework ('Long, Loud and Legal') to create security and confidence for business. The vast majority of companies present at this conference also stressed that they were committed to taking action to reduce emissions and that they saw business opportunities as a result of doing so.[26]

An increasing number of Australian businesses have expressed support, under conditions, for carbon regulation, including the development of a national State-based emissions trading scheme.[27] AGL is one of the companies that has called on the Australian and State governments to agree on a long-term emission reduction target and market-based mechanisms to achieve this goal.

In April 2006, the CEOs of BP Australia, Insurance Australia Group, Origin Energy, Swiss Re, Visy Industries, Westpac and the Australian Conservation Foundation launched the Australian Business Roundtable on Climate Change. The Roundtable is urging governments to work together to develop nationally consistent climate change policies, including establishment of a price signal, encouraging technology and building resilience to the impacts of climate change. [28]

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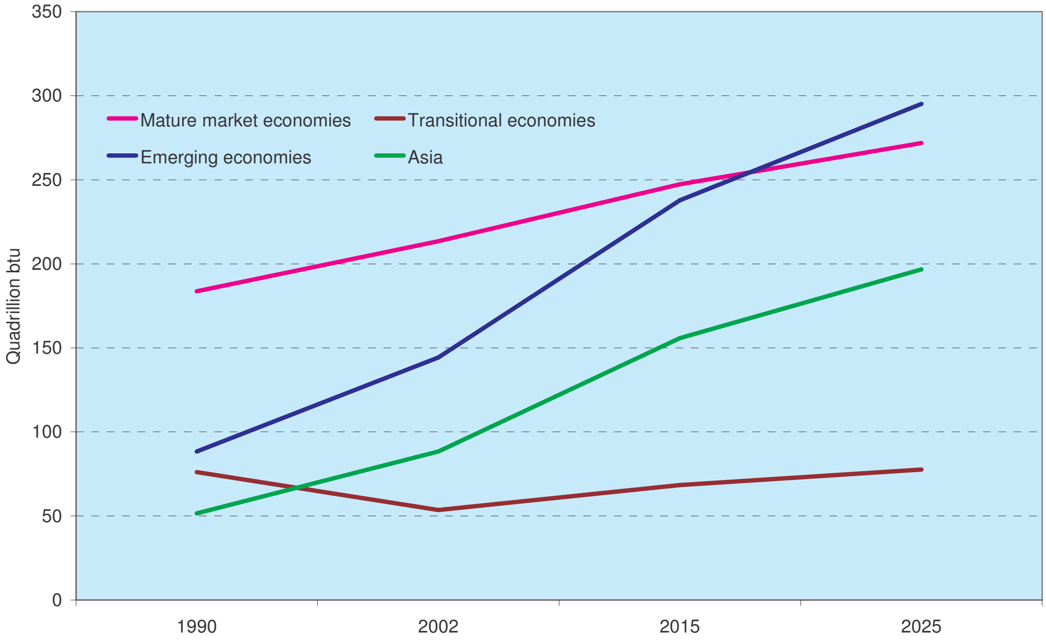
[26] Pew Center on Global Climate Change, Agenda for Climate Action, 2006.
[26] Summary of conference available at http://www.defra.gov.uk/corporate/international/eu-presidency/events/pdf/cc-051005summary.pdf.
[27] Submissions to - A National Emissions Trading Scheme: Background Paper; submissions available at http://www.cabinet.nsw.gov.au/emissions/submissions.html.
[28] Australian Business Roundtable on Climate Change, The Business Case for Early Action, 2006.

2.9 Beyond the initial Kyoto Protocol target: a transitional approach

The purpose of this report is to determine the direct costs of transitioning the Australian electricity sector towards a low emission future. A crucial input in this exercise is the share of global emission cuts the electricity sector should bear.

If global emissions are to be successfully reduced, both developed and developing countries will be required to implement existing and new technologies and policies. However, with rapid energy demand growth in the developing world, it is likely that the developed world will be required to take action first. Figure 6 shows anticipated growth in energy demand across a range of different economies.

Figure 6: Global energy growth[29]



The EU has publicly commented about two pathways for emission reductions:

- Developed countries should reduce their emissions by 15-30% of their Kyoto baseline by 2020.
- Developed countries should reduce their emissions by one real percentage point of their Kyoto baseline every year.[30]

An advantage of pursuing the second approach is that it allows countries to gradually reduce emissions. This minimises any structural adjustment issues and allows the existing capital stock to be used before new lower emission technology is adopted. Beyond 2025, as new technologies are likely to be developed, the reductions required would increase to ensure that the 60% cut by 2050 is met.

Given that the methodology used to identify the possible European target is one percentage point per year, an option would be to apply this to the Australian Kyoto target of 108% of 1990 levels. Given that there are 18 years between 2012 and 2030, the 2030 target for the Australian economy would be that emissions should be no higher than 90% of 1990 levels. In absolute terms, emissions should be no higher than 487 million tonnes in 2030.

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[29] US Energy Information Administration, International Energy Outlook, 2005.
[30] European Union, Action on Climate Change Post 2012: A Stakeholder Consultation, 2004.

An alternative approach, and one favoured by WWF-Australia, is for Australia to adopt policies and measures that would result in an overall emission reduction of at least 30% below 1990 levels by 2030.

It should be noted that AGL and Frontier Economics have not developed positions on what emission reductions are necessary to avoid dangerous climate change. Conversely, WWF-Australia is advocating for a 30% reduction in emissions by 2030 and a 60% reduction in emissions by 2050.

2.10 A transitional target for the Australian electricity sector

Regardless of whether the target for the Australian economy will be to reduce emissions to 70% or 90% of 1990 levels by 2030, it is necessary to determine what proportion of this emission reduction target should be undertaken by the various sectors.

Ideally, the abatement task given to each of the sectors would be determined by the market through a broad market-based policy. This would allow the abatement to be pursued up to the point where the marginal costs of abatement are equalised across the sectors.

However, establishing marginal costs of abatement in some sectors is difficult. It is therefore necessary to make a judgement call about the proportion of the overall abatement task which should be assigned to the electricity sector. Considerations would include:

- The electricity sector is a source of identifiable abatement.
- There is significant scope for emission reductions in the transport sector. The use of compressed natural gas, LPG and hybrid vehicles would result in significant cuts in emissions.
- The land use and agriculture sectors have already contributed significantly to reductions in emissions. Reduced land clearing rates are one of the main reasons Australia is on track to meet its Kyoto target.
- The electricity sector is starting from a significantly higher position. In 2003, emissions were 47% higher than 1990 levels.

The methodology that has been adopted in this report is to set a challenging target for the electricity sector without granting concessions so generous that they increase the burden on other sectors.

Table 2: Emission reduction pathways[31]				
Sector	**1990 Emissions (million tonnes)**	**2010 Emissions forecast by AGO (million tonnes)**	**Target for 2030 'EU Approach' (million tonnes)**	**Target for 2030 'WWF Approach' (million tonnes)**
Stationary energy	195	285	220	191
Of which electricity generation	129	200	120	120
Transport	62	94	55	44
Fugitive energy	29	35	35	22
Agriculture	94	99	105	88
Waste	10	10	8	4
Industry	27	42	42	51
Land use change	126	43	43	10
Forestry sinks	0	-21	-21	-30
Total emissions	543	585 (108%)	487 (90%)	380 (70%)
Note: Columns may not sum due to rounding				

In 2012, overall emissions are forecast to be about 585 million tonnes. If emissions are reduced to 90% of 1990 levels, the 2030 target is 487 million tonnes. If emissions are reduced to 70% of 1990 levels, the target is 380 million tonnes. Table 2 highlights how this reduction may be split between the sectors based upon the factors outlined above.

Under both scenarios, the electricity sector would be expected to reduce emissions from about 200 million tonnes in 2012 to 120 million tonnes in 2030. If the 'EU Approach' is followed, other sub-sectors in the stationary energy sector would be able to increase emissions.

If the 'WWF Approach' is followed, substantial emission reductions can be expected from all other sub-sectors, in particular land use change, agriculture and waste. The policies and measures WWF-Australia propose to achieve the targets in other sectors are beyond the scope of this report.

It should be noted that the 2030 target of 120 million tonnes proposed by both approaches is a considerable challenge for the electricity sector. For the purposes of understanding the direct costs associated with reducing emissions in the electricity sector, the following target has been identified:

<u>By 2030, emissions from the electricity sector should be no higher than 120 million tonnes.</u>

If the electricity sector is required to reduce emissions to 120 million tonnes by 2030, there are at least two emission reduction pathways that could be pursued.

- <u>Linear</u>: Under the Linear approach, emissions are reduced by the same amount each year so that by 2030 the constraint is achieved. The environmental benefit of this approach is that over the 24 year modelling period, the cumulative greenhouse gas reduction is about 300 million tonnes greater than the Staged Transition pathway. This is demonstrated in Table 3.

- <u>Staged Transition</u>: Under this approach, small emission reductions are required early. However, the reductions are gradually increased so that by 2030, the target is achieved. This pathway significantly reduces emissions from the electricity sector. However, the approximately 300 million tonnes of additional greenhouse gases that are emitted under this pathway (as against the Linear pathway), may have to be offset by additional reductions after 2030.

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[31] Australian Greenhouse Office, Tracking the Kyoto Target, 2005.

Table 3: Total targeted emissions over the 24 year period to 2030		
	Staged Transition	Linear
Total emissions (million tonnes)	4,091	3,800

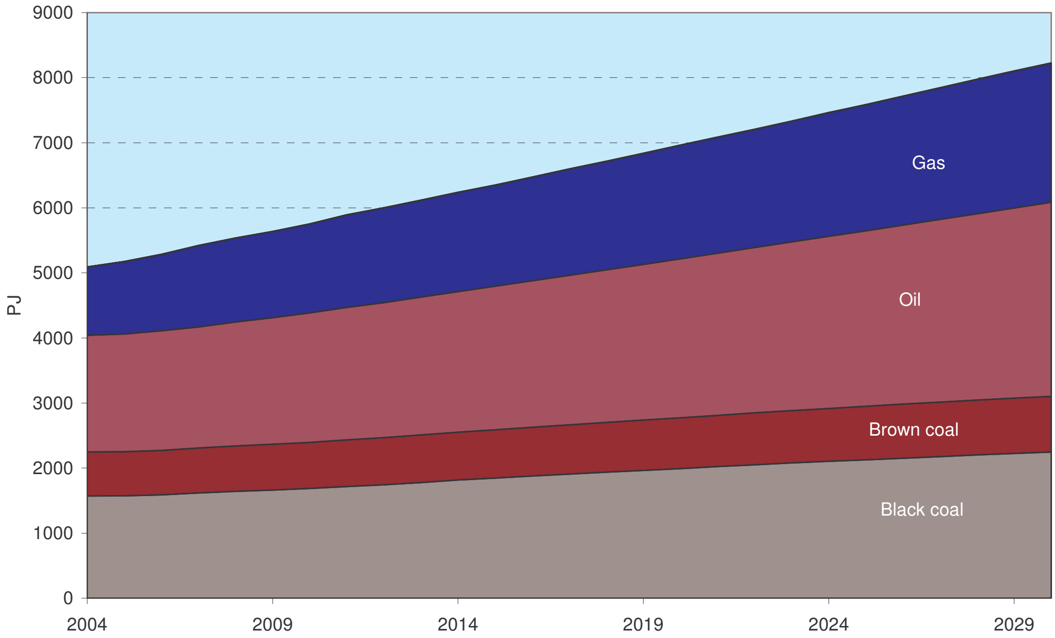
Importantly, even though the analysis so far has assumed that action would not be taken until the end of the first Commitment Period under Kyoto (2012), it is more likely that action will be taken before this date. The analysis therefore assumes that a constraint is imposed in 2007. Table 4 outlines the two different pathways for the electricity sector.

Table 4: Emission reduction pathways for the electricity sector		
Year	Linear (million tonnes)	Staged Transition (million tonnes)
2007	195	195
2008	192	194
2009	189	193
2010	185	192
2011	182	191
2012	179	189
2013	176	187
2014	173	185
2015	170	183
2016	167	181
2017	163	179
2018	160	177
2019	157	175
2020	154	173
2021	151	170
2022	147	167
2023	144	164
2024	141	161
2025	138	159
2026	134	151
2027	131	143
2028	128	135
2029	124	127
2030	120	120

3. A model of the National Electricity Market

Australian energy demand is forecast to grow strongly during the next 25 years. ABARE has indicated that primary energy consumption could grow by about 3,500 PJ by 2030. The forecast increase in energy consumption is highlighted in Figure 7.

Figure 7: Energy consumption growth forecast[32]



3.1 The National Electricity Market

Prior to privatisation in the 1990s, the Australian electricity sector was comprised of State-owned, vertically integrated electricity companies which controlled the entire supply chain from generation to retail. Governments largely controlled the types of electricity generation which was built and the timing and location of these investments. In the late 1990s, a national energy market was established and investments are now largely driven by the private sector.

The National Electricity Market has been in operation since 1998. This wholesale market allows retailers to purchase electricity from generators in a clearing market process. The National Electricity Market Management Company establishes clearing or spot prices for electricity for every five minute trading interval. The clearing price paid by retailers to generators is generally the last (highest) bid made by a generator that ensures demand will be met.

The markets in south eastern Australia are connected through high voltage transmission lines called interconnectors. As a result, consumers in Queensland could potentially consume electricity that was generated in Victoria. Therefore, the greenhouse intensity of generation in a particular State may not precisely match the greenhouse intensity of electricity consumed in that State.

The type of generation technology used in each State depends largely on the availability of different fossil fuels. As Victoria has significant reserves of brown coal, much of the generation in Victoria is brown coal-fired. In comparison, NSW and Queensland have significant reserves of black coal and depend mostly on it as a fuel source for electricity generation. The greenhouse intensities of the different States and existing production techniques is presented in Table 5.

[32] Australian Bureau of Agricultural and Resource Economics, National and State Energy Trends, 2005.

Table 5: Greenhouse intensity of different States[33]		
State	**Predominant fuel**	**Greenhouse intensity (t/MWh)**
Victoria	Brown coal	1.392
New South Wales	Black coal	1.054
Queensland	Black coal	1.058
South Australia	Gas (and Victorian imports)	0.960
Tasmania	Hydro	0.006
Western Australia	Coal/gas	1.053

In most States, customers are free to choose their electricity retailer (exceptions are Queensland, Tasmania and Western Australia). The prices charged by different retailers reflect the different wholesale energy costs they pay to generators they contract with. Customers receive their electricity through the same transmission and distribution network, regardless of their retailer. The price paid for use of this network is regulated by a State regulator or the Australian Energy Regulator.

Customers are able to purchase different types of energy from different retailers. For example, most retailers offer 'green' energy products. These products are sourced from renewable generation such as wind, solar and biomass, or include emission reductions called abatements. There are two main sources of accreditation for these products:

- Green Power: The National Green Power Accreditation Steering Group was established by State governments to oversee accreditation of renewable energy products that provide customers with renewable energy. There are a number of different Green Power accredited products offered by most energy retailers.

- Greenhouse Friendly: The Australian Greenhouse Office has established an accreditation framework for abatement products called Greenhouse Friendly. The emissions associated with supplying customers with Greenhouse Friendly accredited electricity are offset through activities such as methane flaring.

However, while the market for voluntary abatement and renewable energy is growing, government requirements have been more effective at driving investment in greenhouse abatement. There are currently three market-based greenhouse related policies in place in the electricity sector. These are the national Mandatory Renewable Energy Target, the NSW and ACT Greenhouse Gas Abatement Schemes, and the 13% Gas Generation Scheme in Queensland. Each of these schemes is discussed in further detail below:

- Mandatory Renewable Energy Target (MRET): The Australian Government has passed legislation requiring all retailers of electricity to purchase a set amount of renewable energy until 2020. By 2010, retailers will be required to purchase 9,500 GWh of electricity each year.

- NSW and ACT Greenhouse Gas Abatement Schemes: The NSW and ACT Greenhouse Gas Abatement Schemes require retailers in NSW and the ACT to reduce their greenhouse emissions to 7.27 tonnes per capita by 2007.

- 13% Queensland Gas Generation Scheme: The 13% Gas Generation Scheme requires retailers in Queensland to source 13% of their wholesale electricity purchases from gas-fired generation.

3.2 The national gas market

Pipelined natural gas was progressively introduced into parts of Victoria, Queensland, South Australia, NSW, the ACT and Western Australia in the 1960s and 1970s. Given that most gas reserves are located away from major markets, the discovery of new gas reserves has resulted in the expansion of pipeline infrastructure.

There are four main production stages in the gas industry: production, transmission, distribution and retail. Gas is produced through a refining process at locations around the country. It is then transported under pressure through transmission pipelines that link the

[33] Australian Greenhouse Office, Factors and Methods Workbook, 2006.

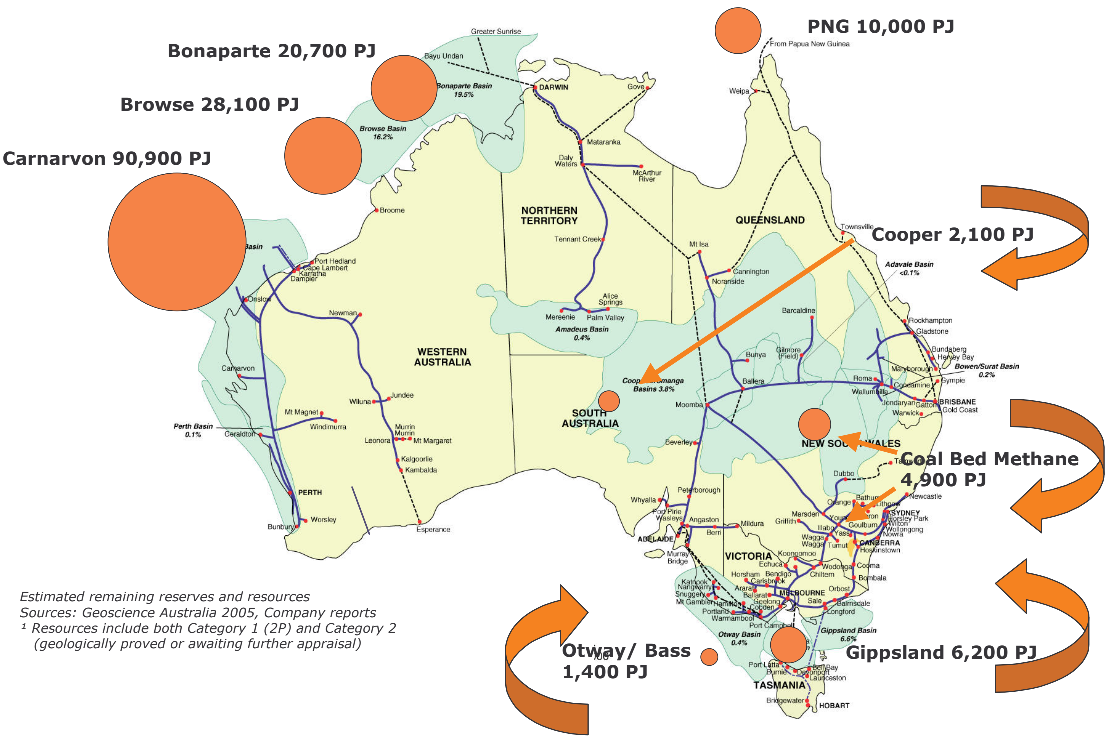
gas fields with major towns and cities. It is then delivered to the customer through a distribution network.

Gas purchases between producers and retailers are typically under long-term contracts. As a consequence, gas prices are not volatile like electricity prices. The transmission charges paid by customers can be either regulated or determined by the market but network charges are generally regulated.

Natural gas has some significant advantages over other fuels. Firstly, with sufficient pipeline infrastructure in place, it can be delivered to markets at relatively low prices. Secondly, it can be used as both an end-use fuel (eg for cooking, heating and industrial uses or for generating other types of energy such as electricity).

It is important to note that Australia has significant gas reserves. There are about 15,000 PJ of reserves, including coal seam methane, already available for consumption in south eastern Australian markets. PNG gas is also expected to supplement Australian markets.[34] To put these reserves in perspective, natural gas sales by AGL in 2004/05 totalled 173 PJ.[35]

Figure 8: Australian gas reserves[36]



Australia has 1.4% of total world gas reserves and, at current production rates, these reserves would last 69 years.[37] However, much of these reserves are located in remote areas such as the North West Shelf. Accordingly, much of the focus of natural gas production has been for liquefied natural gas export markets such as South East Asia.

However, significant additional reserves are likely to be available for consumption by the end of the decade. A major project is underway to build a pipeline from vast reserves of natural gas in PNG to the existing transmission system in Australia. As such, an additional 10,000 PJ of reserves may be available by 2009 as a result of this project alone.

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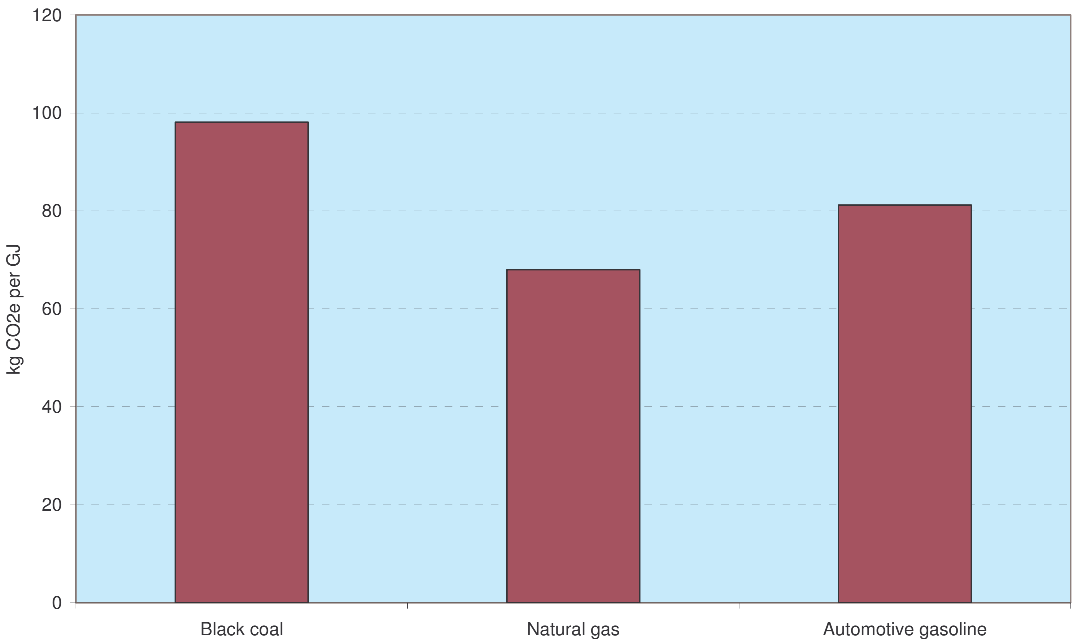
[34] Assuming the PNG pipeline is constructed.
[35] AGL, Annual Report, 2005.
[36] Chart produced by AGL utilising information from Geoscience Australia and individual company reports.
[37] BP, Statistical Review of World Energy, 2005.

The price of natural gas in Australia is significantly lower than in many countries. Natural gas prices in the US, Japan and Europe have increased significantly over the past few years. In Australia, the wellhead (upstream) price of gas varies but is generally less than the price paid in most developed economies.

In addition to being relatively economic as an energy source, natural gas has a low greenhouse emission intensity relative to other fossil fuels. This is primarily because it is a more efficient heat source. For example, when used in a combined cycle generation plant, natural gas produces about 0.4 tonnes of greenhouse gases per MWh. In comparison, modern black coal technologies produce about 0.8 tonnes of greenhouse gases per MWh. The emission intensities of gas, coal and petrol are presented in Figure 9.

Figure 9: Emission intensities of gas, coal and petrol[38]



3.3 Outline of the economic model

The Frontier Economics WHIRLYGIG model has been used to estimate optimal investment and dispatch decisions in the electricity market. The model uses a mixed integer linear programming approach. The model selects the least cost way of meeting electricity demand. Forecasts for WHIRLYGIG were obtained from the NEMMCO Statement of Opportunity. The model seeks to minimise the net present value[39] (NPV) of the costs of meeting total electricity demand. To meet demand, the model either dispatches existing capacity or builds new generation. However, a number of constraints have been developed to make the model as realistic as possible:

- Supply must equal demand at all demand points. This ensures that ‘blackouts’ do not occur.
- The minimum reserve requirement must be met in each region. Regulators would be unlikely to reduce current reserve requirements.
- Existing greenhouse schemes, such as the Mandatory Renewable Energy Target and the NSW Greenhouse Gas Abatement Scheme, are incorporated into the model.

[38] Australian Greenhouse Office, Factors and Methods Workbook, 2006.
[39] The net present value (NPV) of an investment is the present (discounted) value of future cash inflows minus the present value of the investment and any associated future cash outflows: ie the net result of a multi-year investment expressed in today’s dollars.

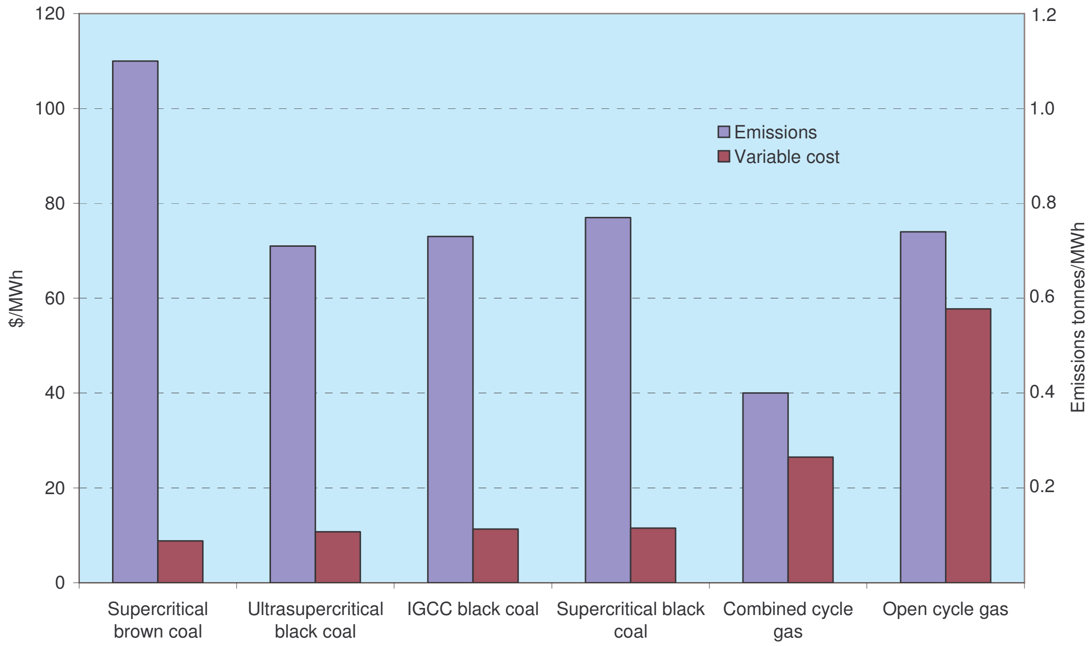
- Generation cannot be installed instantaneously. Generation takes several years to build. As such, the model requires a commitment to build a power station several years before it can be utilised.

- Generation capacity must be built in realistic increments. For example, it would be impractical to build a 10 MW black coal-fired power station.

In the context of this study, the most important constraint is the level of greenhouse emissions. The types of generation capacity built and operated to meet demand must be sufficiently 'greenhouse friendly' to meet the targets. The model effectively acts to minimise costs while meeting the greenhouse constraints identified in Section 2.

There are a range of different technologies that the model can choose from to meet new demand. An estimate of the costs and emission intensities of traditional forms of electricity generation is outlined in Figure 10.

Figure 10: Potential new entrant traditional thermal technologies

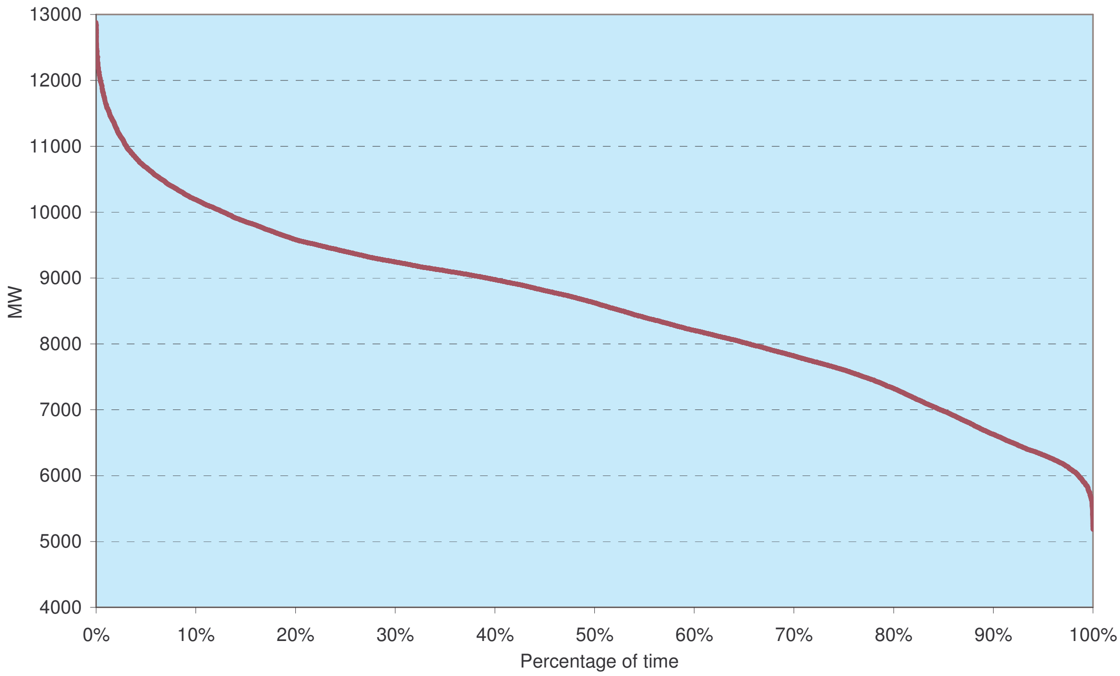


One of the most determining features of the market for electricity is that it must be consumed when it is produced or it is wasted. While electricity can technically be stored, it is prohibitively expensive. Therefore, at different times of the day, production of electricity must change to meet demand at that time.

The most significant driver of demand fluctuations in recent times has been the widespread use of air conditioning. On a hot summer afternoon, electricity demand often increases substantially as a result of consumers simultaneously switching on their air conditioning. Conversely, in the early hours of the morning, demand is often very low as many businesses are closed and people are asleep.

When this varying demand is considered over a longer timeframe, it becomes clear that peak or maximum demand only occurs for a few hours each year. Figure 11 shows a typical load duration curve. This curve demonstrates that relatively low levels of demand occur 100% of the time (eg street lighting) whereas higher levels of demand progressively occur less frequently. To accurately depict this feature of the market, a number of demand points are created for each time period in the WHIRLYGIG model.

Figure 11: Example of a load duration curve



Over time, the varying nature of electricity demand influences the type of generation capacity that is installed. Generation that has low capital costs but higher operating costs is more appropriate for meeting demand that does not occur very often (ie peaking demand). Conversely, generation that has higher capital costs but lower operating costs is more appropriate for meeting ongoing demand (ie baseload demand).

Coal-fired generation and combined cycle gas generation have traditionally been installed to meet ongoing demand. This is because these generators have high upfront capital costs but lower operating and maintenance costs. Open cycle gas-fired generation is generally used to meet high levels of demand for short periods of time (peaking) because it is characterised by low upfront capital costs but higher operating costs. Figure 12 outlines the cost structures of these technologies at different levels of operation (ie capacity factors).

Figure 12: Cost structure of different technologies with a carbon constraint

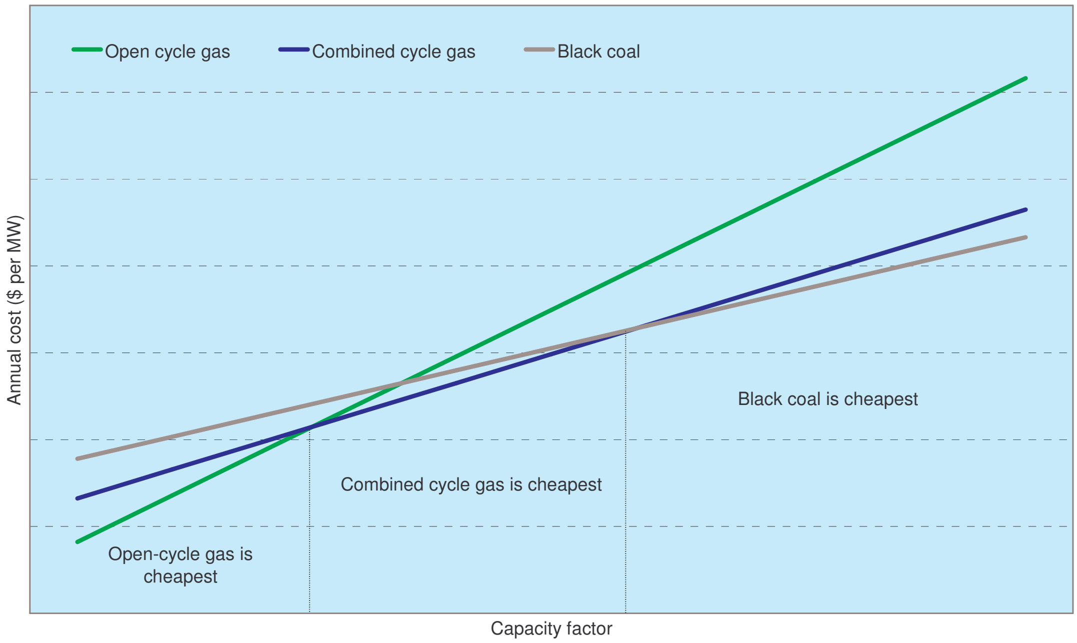


Figure 12 shows a simple hypothetical representation of how the costs associated with three generic generating technologies are captured in WHIRLYGIG. The figure shows the cost curves for an open cycle gas (OCG), a combined cycle gas (CCG) and a black coal plant. The intercept of each curve with the vertical axis represents the fixed costs associated with building the plant and are incurred even if the plant is not run (ie at a capacity factor of 0%). As the plant is utilised to a greater degree the associated costs increase, where the slope of each curve represents the variable cost of running the plant.

It is clear that if plant was needed only to meet peak demand for a few hours each year (eg to meet peak air conditioning demand), then the low fixed costs of OCG technology make it the optimal choice. Past a certain point of utilisation, roughly 20-30%, the high variable costs of OCG technology make it uneconomic and CCG becomes the optimal choice. For capacity factors greater than 60%, coal becomes the optimal choice.

WHIRLYGIG simultaneously considers the discounted cost curves of hundreds of new generating options over the multiple years of the modelling period to determine the optimal, least cost, pattern of investment and dispatch. These curves also incorporate the cost effects of any greenhouse constraints. For example, a cap and trade scheme penalises emissions, with more greenhouse intensive plant receiving a higher penalty. The costs curves for both CCG and coal would be shifted upwards in the presence of such a scheme (as would OCG). However, coal gets shifted to a greater degree due to its higher carbon intensity. The effect of this is that CCG becomes economic at higher capacity factors relative to coal. At a sufficiently high carbon price, CCG becomes a viable alternative generating technology for meeting baseload demand for electricity.

WHIRLYGIG produces a range of results for each of the scenarios (business as usual (BAU), Linear constraint and Staged Transition constraint) including:

- The total NPV cost of meeting demand.
- The marginal costs of abatement (ie carbon prices) associated with each of the constraint levels.
- The changes in investment patterns created when greenhouse constraints are imposed.

With this information, policy makers will be better able to determine the appropriate emission reduction pathways to minimise costs to the economy while ensuring environmental outcomes.

3.4 Key assumptions in the economic model

The following key assumptions have been made:

- Demand growth has been estimated for the 24 year modelling period from 2007 to 2030. The growth in demand is based on the 2005 NEMMCO Statement of Opportunity. Demand grows from about 200,000 GWh in 2007 to 315,000 GWh in 2030.

- The capital costs of existing plant do not affect patterns of investment or dispatch and are considered to be sunk costs for the purpose of the modelling. As such, only the operating and maintenance costs of existing plant are explicitly modelled.

- The operating and maintenance costs of existing plant are based on estimates by ACIL Tasman produced for NEMMCO.

- Costs of new generation, both capital and operating, are based on estimates by ACIL Tasman for new thermal plant and on estimates collected over time by Frontier Economics and AGL in the case of non-thermal options.

- The model only allows existing technologies to be deployed throughout the modelling period.

- Gas prices are assumed to increase by one real percentage point each year throughout the modelling period to capture impacts of increased demand and the cost of developing new transportation infrastructure. This results in a real gas price increase of 25% over the modelling period. In addition, an additional scenario has been tested where gas prices increase by four percentage points each year to reflect a possible shift to international gas pricing. This results in a real gas price increase of 100%.

- The model allows ‘banking’ and ‘borrowing’ between years in order to meet greenhouse targets. As such, the model does not have to meet the target exactly in any given year. This is in keeping with the design of current schemes.

3.5 Scenarios modelled

The results of seven scenarios modelled using WHIRLYGIG are presented in Section 4. All scenarios except the BAU assume that emissions will be constrained from 2007 and meet a target of 120 million tonnes per annum at the end of the modelling period in 2030. The modelling period is for 24 years from 2007 to 2030. The first five scenarios are:

- <u>Business as usual (BAU)</u>: Under the BAU scenario, emissions are not constrained and least cost options are used to meet demand. Gas prices are assumed to increase by one real percentage point each year.

- <u>Linear 25%</u>: Under the Linear 25% scenario, emissions are constrained to meet the 2030 target. An equal emission reduction is required each year to meet the target. Least cost options are selected to meet demand, subject to them being able to comply with the constraint. Gas prices are assumed to increase by one real percentage point each year. This is equivalent to a 25% real increase in gas prices over the modelled period.

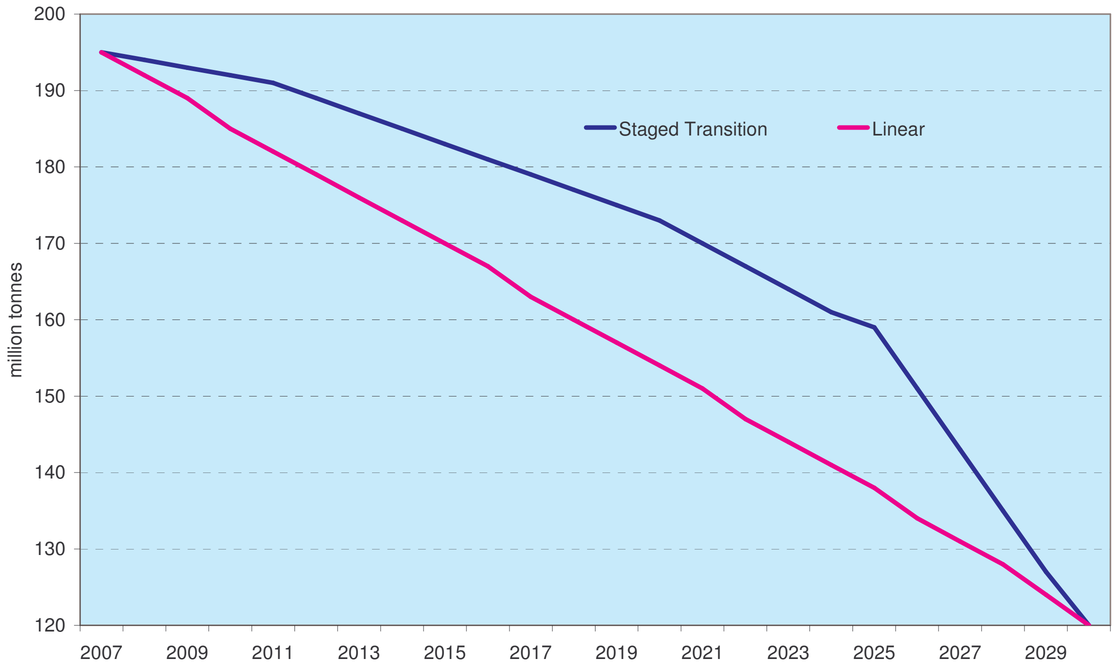
- <u>Staged Transition 25%</u>: Under the Staged Transition 25% scenario, emissions are constrained to meet the 2030 target. The emission reductions required each year are increased gradually. Least cost options are selected to meet demand, subject to them being able to comply with the constraint. Gas prices are assumed to increase by one real percentage point each year. This is equivalent to a 25% real increase in gas prices over the modelled period.

- <u>Linear 100%</u>: Under the Linear 100% scenario, emissions are constrained to meet the 2030 target. An equal emission reduction is required each year to meet the target. Least cost options are selected to meet demand, subject to them being able to comply with the constraint. Gas prices are assumed to increase by four real percentage points each year. This is equivalent to a 100% real increase in gas prices over the modelled period.

- Staged Transition 100%: Under the Staged Transition 100% scenario, emissions are constrained to meet the 2030 target. The emission reductions required each year are increased gradually. Least cost options are selected to meet demand, subject to them being able to comply with the constraint. Gas prices are assumed to increase by four real percentage points each year. This is equivalent to a 100% real increase in gas prices over the modelled period.

The emission profiles of the Linear and Staged Transition targets are shown in Figure 13.

Figure 13: Emission reduction pathways



In addition to these scenarios, the results of two other scenarios incorporating energy efficiency are presented in Section 4. These scenarios present the same greenhouse constraints but incorporate assumptions on energy efficiency provided by Energy Strategies. The assumptions provided by Energy Strategies relate to cost-effective measures that may be deployed to reduce forecast demand. The assumptions provided by Energy Strategies are outlined in Table 6.

Based on these additional assumptions, the two scenarios incorporating energy efficiency are outlined below:

- Linear 25% with Energy Efficiency (EE): Under this scenario, emissions are constrained to meet the 2030 target. An equal emission reduction is required each year to meet the target. Growth in electricity demand is reduced by the assumptions referred to above. Least cost options are selected to meet demand, subject to them being able to comply with the constraint. Gas prices are assumed to increase by one real percentage point each year. This is equivalent to a 25% real increase in gas prices over the modelled period.

- Staged Transition 25% with EE: Under this scenario, emissions are constrained to meet the 2030 target. The emission reductions required each year are increased gradually. Growth in electricity demand is reduced by the assumptions referred to above. Least cost options are selected to meet demand, subject to them being able to comply with the constraint. Gas prices are assumed to increase by one real percentage point each year. This is equivalent to a 25% real increase in gas prices over the modelled period.

It should be noted that the first five scenarios do contain a number of energy efficiency options. However, these have been identified as likely to occur based on current policy settings. For grouping purposes, they are presented as renewable investment for the first five scenarios.

Table 6: Energy efficiency assumptions			
	Residential	Commercial	Primary metal/industrial
Year	Annual GWh	Annual GWh	Annual GWh
2007	636	412	484
2008	1,163	754	885
2009	1,506	976	1,147
2010	1,784	1,156	1,358
2011	2,023	1,312	1,540
2012	2237	1,450	1,703
2013	2,433	1,577	1,852
2014	2,613	1,694	1,989
2015	2,782	1,803	2,118
2016	2,941	1,906	2,239
2017	3,092	2,004	2,354
2018	3,236	2,098	2,463
2019	3,374	2,187	2,568
2020	3,506	2,273	2,669
2021	3,634	2,355	2,766
2022	3,757	2,435	2,860
2023	3,876	2,513	2,951
2024	3,992	2,588	3,039
2025	4,105	2,661	3,124
2026	4,214	2,732	3,208
2027	4,321	2,801	3,289
2028	4,425	2,868	3,368
2029	4,527	2,934	3,446
2030	4,626	2,999	3,521

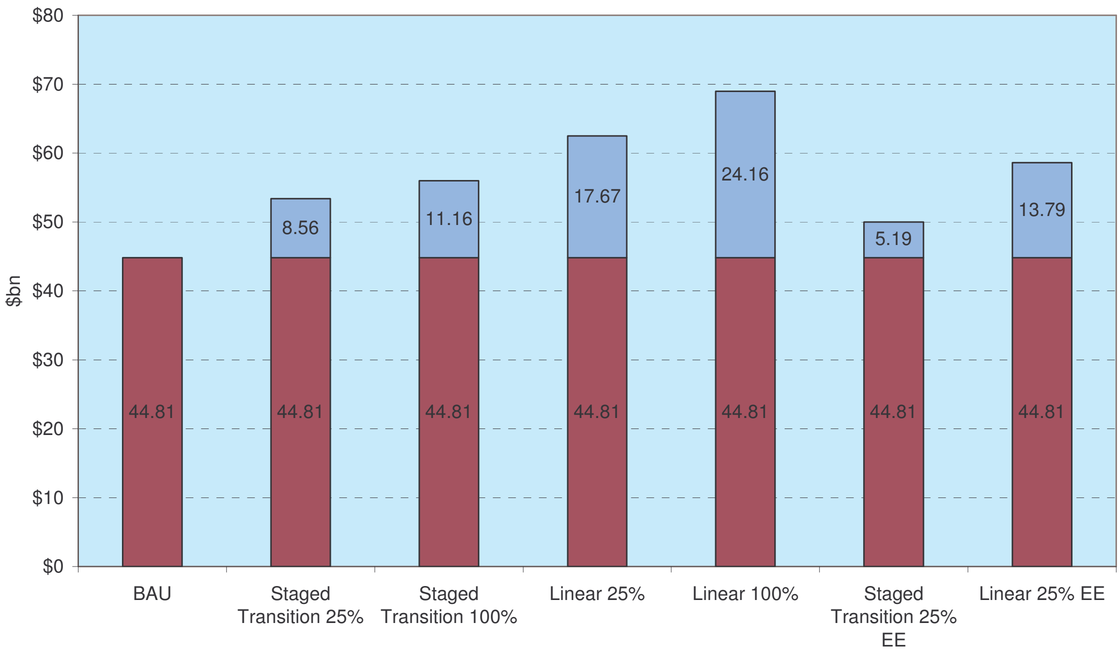
4. Emission reduction pathway modelling results

4.1 Cost of meeting electricity demand during the modelling period

The net present value (NPV) cost of meeting demand in the BAU scenario is $44.81 billion. This cost represents the operating and maintenance costs of all electricity generators and the capital costs of all new plant installed during the modelling period. It does not include the sunk costs of existing plant. It is the cost of meeting wholesale demand and does not include transmission and distribution expenditure.

As expected, the costs of meeting demand are higher in the scenarios where greenhouse emissions are constrained. However, additional costs vary across each of the scenarios. This is shown in Figure 14.

Figure 14: NPV cost of meeting electricity demand



The additional costs of meeting demand in each of the scenarios relative to the BAU case are shown in blue. As expected, by gradually increasing the constraint under the Staged Transition scenarios, the costs of meeting demand are reduced. For example, where gas prices increase by 25%, the additional cost is reduced by about $9 billion as a result of having a Staged Transition rather than Linear constraint. This is a result of two factors:

- It provides for more 'transition'. As existing plant has a higher emission intensity, under the Staged Transition scenarios it is able to run for longer. This reduces the need to replace existing plant before it reaches the end of its economic life.
- Although the abatement task starts immediately, relatively greater reductions are assumed to take place in the second half of the modelling period, which lowers the economic cost. By using NPV as a valuation technique, costs incurred in later periods are discounted to reflect the lower real value of a dollar spent in later periods relative to today.

In reality, the Staged Transition scenarios provide for one additional cost benefit which is not captured by the economic model. By gradually increasing the target over time, companies have more time to invest in research and development. It is likely that this would provide for new technological development in areas such as geosequestration and renewable energy.

To put these cost impacts in perspective, it is worth comparing them with national measures of income and wealth. Australia's annual GDP is currently about $860 billion.[40] The total additional cost of the Staged Transition 25% pathway at NPV is $8.56 billion or about 1% of present annual GDP. The cost of the Linear 25% pathway is $17.67 billion NPV or about 2% of present annual GDP.

If each individual in Australia was required to contribute towards this additional cost, it would represent a NPV cost per person of $415 (Staged Transition 25%).[41] The cost per person (in NPV terms) is shown for each scenario in Table 7. As electricity prices may not reflect this underlying cost, the impact of possible price increases for industry with large energy input costs needs to be considered.

Table 7: NPV cost per person

	Staged Transition 25%	Staged Transition 100%	Linear 25%	Linear 100%	Staged Transition 25% EE	Linear 25% EE
Total cost ($b NPV)	8.56	11.16	17.67	24.16	5.19	13.79
Total cost per person ($ NPV)	415	542	857	1,172	252	669

Figure 14 demonstrates the potential of energy efficiency in reducing the cost of meeting emission constraints. In the Staged Transition 25% scenario, cost-effective energy efficiency options reduce the additional cost from $8.56 billion NPV over the 24 year modelling period to only $5.19 billion NPV. This is a result of less additional generation capacity and output being needed to meet overall demand.

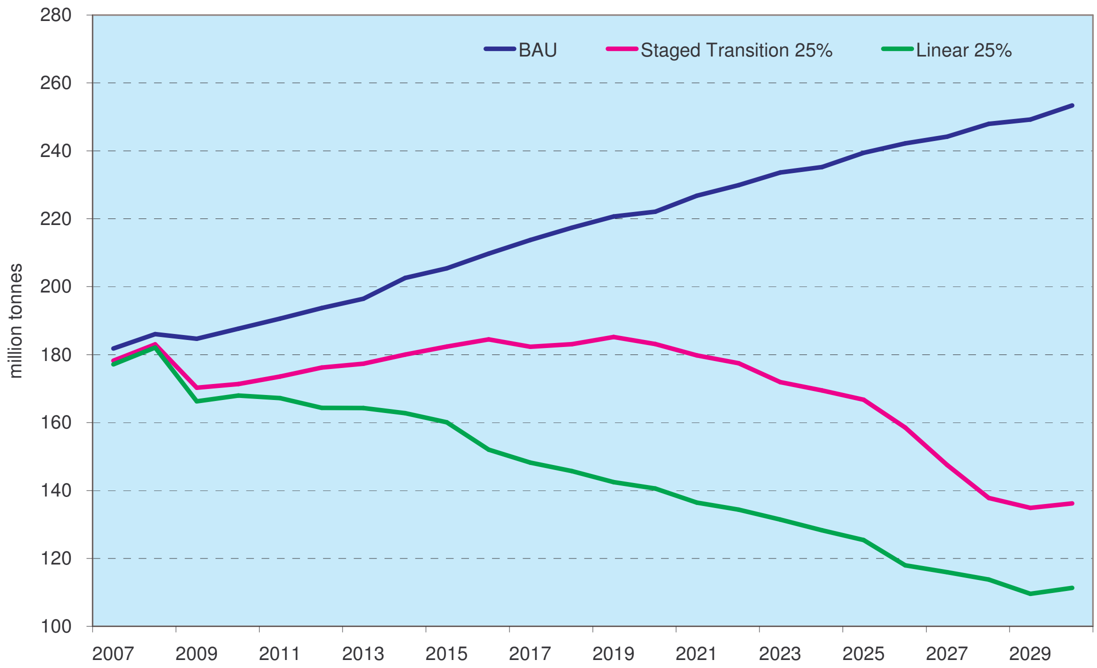
Figure 14 also demonstrates that the assumption regarding gas prices is a key factor in determining costs when emissions are constrained. The difference in total cost between the Staged Transition 25% and 100% scenarios is about $2.6 billion NPV.

[40] Australian Bureau of Statistics, Australian Economic Indicators, 1350.0, p 18 (based on 2004/05).
[41] Based on a population of 20,608,000 obtained from www.abs.gov.au.

4.2 Emissions

As a result of minimising cost, the emission reduction profile is different in each scenario. This is demonstrated in Figure 15. The most notable feature of Figure 15 is the significant divergence from the BAU with no constraints, and other scenarios. This demonstrates how challenging the targets are.

Figure 15: Emission profiles of scenarios



Although the annual emissions target for 2030 is the same under each Scenario, there are two points worth noting:

- Firstly, emission reductions occur earlier in the Linear scenarios and hence cumulative emissions (the area under the curve) are smaller;
- Secondly, the modelling allows for some ‘banking’ and ‘borrowing’ of permits across years, which is a flexibility mechanism typical of emissions trading schemes.

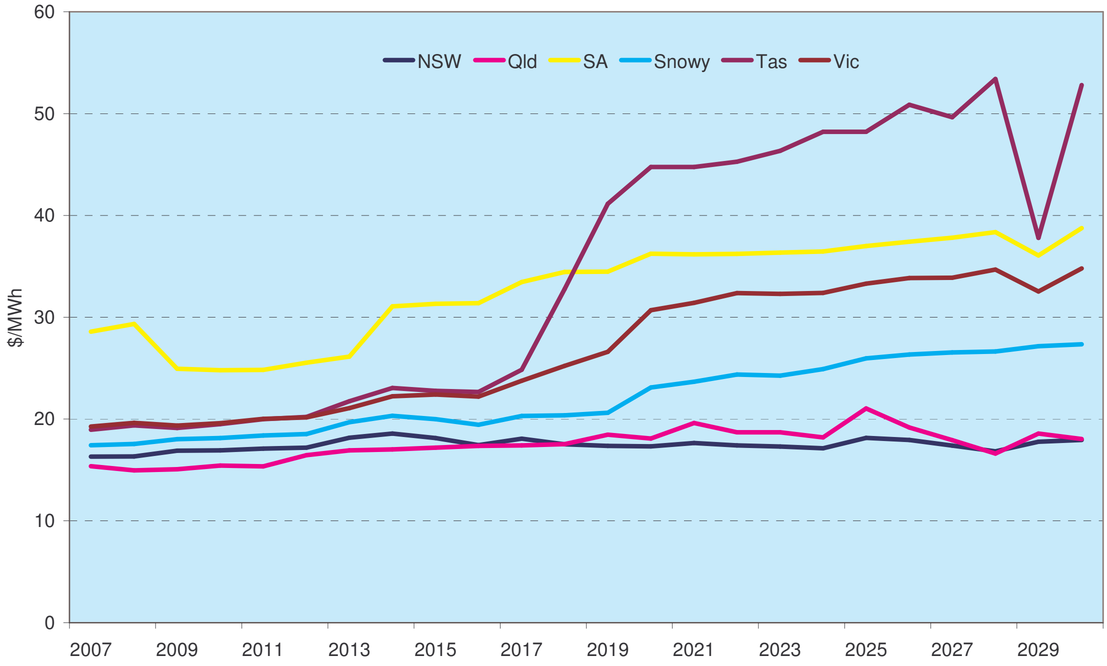
This explains the slight divergence shown in Figure 15 of projected emissions between the scenarios in 2030, despite the equivalent annual target. The overall target in the Staged Transition scenario is met through additional reductions being 'banked' in earlier periods and then 'borrowed' in later periods. Similarly, this banking and borrowing explains the marginal variance between projected emissions and the target pathways. In all scenarios, no significant capacity can be built in the first two years due to construction lead times. This results in 'borrowing' in the first two years as the only mechanism for meeting the target is to alter the dispatch of the existing stock of plant. From 2009 to 2012, significant 'banking' is observed while the supply-demand balance is still relatively loose. This is then utilised in the 2013 to 2017 period where large amounts of baseload capacity are required to meet demand.

4.3 Marginal costs of generation

The marginal costs of generation refer to the cost of meeting the last MWh of demand. It does not necessarily reflect the retail price of electricity. It does not reflect the underlying cost of all electricity generation. Therefore, if the marginal cost of electricity generation increases significantly, the total cost of meeting demand may remain low (as most consumption may still be met by lower cost existing generators). That said, prices are likely to reflect the marginal costs of generation.

The marginal costs of generation in each of the National Electricity Market (NEM) regions are presented in Figure 16 below for the BAU scenario.

Figure 16: Marginal costs of generation (BAU)



In NSW and Queensland, the marginal cost of generation stays relatively constant at about $15 to $20 per MWh. This reflects the abundance of relatively inexpensive black coal. However, cost increases are experienced in all other regions. This is due to baseload natural gas being deployed in Victoria, South Australia and Tasmania to meet demand.

Upon introduction of the 2030 target, the marginal cost of generation increases in each of the regions. With assumed lead times on any new investment, except for small renewable plant, no gas or coal plant could be built until 2009 and 2011 respectively. The significant increases in marginal costs in the first few years reflect the altered pattern of dispatch necessary to meet the target in these early years. From 2009, a dip in costs occurs as less expensive technology can now be installed but costs remain higher throughout the modelling period as significant quantities of new investment are required to meet the target. As would be expected, the increase in marginal costs of generation in the Staged Transition 25% and 100% scenarios is less than in the Linear 25% and 100% scenarios.

This analysis is demonstrated in Figures 17 to 22. These Figures outline the marginal costs of generation in each of the constrained scenarios.

Figure 17: Marginal costs of generation (Staged Transition 25%)

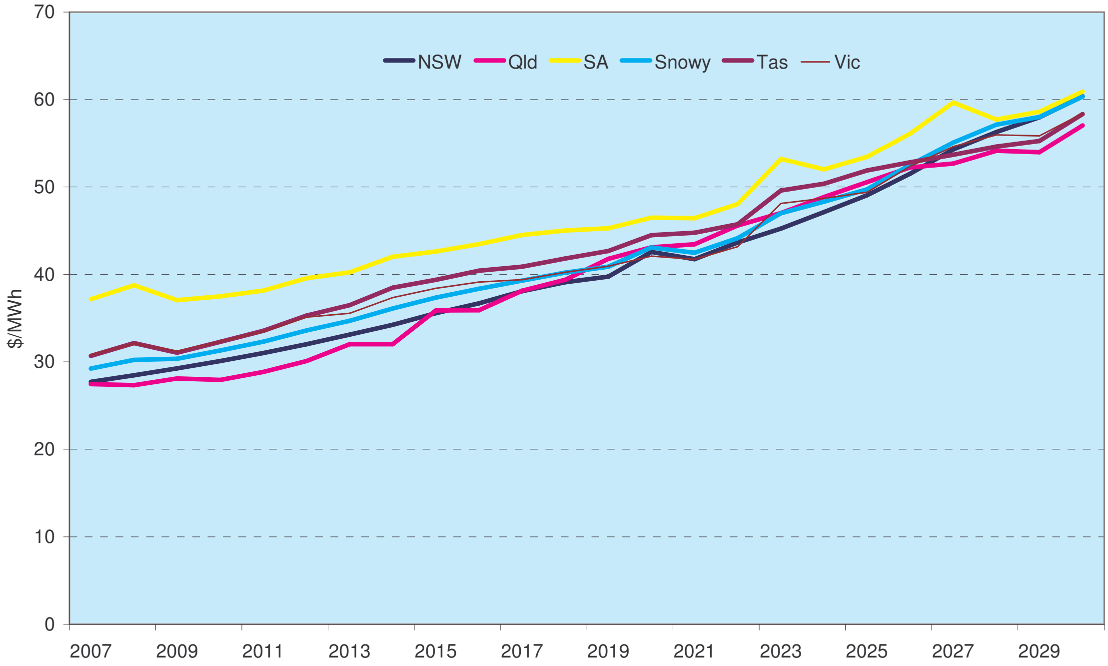
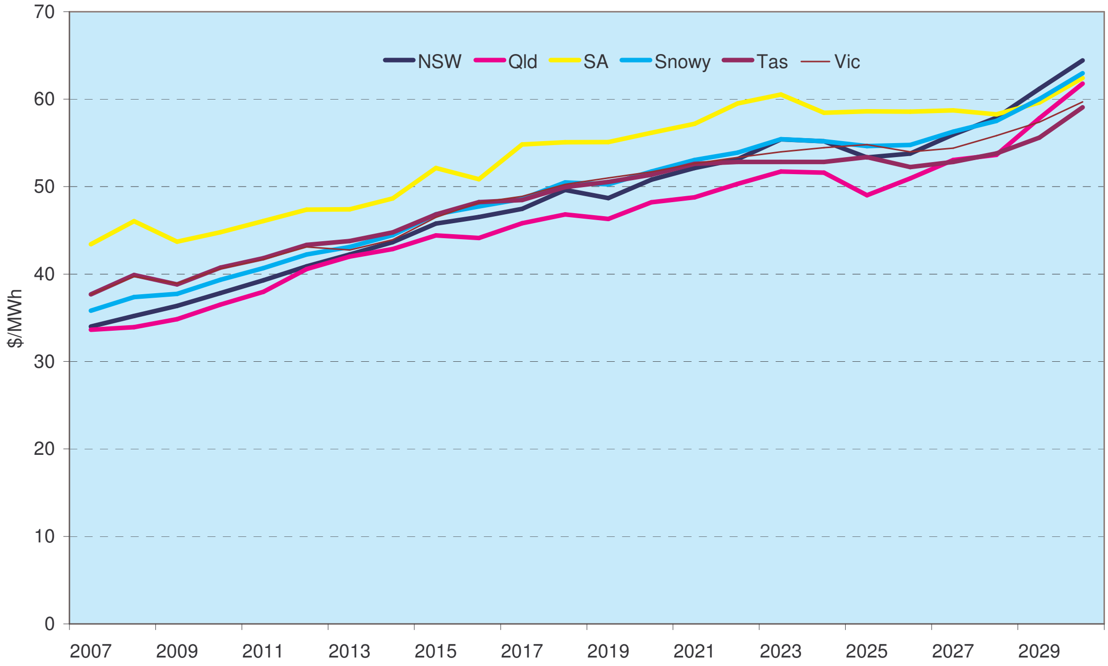


Figure 18: Marginal costs of generation (Linear 25%)



Figures 17 and 18 show the marginal costs of generation in the Staged Transition 25% and Linear 25% scenarios. Relative to the BAU case, the most notable increase in marginal costs of generation is in NSW and Queensland. This is due to the fact that natural gas is deployed to meet demand rather than coal. The marginal cost of the region increases to reflect the higher marginal cost of natural gas.

There is a reasonably significant difference in the regional marginal cost of generation between the Linear 25% and Staged Transition 25% scenarios. This is not unexpected given that the total cost of meeting demand is significantly lower in the Staged Transition 25% scenario. Because the marginal cost reflects the cost of meeting the last MWh of demand, the technology deployed in both scenarios is mostly the same (ie natural gas).

However, substitution of existing baseload coal-fired demand is not required as early in the Staged Transition 25% scenario.

Figure 19: Marginal costs of generation (Staged Transition 100%)

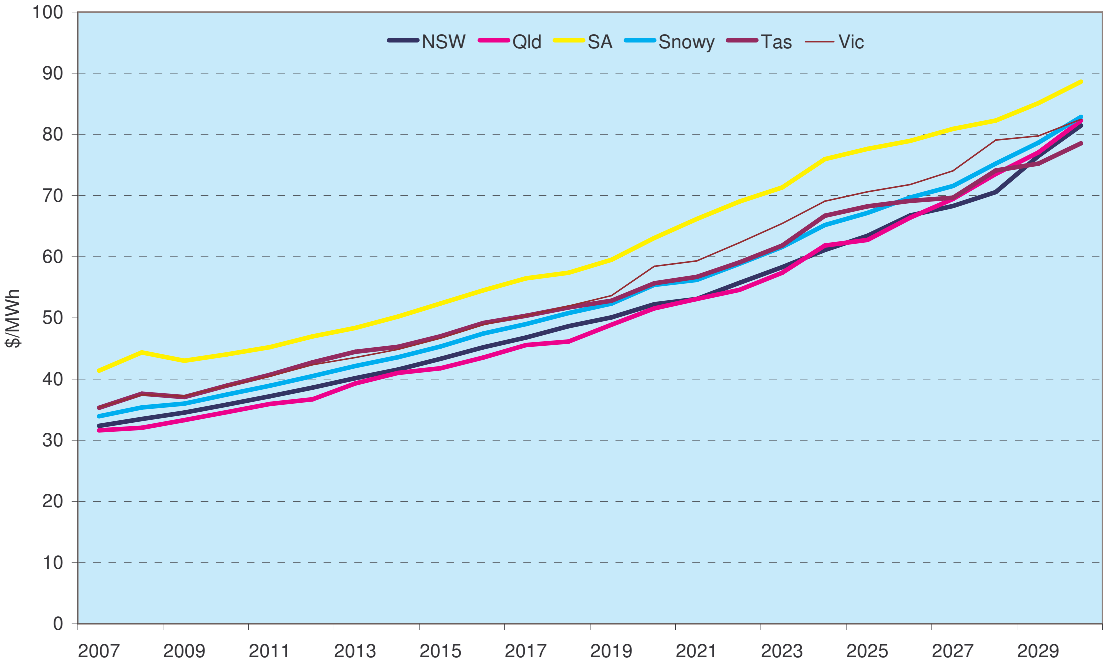
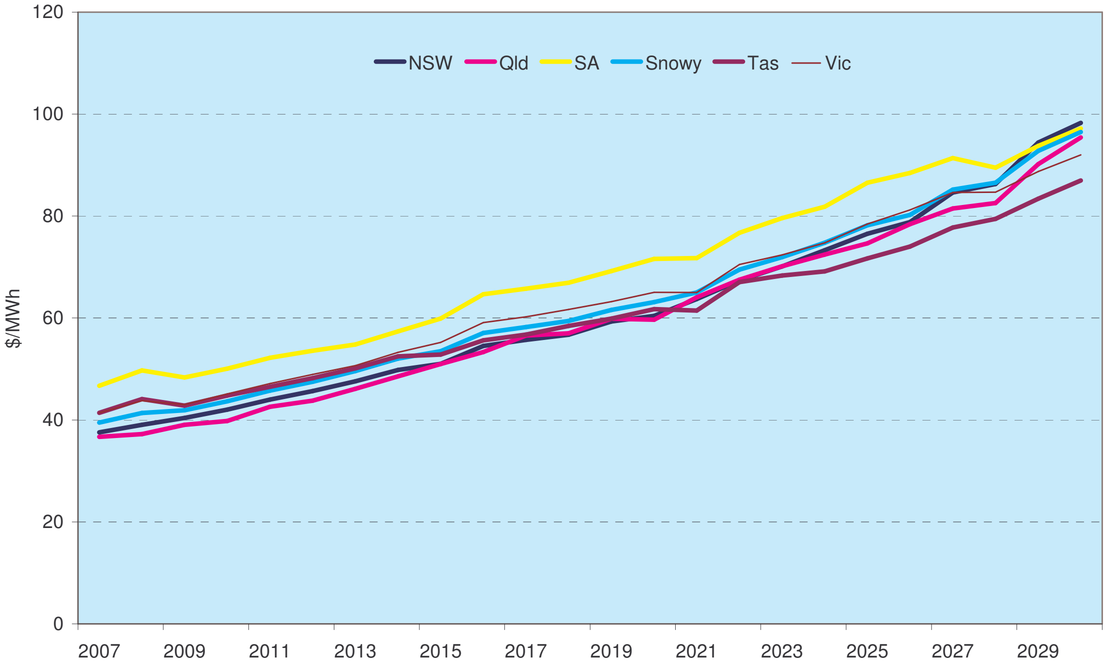


Figure 20: Marginal costs of generation (Linear 100%)



Figures 19 and 20 show how increasing gas prices significantly impacts on the marginal costs of generation. The significantly higher marginal costs reflect the 100% increase in natural gas prices. This is consistent with the significantly higher cost of meeting total demand in the 100% scenarios outlined earlier in this section.

Figure 21: Marginal costs of generation (Staged Transition 25% EE)

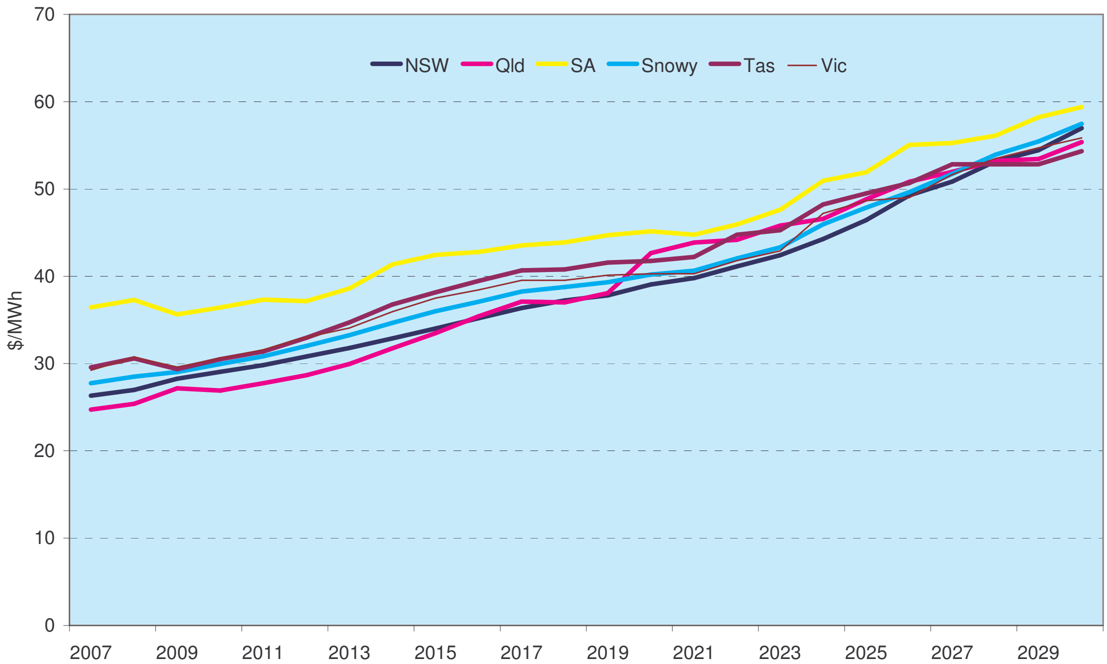
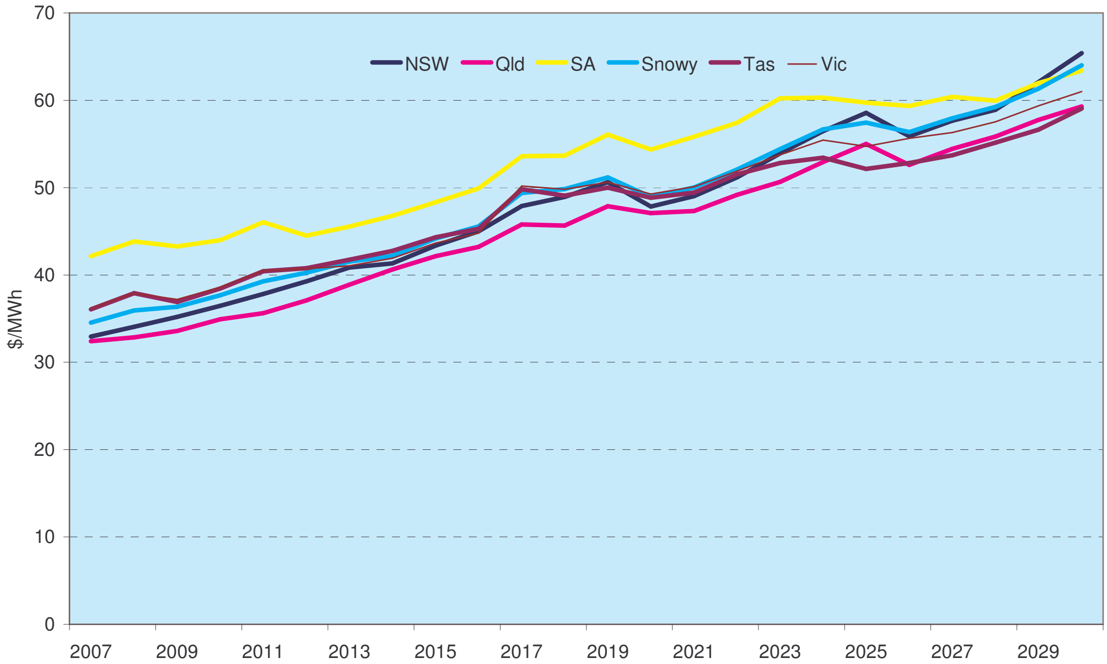


Figure 22: Marginal costs of generation (Linear 25% EE)

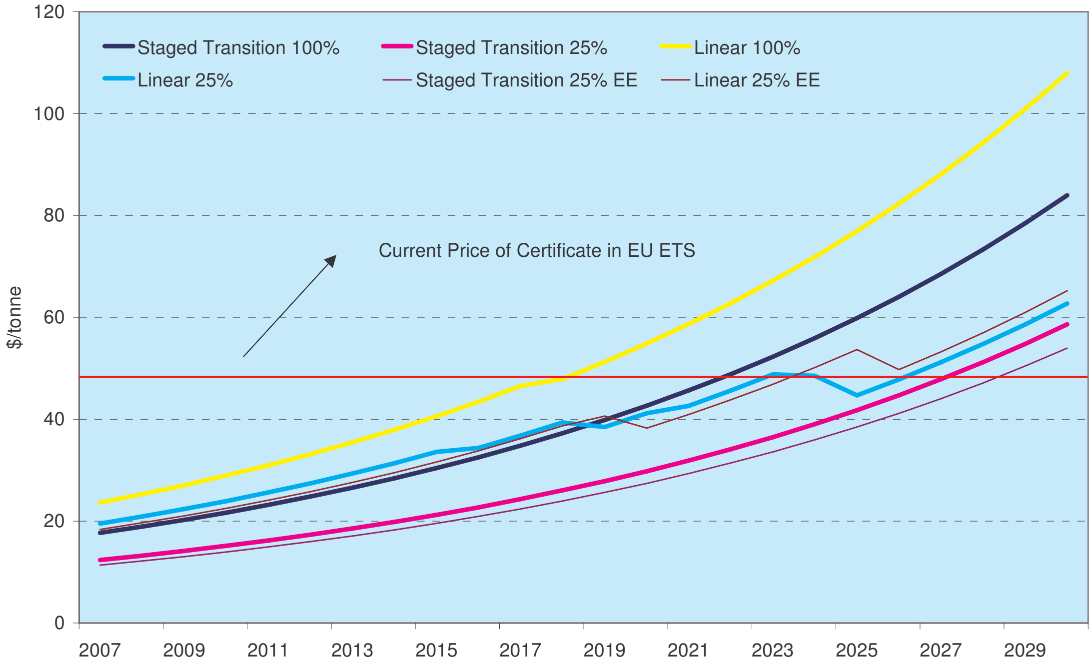


Figures 21 and 22 show the marginal costs of generation in the two energy efficiency uptake scenarios. Interestingly, the marginal costs of generation are not significantly different from the scenarios where energy efficiency is not assumed. This is not unexpected given that the same new technologies are required to meet demand (although demand is not as high). As gas-fired generation is installed to meet new demand, the marginal cost reflects this. However, the total cost to society is still much lower because of the lower volumes of gas-fired generation needed to meet demand.

4.4 Marginal costs of abatement

The marginal cost per tonne of carbon dioxide abated ranges from $20 per tonne at the beginning of the modelling period (when the cap is relatively lenient) to $60 to $100 per tonne by the end of the modelling period (depending upon the assumed gas price increase). This is shown in Figure 23.

Figure 23: Marginal costs of abatement



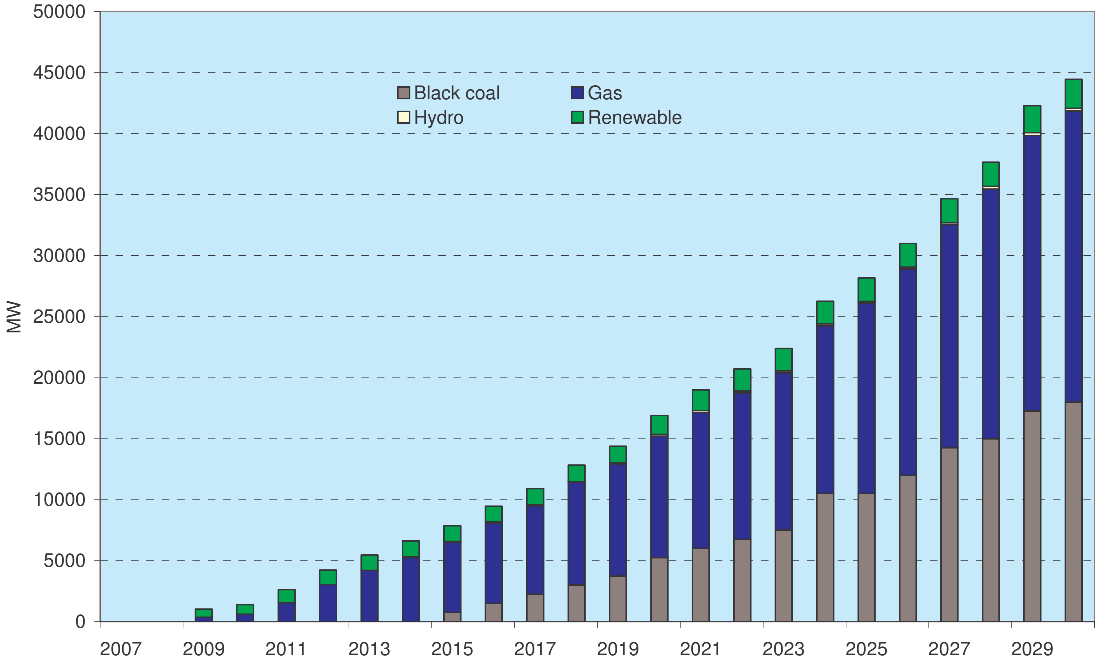
As demand for energy increases and the cap on emissions becomes more stringent, the marginal cost of abatement increases. The significant difference in abatement costs in 2030 arises due to the difference in gas price assumptions: a 100% increase in gas prices results in a marginal cost of abatement of $80 to $100 per tonne (given the demand and emissions cap assumptions) compared with $60 per tonne assuming only a 25% increase in gas prices. One of the most interesting observations is that costs are reduced far more in the 100% scenarios than in the 25% scenarios when the target is increased over time (as opposed to Linear).

The marginal cost of abatement does not increase above the current cost of emission permits in the EU Emissions Trading Scheme until 2018 (in the 100% scenarios) or 2023 (in the 25% scenarios).

4.5 New generation capacity installed

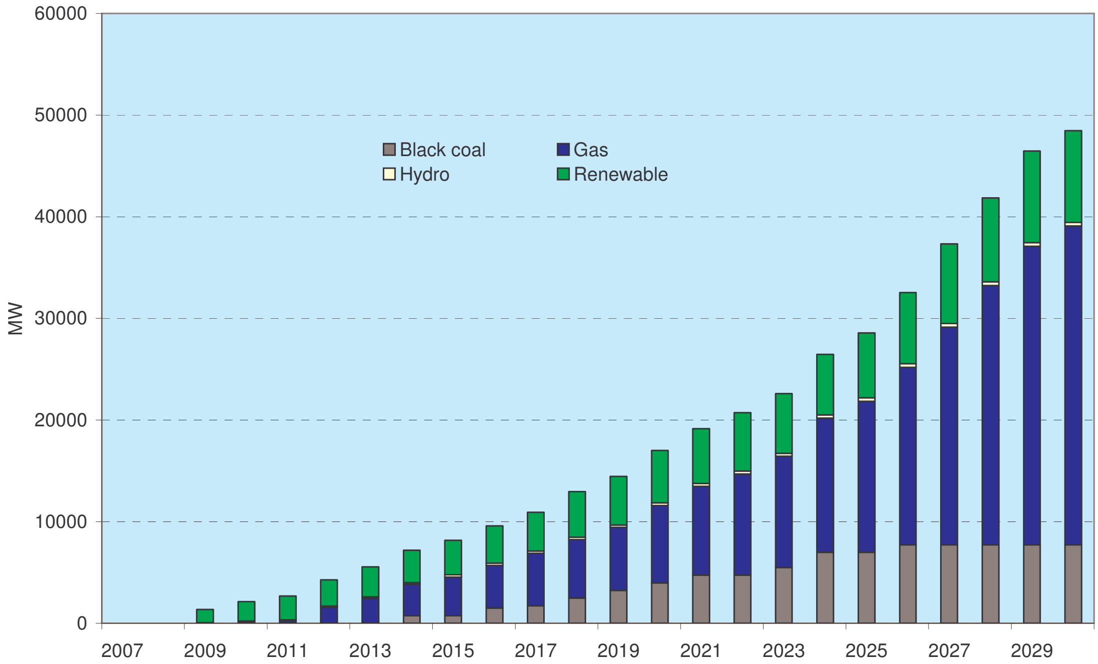
As energy demand increases in each of the scenarios, additional electricity generation capacity is required. Much of this capacity is peaking capacity – capacity required for peak time periods and to meet reserve requirements. However, from 2010-2015 (depending upon the region), new intermediate and baseload capacity is required. The new generation capacity installed in the BAU case is shown in Figure 24.

Figure 24: New generation capacity installed (BAU)



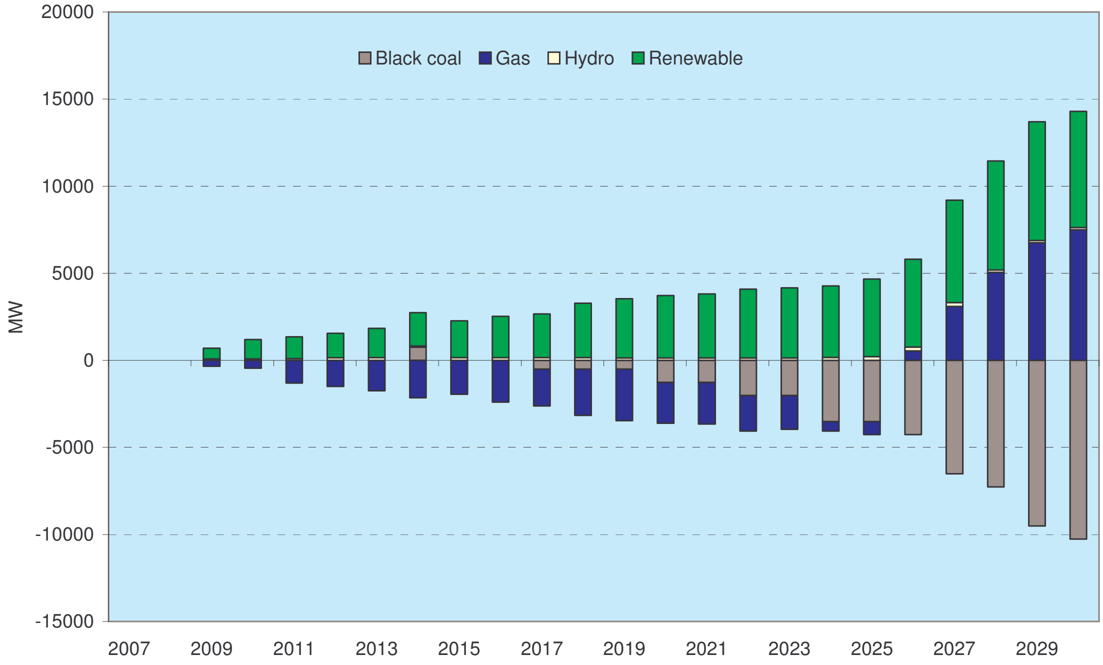
As would be expected, without a greenhouse constraint, most of the baseload capacity installed is coal (because of its relatively low long-run marginal cost). Because of constraints about the lead times required for new investment, relatively flexible renewable technology is installed to meet increasing demand at the beginning of the period. Significant volumes of gas are installed throughout the period to satisfy peaking and intermediate demand.

Figure 25: New generation capacity installed (Staged Transition 25%)



Once a greenhouse constraint is introduced, the type of technology used to meet demand changes. Figures 25 and 26 outline the new generation capacity under the Staged Transition 25% scenario and the difference between the BAU and Staged Transition 25% scenarios respectively.

Figure 26: Difference in installed capacity (Staged Transition 25% relative to BAU)



As expected, the Staged Transition 25% scenario results in less black coal being installed but significantly more natural gas and renewable generation. This difference is most noticeable beyond 2018. Initially (pre-2018), the optimal investment mix involves replacing gas in the base case with a mixture of black coal and renewables. This reflects the fact that early investment in gas in the base case is mostly in open cycle gas plant, built to meet peaking and reserve requirements. In the Staged Transition 25% case, investment in renewables is required to meet the target. Beyond 2018, once the need for large amounts of new baseload capacity increases, new black coal investment is replaced by combined cycle gas and some renewable options (eg thermal renewable fuel such as wood waste).

Figure 27: New generation capacity installed (Linear 25%)

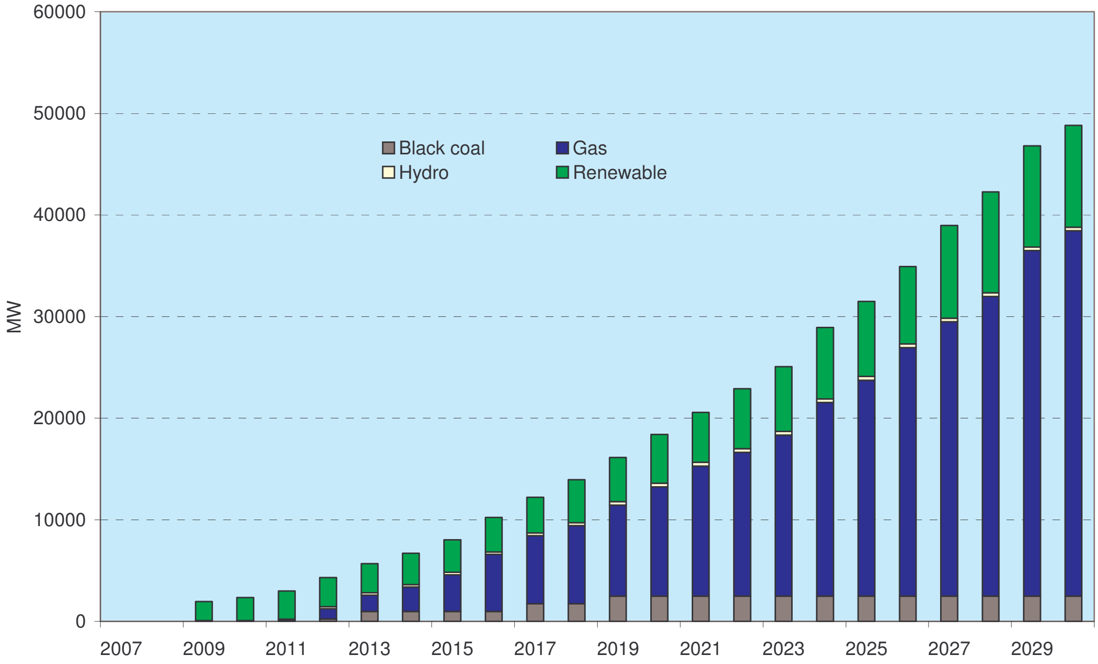
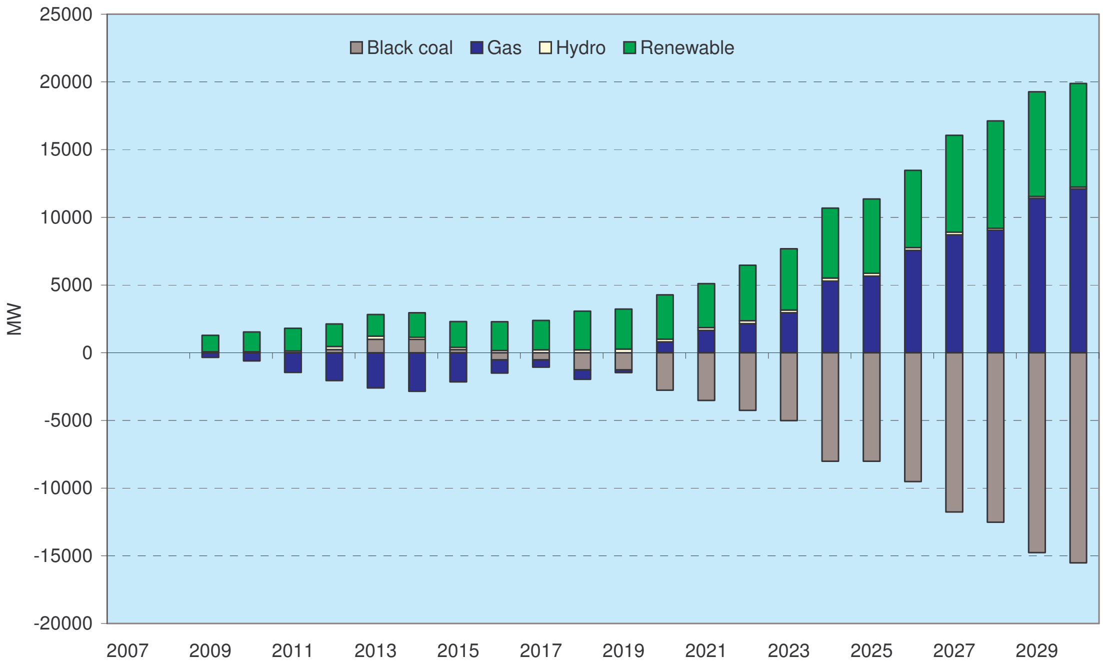


Figure 28: Difference in installed capacity (Linear 25% relative to BAU)



Figures 27 and 28 outline the new installed capacity in the Linear 25% scenario and the difference in installed capacity in the Linear 25% and BAU scenarios respectively. There is very little difference between the Linear 25% and Staged Transition 25% scenarios. The effect of the slow start, quick finish nature of the target in the Staged Transition case is apparent in the (slightly) lower levels of investment in renewables pre-2020 and the deferment of baseload gas to 2023. Figures 29 to 32 provide similar analysis for the Staged Transition 100% and Linear 100% scenarios.

Figure 29: New generation capacity installed (Staged Transition 100%)

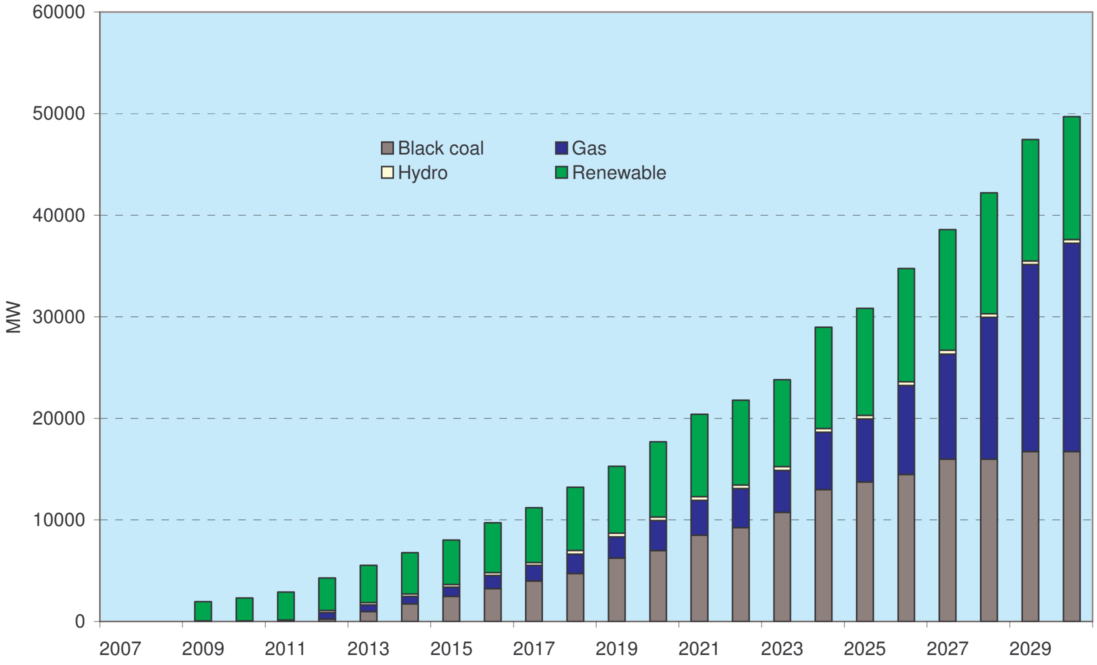


Figure 30: Difference in installed capacity (Staged Transition 100% relative to BAU)

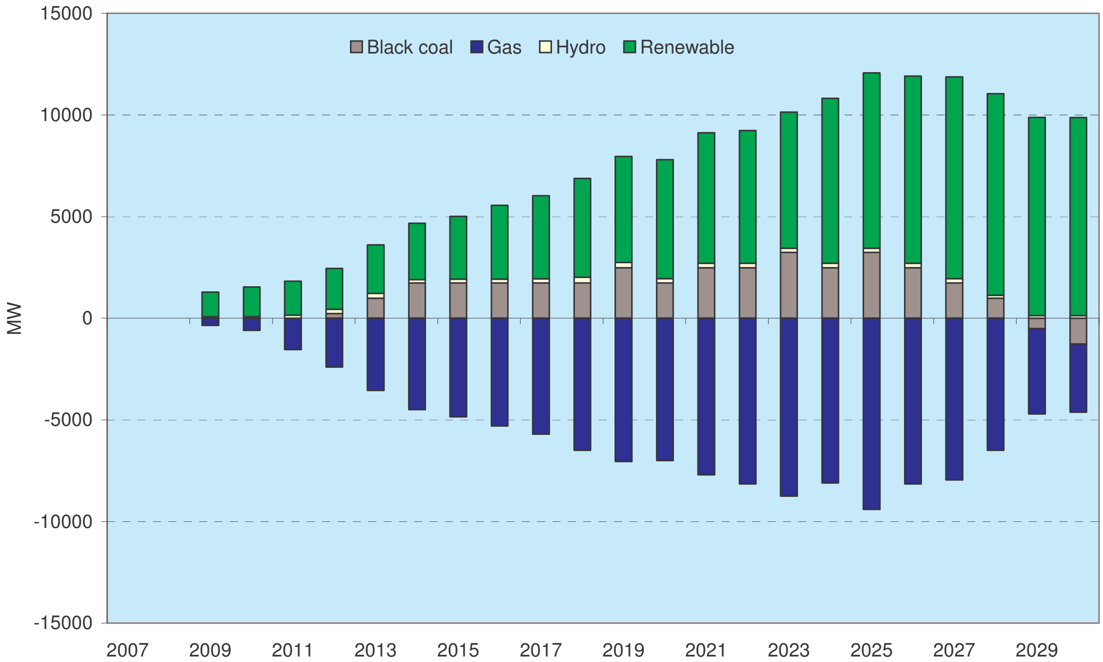


Figure 31: New generation capacity installed (Linear 100%)

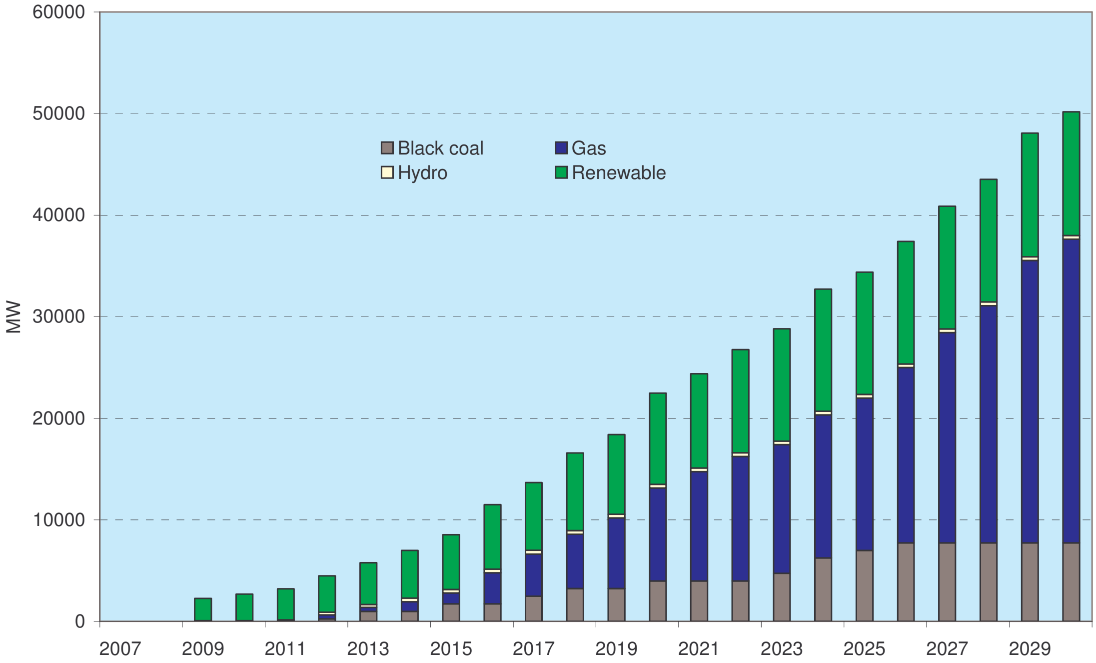
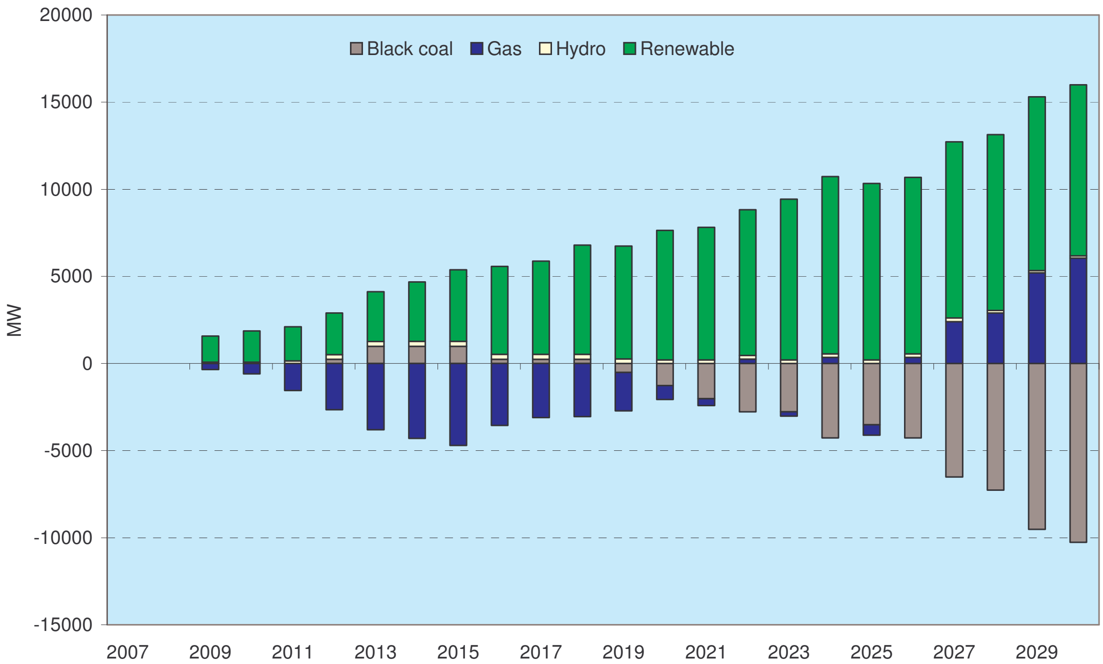


Figure 32: Difference in installed capacity (Linear 100% relative to BAU)



The introduction of the emissions constraint with a 100% increase in gas prices over the period results in substantial increased investment in new renewable capacity. The higher levels of renewable capacity are installed instead of black coal and new gas investment experienced in the BAU scenario. Increasingly expensive gas brings on the earlier and increased adoption of renewable alternatives. This is based on current renewable prices. It is highly likely that the cost of these renewable technologies will fall over time.

Compared with the Linear 100% scenario, the Staged Transition 100% scenario results in higher black coal capacity early in the period. This reflects the slow start nature of the emissions target. Interestingly, new black coal technologies are still optimal for a significant proportion of baseload demand as a result of the substantial increase in gas prices. These results suggest that the constraints would result in clean coal technologies becoming economic (cleaner coal could still be an optimal investment choice post-2020) even in a market with significant constraints such as this.

Figures 33 to 36 show how installed capacity changes when significant energy efficiency is assumed in the Staged Transition 25% and Linear 25% scenarios.

Figure 33: New generation capacity installed (Staged Transition 25% EE)

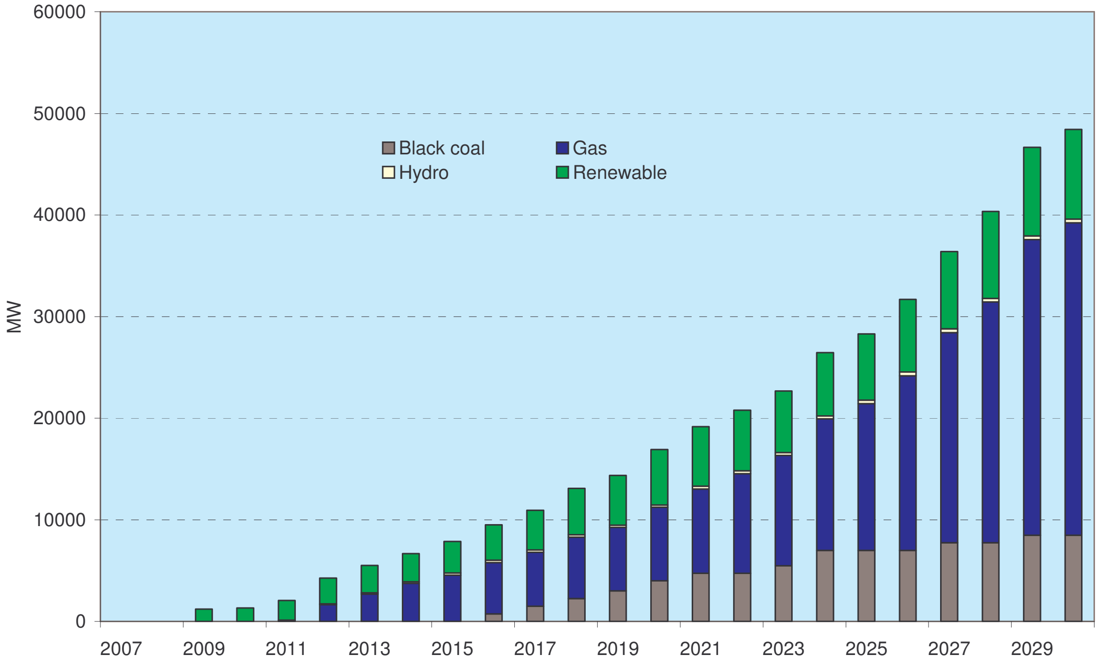


Figure 34: Difference in installed capacity (Staged Transition 25% EE relative to BAU)

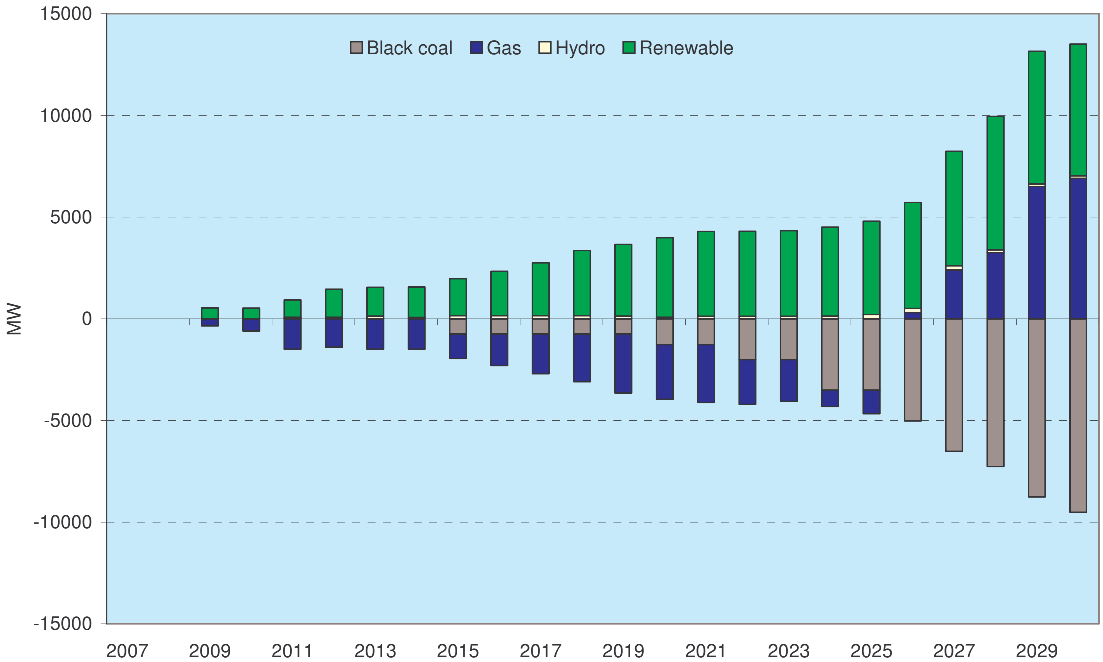


Figure 35: New generation capacity installed (Linear 25% EE)

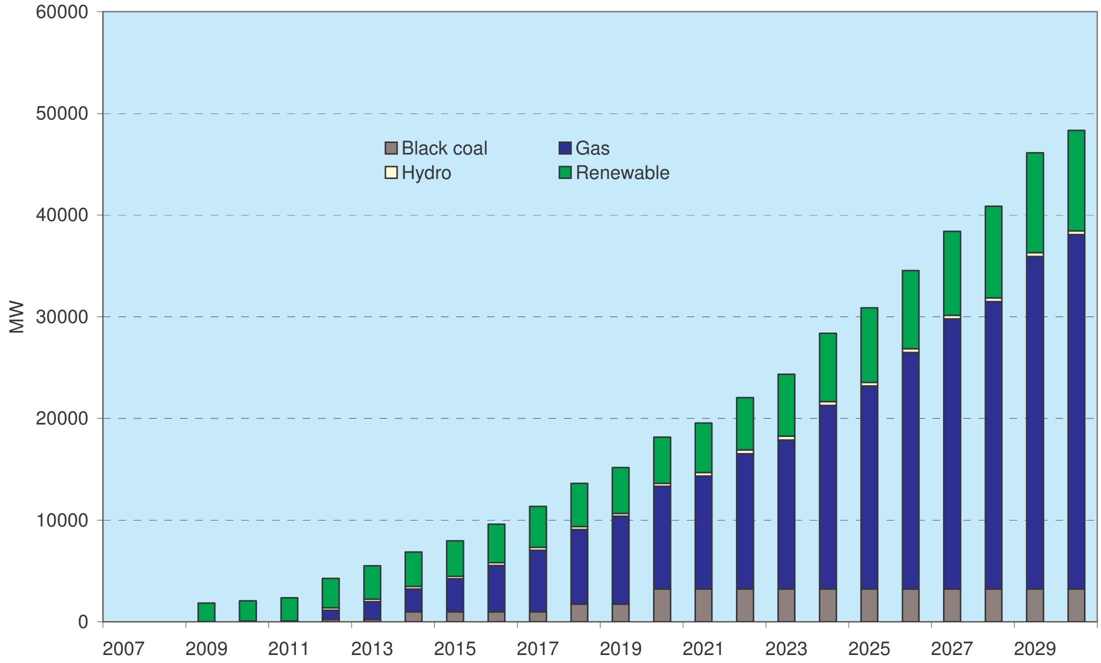
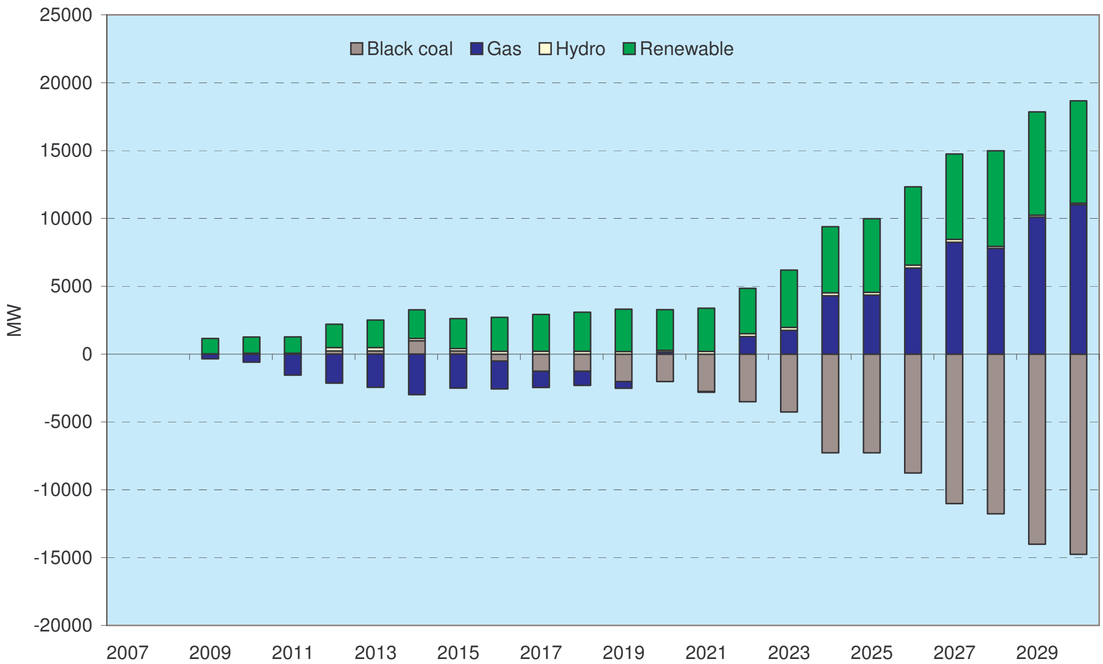


Figure 36: Difference in installed capacity (Linear 25% EE relative to BAU)



As expected, the changes in installed capacity are not dissimilar to those experienced in the scenarios without significant energy efficiency. While the changes are different in overall volume reflecting the lower net demand growth, the increased use of gas-fired and renewable generation is similar.

4.6 Generator output

As energy demand increases during the period, output from existing and new generators grows significantly. Figure 37 shows the output from different generators over the 24 year period.

Figure 37: Generator output (BAU)

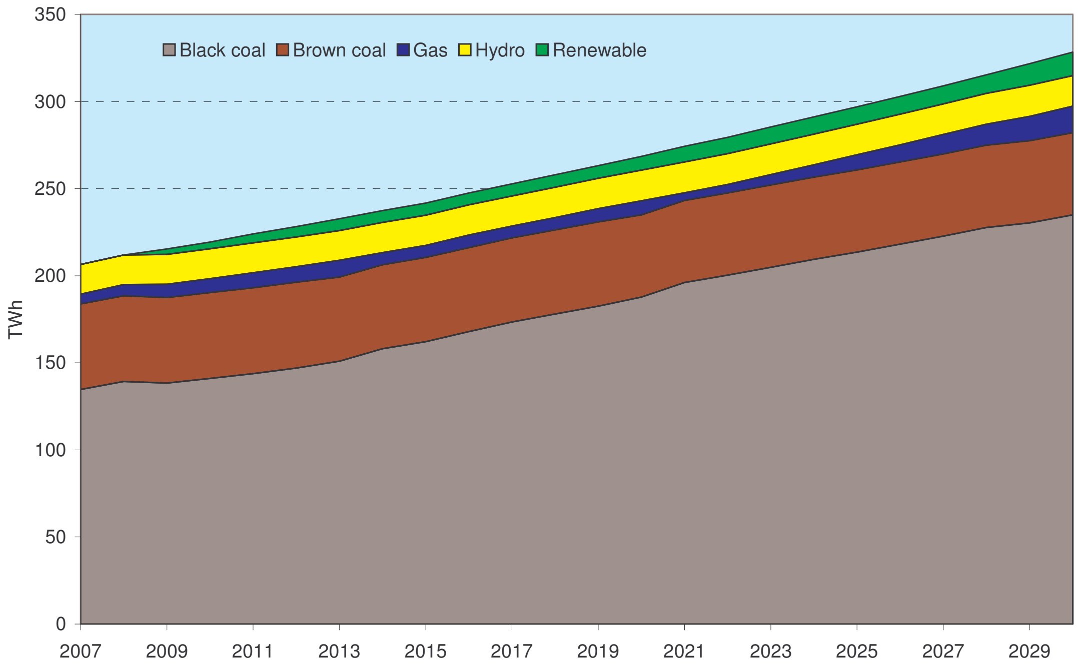
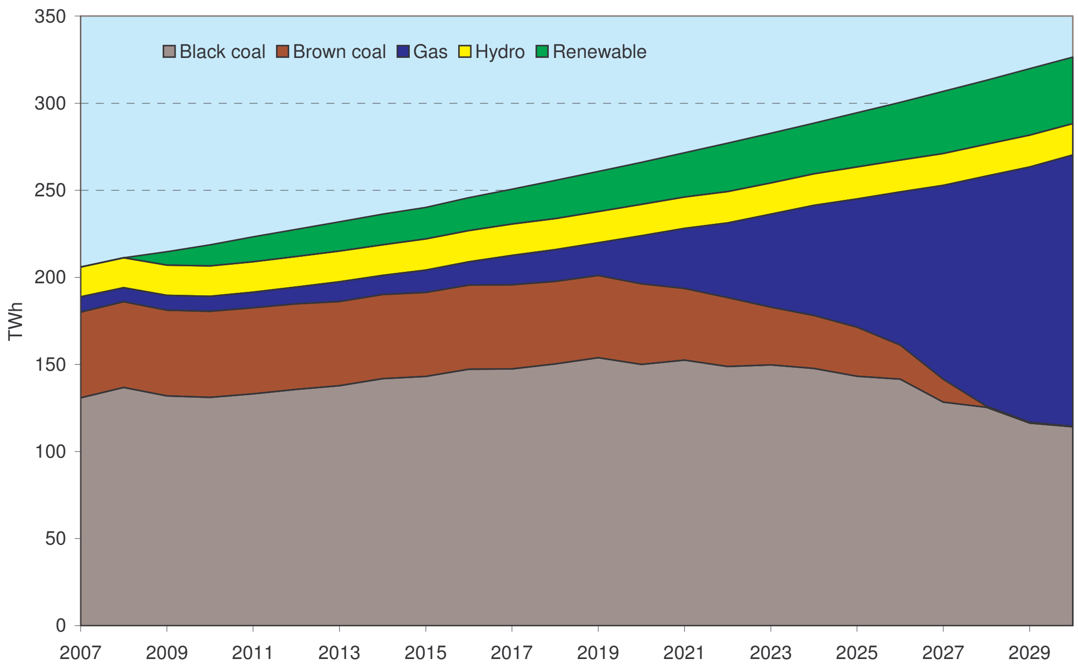


Figure 38: Generator output (Staged Transition 25%)



As would be expected, black coal continues to expand without greenhouse constraints in place. This is because it is relatively inexpensive. It is worth noting that while gas expands significantly in terms of installed capacity, it does not significantly expand in terms of output. This is because the new coal-fired capacity operates as baseload (high capacity factor) and the new gas-fired capacity is mostly used for intermediate and peaking purposes and to meet reserve requirements.

However, once greenhouse constraints are introduced, the composition of generator output changes significantly. Figure 38 shows generator output in the Staged Transition 25% scenario. The major difference between the two scenarios is the significant expansion in gas and renewable generation beyond 2019. At this point, the increasing constraint results in gas-fired and renewable generation becoming competitive for intermediate and baseload generation. Figure 39 shows the difference in output between the BAU and Staged Transition 25% scenarios.

Figure 39: Difference in output (Staged Transition 25% relative to BAU)

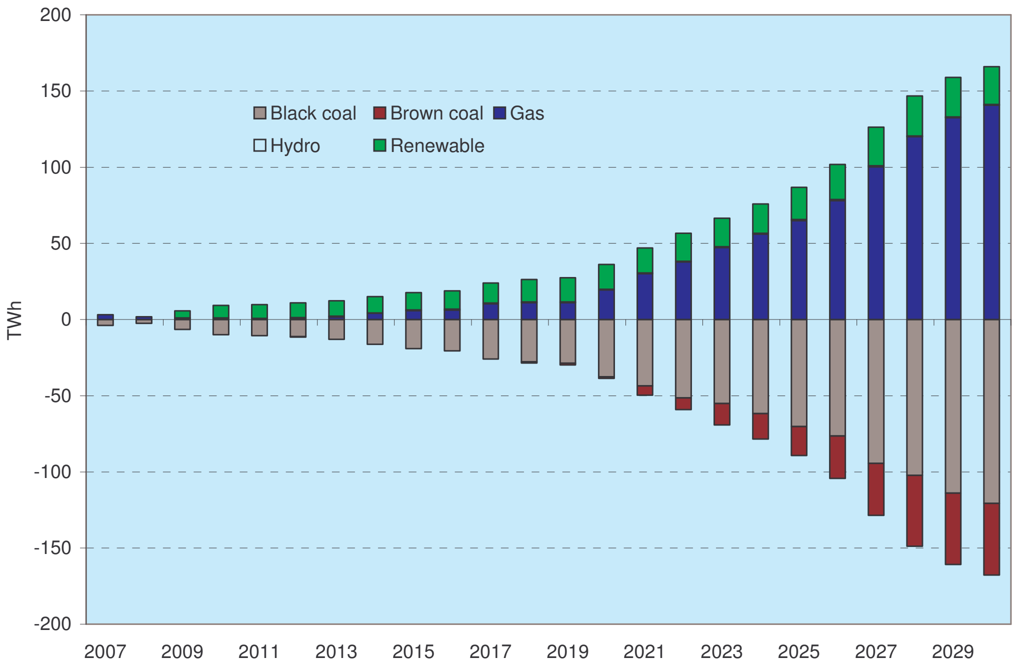


Figure 40 and 41 show the output in the Linear 25% scenario and the difference in output between the Linear 25% and BAU scenarios. As in the Staged Transition 25% scenario, there are significant reductions in black and brown coal output. These reductions in output are offset by increases in gas-fired and renewable output.

The most interesting observation from this analysis is the difference in timing of the reduction in coal-fired output and increase in gas-fired and renewable output. In the Staged Transition 25% scenario, the wide-scale reduction in coal-fired output does not occur until 2020. However, in the Linear 25% scenario, the wide-scale reduction in coal-fired output occurs around 2015.

Therefore, a Staged Transition provides time for technological development. This is likely to minimise any structural impacts on individual sectors within the industry and the economy more broadly. New technologies (such as carbon capture and storage) are more likely to emerge before output significantly changes in the Staged Transition scenario.

Figure 40: Generator output (Linear 25%)

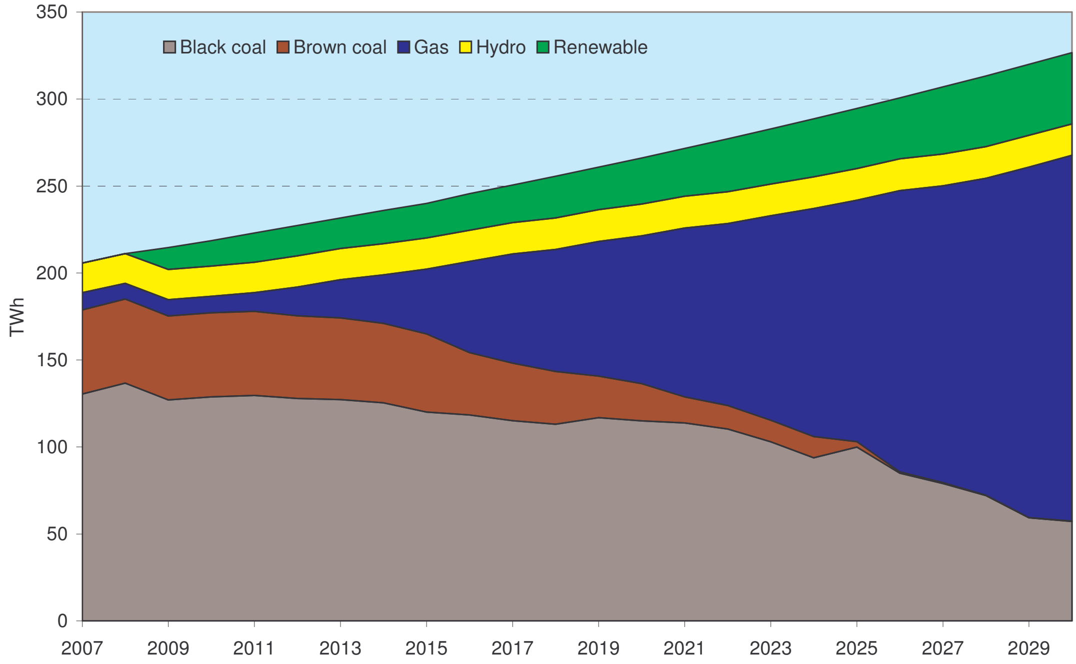


Figure 41: Difference in output (Linear 25% relative to BAU)

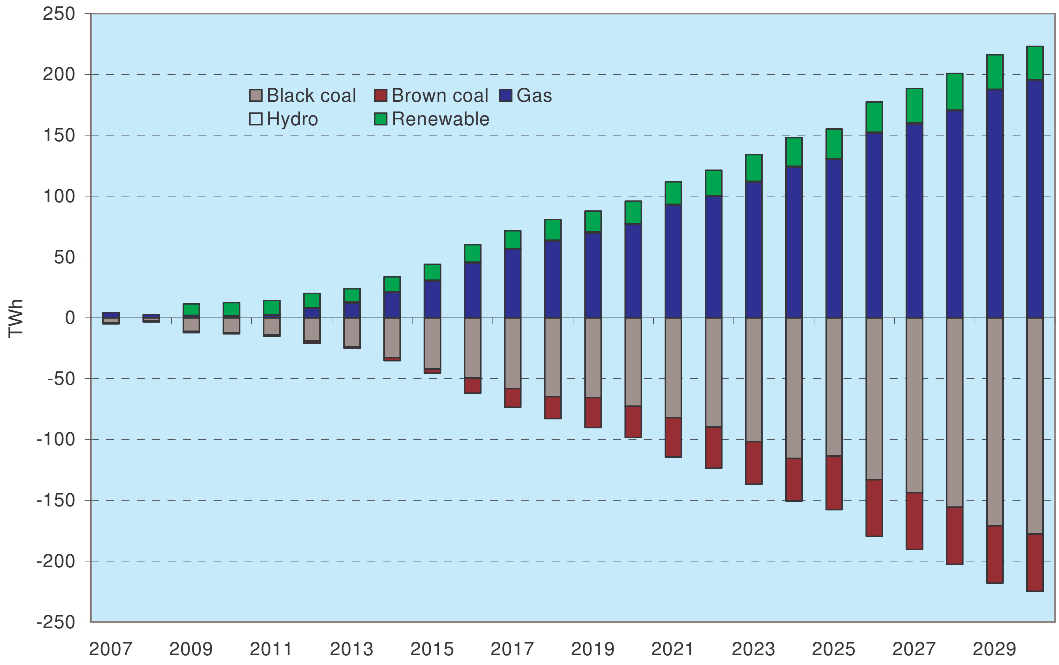


Figure 42: Generator output (Staged Transition 100%)

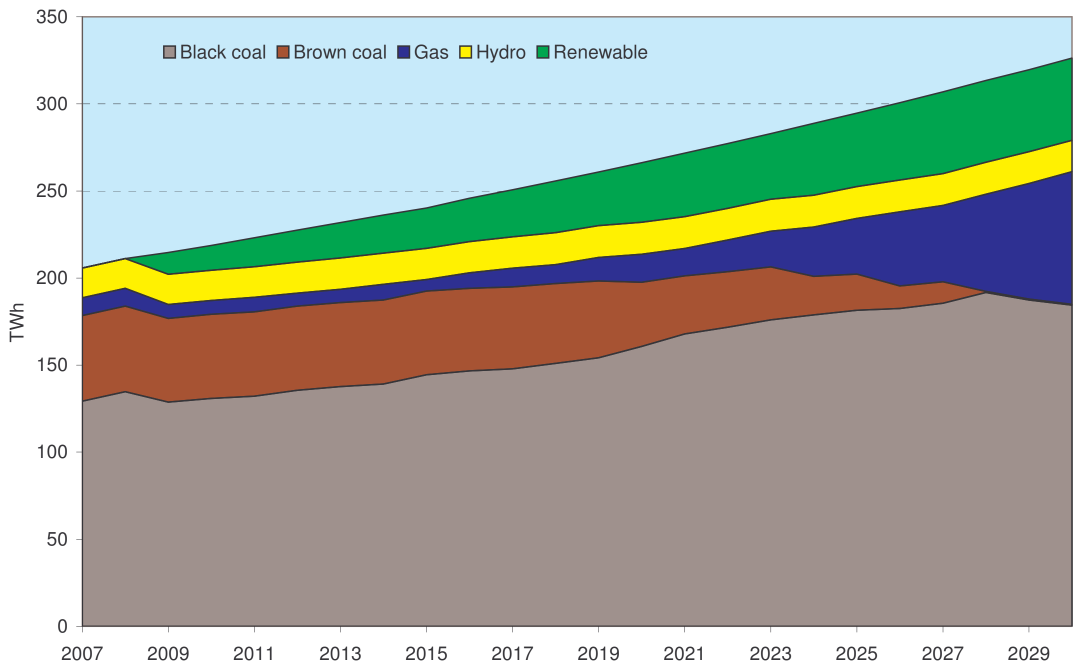
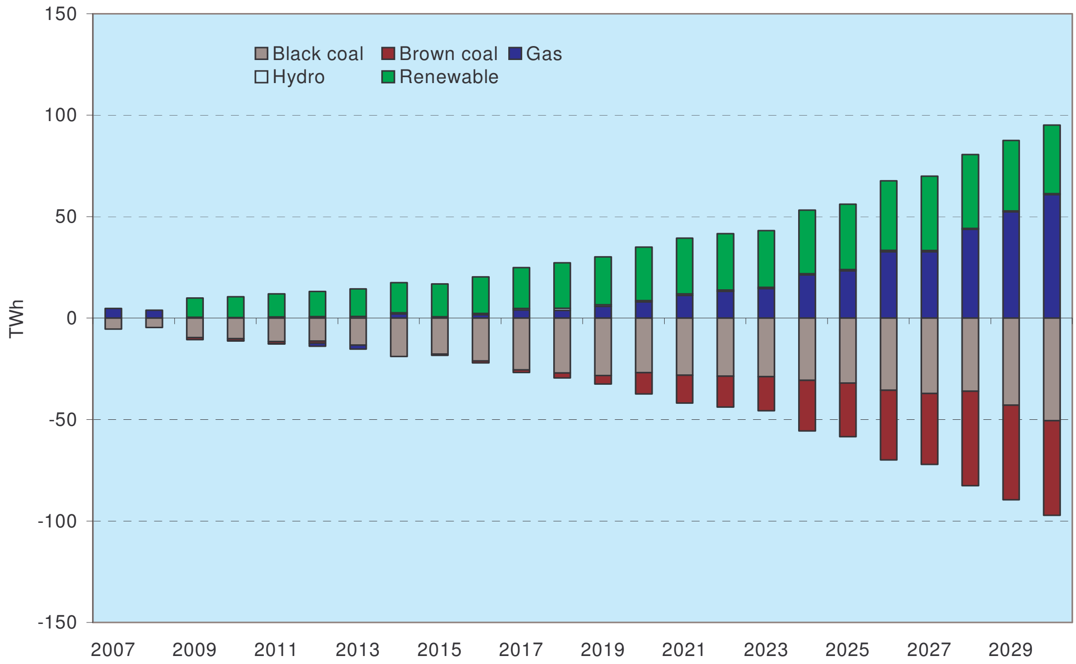


Figure 43: Difference in output (Staged Transition 100% relative to BAU)



Figures 42 to 45 show the output in the Staged Transition 100% and Linear 100% scenarios and the difference between the BAU and these scenarios. As would be expected, the most significant change between the 25% and 100% scenarios is the increased output of renewable generation in the 100% scenarios. This is caused by higher gas prices increasingly making renewable technologies economic (at current renewable prices).

Figure 44: Generator output (Linear 100%)

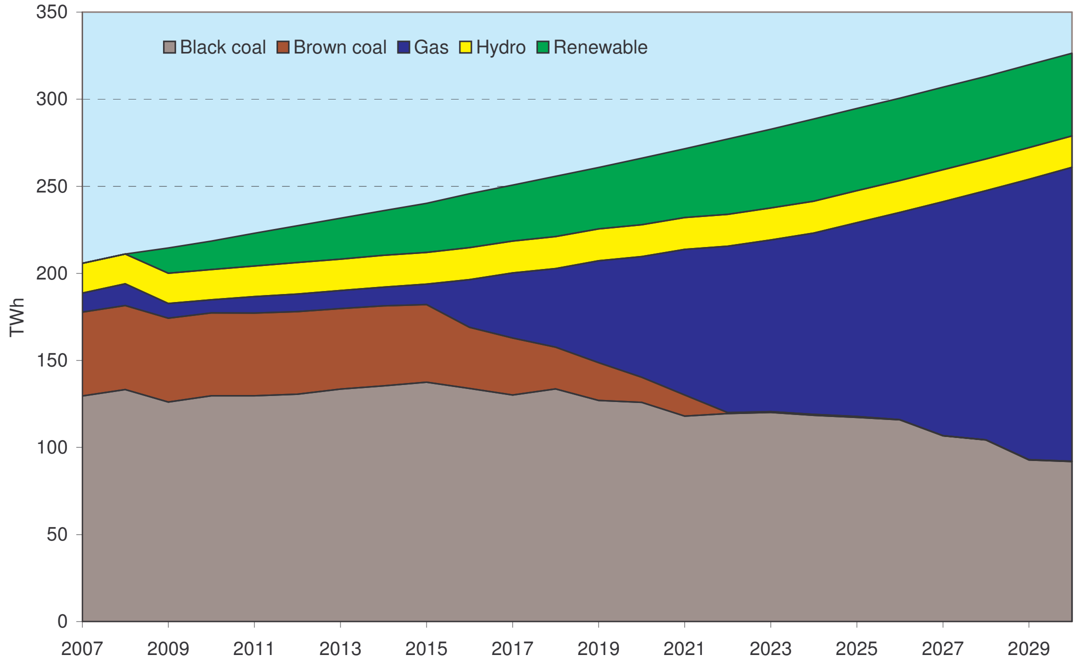
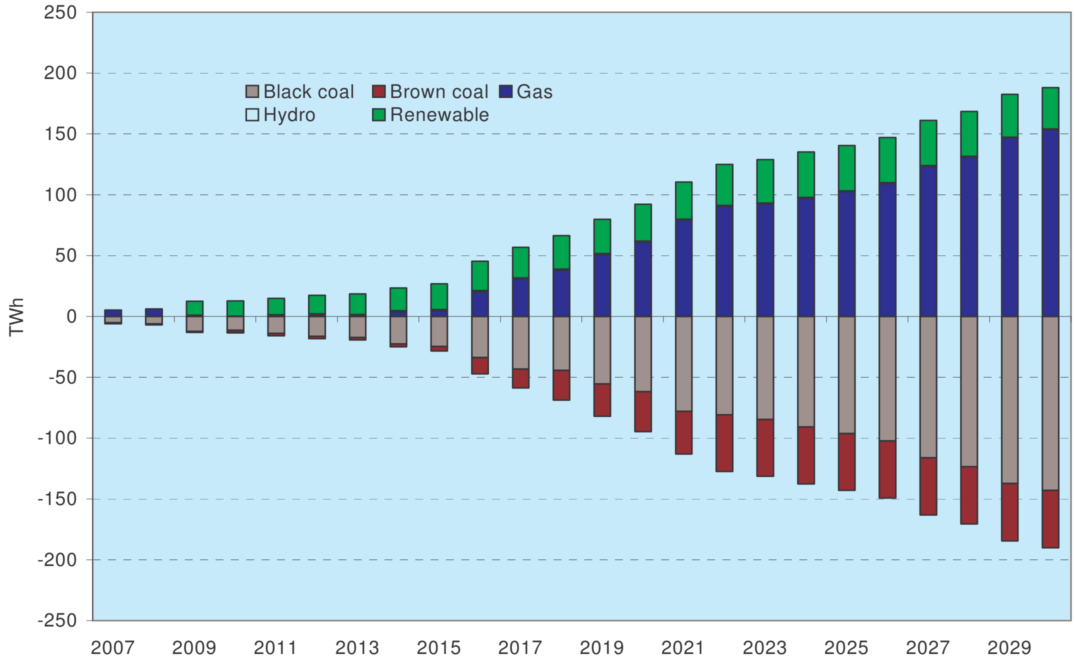


Figure 45: Difference in output (Linear 100% relative to BAU)



Figures 46 to 49 show generator output in the Staged Transition 25% EE and Linear 25% EE scenarios. As expected, while output is lower overall, the same trends in fuel type can be seen as in the Staged Transition 25% and Linear 25% scenarios. While energy efficiency has the potential to reduce overall demand, a change in the supply mix is still required to achieve the emissions objective.

Figure 46: Generator output (Staged Transition 25% EE)

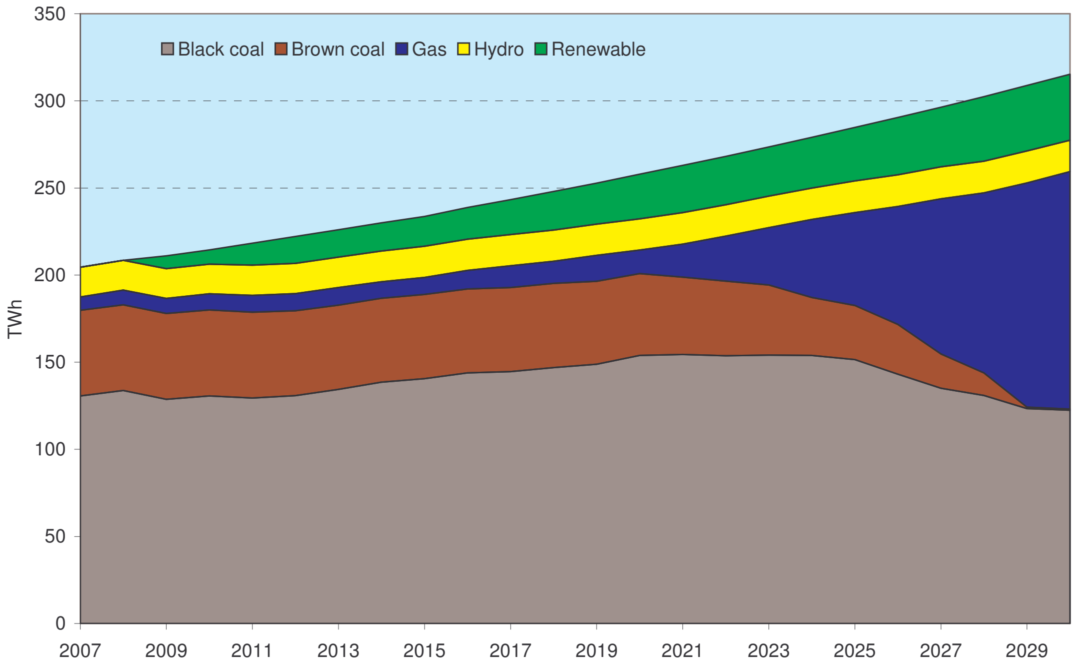


Figure 47: Difference in output (Staged Transition 25% EE relative to BAU)

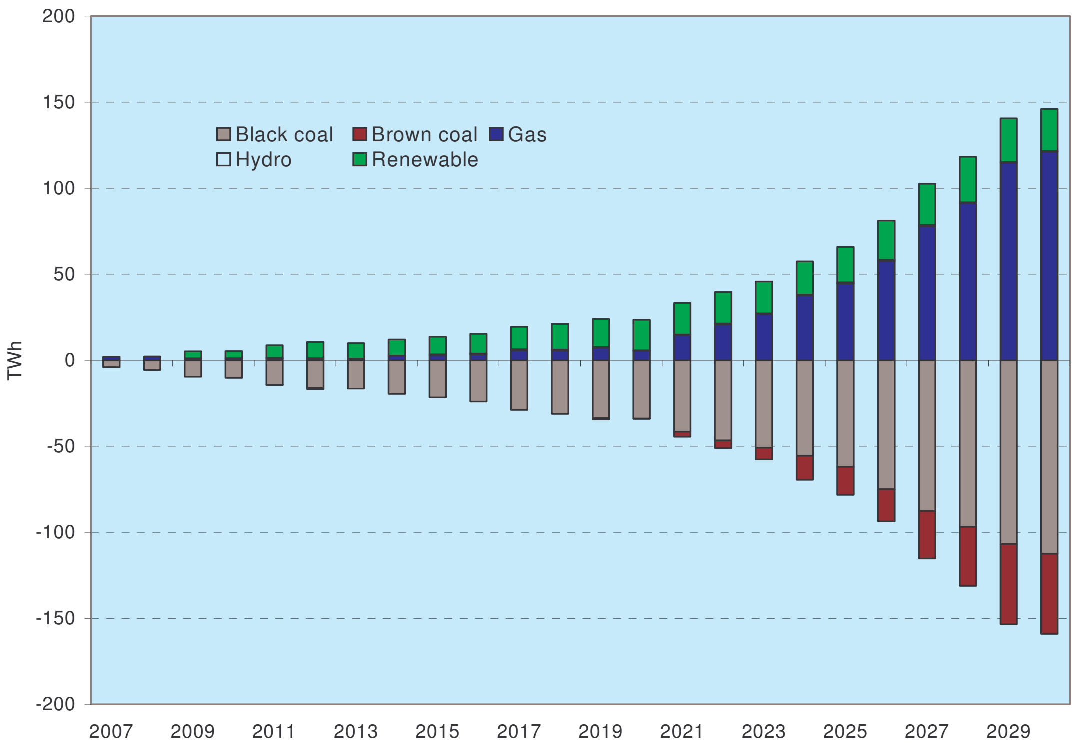


Figure 48: Generator output (Linear 25% EE)

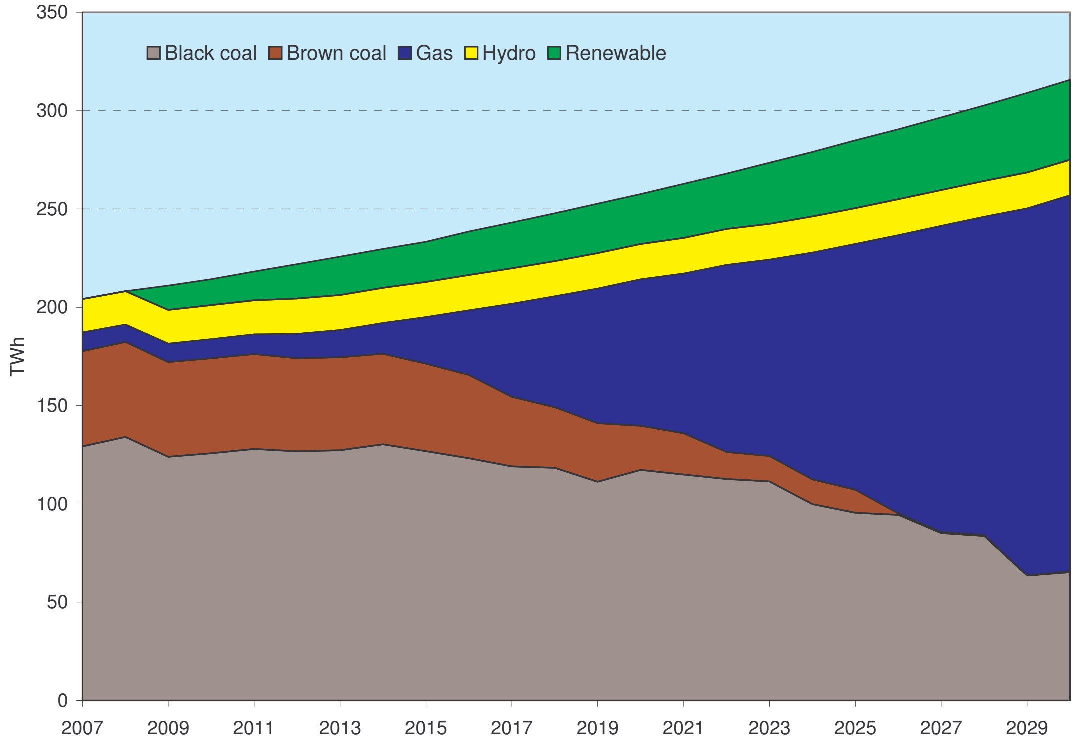
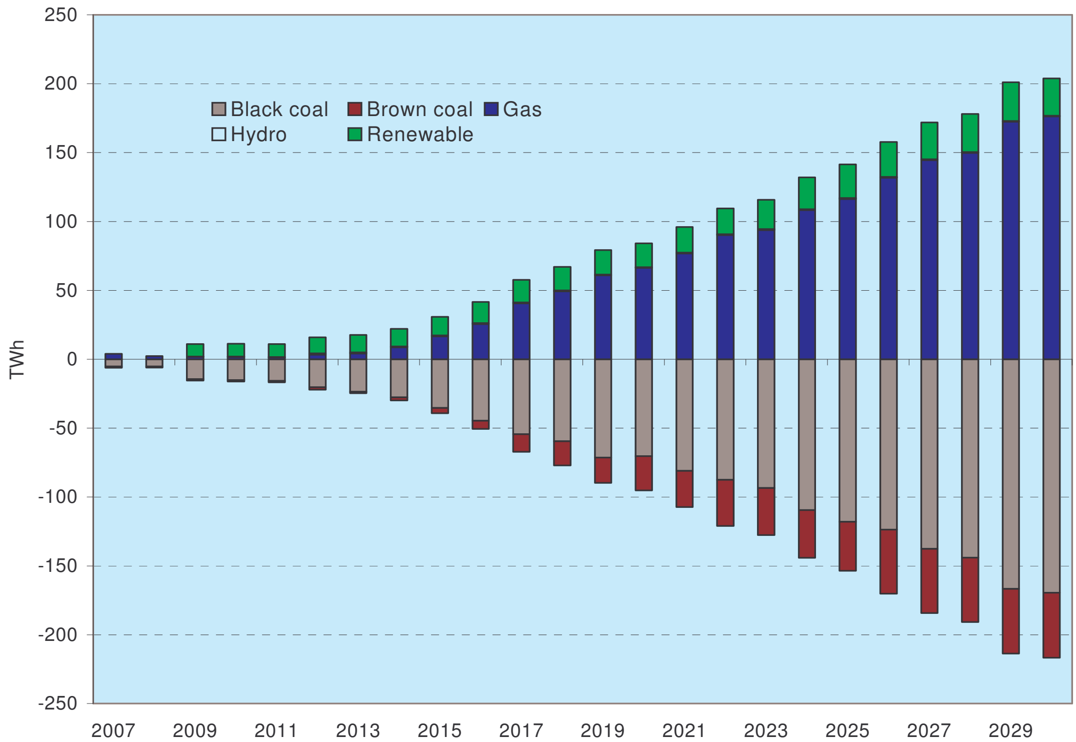


Figure 49: Difference in output (Linear 25% EE relative to BAU)



In reality, it is likely that new technologies would emerge during the 24 year period. As in the Staged Transition and Linear cases without major uptake of energy efficiency, the Staged Transition scenario allows greater time for technological development. In particular, it allows for carbon capture and storage to become cost effective, thereby minimising any structural adjustment issues associated with a move to a low emission future.

5. Policy implications

There are many implications for greenhouse reduction policy design as a result of this study. To date, the focus of public policy debate has been on whether it is necessary to establish an emissions trading scheme. While this is an important policy decision, the rate at which emission reductions should be pursued is an important policy decision in its own right as it will determine the costs of meeting proposed targets and impact on the types of technology used to reduce emissions. This is why this study has focused on establishing targets and timetables for emission reductions.

Committing to a target and adopting the right emission reduction pathway are important for a number of reasons:

- If emission reductions are pursued at a reasonable rate, the risk of significant stranding of existing capital is limited. The Australian electricity sector is capital intensive but will be able to respond effectively to clearly identified long-term and interim emission reduction targets.

- Action to reduce emissions is required now. If emission targets are not put in place, there is little incentive for the energy industry to develop new low emission technologies.

- While existing technologies are available to reduce emissions, they are more expensive than higher emitting technologies. Clearly identified long-term and interim emission reduction targets will allow more time for additional research and development in renewable technologies and clean fossil fuels which could drive down costs further.

- A wide range of cost effective energy efficiency measures could be used to significantly reduce electricity demand and the costs associated with meeting greenhouse gas emission targets.

- While emissions trading could be used as a mechanism to implement the reductions investigated in this study, it would not determine the overall additional cost to society of meeting electricity demand. The overall cost would be determined by the emissions target, reduction pathway and the costs of installing lower emission technologies to meet growing demand.

This study has shown that the costs associated with pursuing a Linear emission reduction pathway are significantly higher than pursuing a Staged Transition pathway where emission reduction targets gradually increase. However, the Linear pathway does have significant environmental benefits and avoids the possibility that even greater annual reductions in greenhouse gas emissions might be required after 2030.

In terms of overall costs, it should be noted that the additional cost of meeting the target in the Staged Transition 25% scenario is about $8.56 billion NPV. When measured in per capita terms, this equates to a one-off investment of about $415 NPV per person based on the current Australian population. If the Staged Transition 25% EE scenario is adopted, the costs equate to a one-off investment of $252 NPV per person.

The broader impact that the emission reduction constraint would have on the electricity market is more difficult to predict. In the National Electricity Market, all market participants are paid the same price as the final bid required to meet demand. This has significant implications for policy design. The actual cost of meeting demand in the electricity market is likely to be lower than the observed increase in electricity prices. As electricity prices will reflect the marginal cost of the last technology deployed to meet demand, operators of existing technologies will receive the same price even though their cost structures are not reflective of this price. There are also questions as to how such an emission target would alter the strategic bidding incentives of market participants.

This study has demonstrated that if the additional cost of meeting demand was evenly distributed throughout the Australian economy, the cost per person would be a once-off NPV contribution of between $252 and $1,172 depending upon the pathway chosen. However, the costs are likely to be unevenly distributed on the basis of energy consumption. It should be noted that the study did not model the effects on retail pricing and this warrants further study. In this context, the impact of possible price increases for industry with large energy input costs and low income households needs to be considered.

5.1 Challenging target

The results presented in this report represent a challenging target for the electricity sector. This is because of two key assumptions that were made during the modelling process:

- The emission reductions required in the electricity sector were significantly higher than in other sectors. However, the emission reduction target for the electricity sector would become fairer if, as proposed by WWF-Australia, other sectors are required to make significant reductions at the same time.

- The investment options in the economic model are based on existing technology and cost structures. Given that the 24 year period from 2007 to 2030 is significant, it is highly likely that new technologies would have been developed during this period. This is particularly important for policy design as outlined below.

It is difficult to predict the cost reductions which may emerge as a result of technological development. One of the implications of a challenging goal for the electricity sector is that emission reduction targets should be set sooner rather than later. If targets are not set, the emission reductions required by 2030 may be harder to achieve because relatively high emitting plant is being installed now.

5.2 Staged Transition target minimises costs

As outlined above, an increasing target as used in the Staged Transition scenarios as opposed to the Linear scenarios minimises the costs associated with reducing emissions. It is true that cumulative emission reductions at the end of the modelling period are lower because reductions are higher earlier and more sustained in a Linear pathway. However, a Staged Transition pathway provides for a similar transition to a lower emission 2030 future, and positions the electricity sector well to continue to make bigger emission reductions in the years beyond 2030.

Assuming that gas prices increase by 25%, the Staged Transition pathway involves an additional NPV cost of $8.56 billion. When a Linear 25% pathway is in place, the cost of meeting the target is $17.67 billion NPV. If gas prices are assumed to increase by 100%, the Staged Transition pathway involves an additional cost of $11.16 billion NPV and the Linear pathway $24.16 billion NPV. Accordingly, by pursuing a gradual or increasing emission reduction pathway, policy makers can provide for a smoother transition to a low emission future.

5.3 New technology development

The Australian Government has devoted significant resources to support the development of new low emission technology. This policy is consistent with the move towards a low emission future. However, while new technology is important, it cannot currently compete with existing inexpensive but higher emitting plant. Over time, this is likely to change as more funds are invested through programs such as:

- Low Emission Technology Development Fund: The Low Emission Technology Development Fund (LETDF) is a $500 million industry development fund administered by the Australian Government. Industry is able to apply for funding to demonstrate low emission technologies. By providing one third of eligible expenditure, the Fund effectively encourages industry to invest in low emission projects.

- Renewable Energy Development Initiative: The Renewable Energy Development Initiative (REDI) is a $100 million development fund for renewable technology. The fund is available to developers of new technology, not just demonstration projects.

By immediately beginning to reduce emissions but pursuing a Staged Transition, policy makers can provide additional time for these programs to deliver new low emission technologies. In particular, new technologies that can be 'retrofitted' to the existing capital stock can be developed to minimise structural adjustment issues.

5.4 Energy efficiency

The costs associated with emission reductions represent a challenging scenario for the electricity sector. However, a significant low cost method of emission reduction is likely to be found in energy efficiency. By including significant amounts of cost effective energy efficiency in policy design, overall costs can be reduced. Furthermore, it would also delay the introduction of higher cost technologies which would, in turn, place downward pressure on prices as the marginal cost of generation would not need to increase by as much or as early during the modelling period to 2030.