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ELECTRICITY RESTRUCTURING GROUP

Beyond Kyoto – Innovation and Adaptation: A critique of the PMSEIC assessment of emission reduction options in the Australian stationary energy sector

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The Australian Prime Minister's Science, Engineering and Innovation Council (PMSEIC) has recently reported on opportunities to develop greenhouse emission reduction technologies for Australia's energy sector, as well as strategies to help Australia adapt to the expected impacts of climate change.

This paper critiques the findings of 'Beyond Kyoto – Innovation and Adaptation'. We believe that the report has important strengths. 'Beyond Kyoto' recognises the growing risks that climate change poses for Australia and our present status as one of the world's highest per-capita greenhouse emitters. It establishes a target of reducing Australia's greenhouse emissions to 50% of present levels by 2100 and recognises the critical importance of the stationary energy sector in achieving such reductions. Beyond Kyoto argues the need for government support to promote the major technical innovation in energy supply that will be required. It also makes a strong case that no more coal-fired generation should be built in Australia unless it incorporates CO2 capture and geosequestration.

However, 'Beyond Kyoto' has some serious weaknesses. It places extraordinary emphasis on geosequestration as Australia's key emission reduction strategy and, in doing so, ignores the fact that the safest way to sequester carbon is to leave fossil fuels in the ground. The report therefore undervalues the crucial role of end-use energy efficiency, distributed generation and renewable energy in any rational response to climate change. It also relies on cost estimates for CO2 geosequestration that are substantially lower than those in other studies, and fails to consider other environmental or social impacts with the different energy options.

By attempting to pick a winner in this way, 'Beyond Kyoto' flies in the face of stated energy sector policy restructuring objectives aimed at implementing a 'level playing field' for all the technical options that might help meet desired societal outcomes. To maximise the benefits while minimising the costs and risks of our climate change response, geosequestration should be only one of a broad range of options supported by a coherent innovation strategy. This strategy has to be carefully integrated within a wider policy framework for climate change and energy, and also be compatible with a competitive stationary energy sector.

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EXECUTIVE SUMMARY

The PMSEIC *Beyond Kyoto* Report

The Australian Prime Minister's Science, Engineering and Innovation Council[2] (PMSEIC, 2002) has recently tabled a report, *Beyond Kyoto – Innovation and Adaptation*.

Its terms of reference were to address how Australian science, engineering and technology can help identify:

- opportunities to utilise and develop emission reduction technologies appropriate to Australia's energy sector, and
- strategies and research activities to help Australian industries and communities adapt to the expected impacts of climate change.

There is an urgent need to consider how Australia might be able to undertake its share of the very significant greenhouse gas emission reductions that will be required to protect the climate. Technical innovation will clearly play a vital role in such a transformation.

The *Beyond Kyoto* report would seem to be one of the first public Australian government efforts to explore some of these questions. Further, it makes some major recommendations for government action. Recent policy developments also suggest growing Federal Government support for actions that fall within these recommendations.

This critique paper reviews the *Beyond Kyoto* report with particular focus on its analysis and recommendations on emission reduction opportunities within the Australian stationary energy sector. This sector presently contributes almost half of Australia's total emissions, with two thirds of these arising from electricity generation.

Unsurprisingly, therefore, *Beyond Kyoto* focuses a great deal of attention on electricity supply. Also, some of the report's most significant recommendations relate to this sector.

We consider, first, the longer-term GHG target of 50% emission reductions taken by *Beyond Kyoto*. This is followed by a discussion of how the report considers the innovation process and, in particular, the role of governments in inducing technological change.

We critique the report's assessment of stationary energy sector emissions and trends, and current government abatement policies and measures. The rest of this paper then focuses on the *Beyond Kyoto* assessment and comparison of different emission reduction options in the stationary energy sector.

Looking beyond Kyoto

The 'Beyond Kyoto' report takes as its target a 50% reduction in Australian emissions by 2100.

The question of longer-term policy to address climate change is of critical importance. IPCC (2001) studies indicate that global emissions may have to be reduced by 50-60% from present levels over this century to avoid dangerous climatic change. This has been acknowledged by many nations including Australia.

Our policy makers must therefore consider how Australia might be able to make very significant emission reductions over the longer term. The *Beyond Kyoto* 50% target certainly requires far greater emission reductions than the average 108% emissions target for Australia in 2008-12 negotiated within the Kyoto Protocol.

The Protocol's modest objectives and generous land-use provisions for Australia mean that our 108% target might actually be met without any significant change within the energy sector.

Such a transformation is, however, clearly required in the longer term, and failure to act now may impede our ability to make future serious emissions cuts. Driving longer-term action therefore represents a rather different policy challenge to that of merely meeting our Kyoto Protocol target.

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[2] The PMSEIC Executive Officer is Dr Robin Batterham, Australia's part-time Chief Scientist and also the Chief Technologist for Rio Tinto Corporation. The *Beyond Kyoto* working group included members from the Universities of NSW and Queensland, CSIRO, Bureau of Rural Sciences and Rio Tinto Corporation.

The role of innovation, and policy

Longer-term protection of the climate will require a fundamental transformation of the present Australian, largely fossil fuel based, energy sector. The critical role of technical innovation in this transformation is well understood. The IPCC identifies “technology as a more important determinant of future greenhouse gas emissions and possible climate change than all other driving forces put together.” (IIASA, 2002)

Innovation has two key themes, *invention* and *application.* Research and development are the key steps of the invention phase. Demonstration and commercialisation are needed to move from invention to possible widespread adoption. Many would argue that taking a technology from technical feasibility to full commercialisation actually poses the greatest innovation challenge.

The important role of Government in driving ‘public good’ innovation is widely accepted yet not entirely understood. One of the key policy opportunities for governments is ‘induced technical change’ – that is measures which stimulate technological progress to rapidly drive down the costs of particular technologies.

The IEA (2003) has recently reported on the development of markets for new energy technologies, identifying three key perspectives:

- Research, Development and Deployment, focussing on the innovation process,
- Market Barriers, focussing on decision making within markets using economic analysis, and
- Market Transformation, focussing on the distribution chain from producer to user.

‘Beyond Kyoto’ does not make any detailed reference to the innovation process, and the role of policy in inducing technological change. For the stationary energy sector, the report focuses largely on the R&D and Deployment perspective of technology innovation for developing new ‘zero emission coal’ technologies.

Driving technical innovation in order to protect the climate is likely to require careful and thoughtful policy development. A policy framework that focuses on short-term ‘least cost’ emissions reductions may not drive the innovation required over the longer term.

PMSEIC would seem to have an important policy role as “the Government's principal source of independent advice on issues in science, engineering and innovation” (PMSEIC, 2003). Unfortunately, its report focuses almost entirely on just the R&D and Deployment perspective of technological innovation, and this for just one technology option – zero emission coal.

Beyond Kyoto fails to adequately stress the importance of addressing market barriers and driving market transformation as well as R&D and Demonstration. Commercialisation is actually proving to be the greatest challenge in successfully introducing many new technologies (IIASA, 2002).

Stationary energy sector emissions sources and trends

‘Beyond Kyoto’ highlights the Australian stationary energy sector’s major contribution to overall greenhouse emissions, particularly from electricity generation. The report also notes that this sector has had the highest rate of emissions growth over the past decade, making it a principal target for emissions reduction strategies.

We agree that the stationary energy sector represents an important target for emissions reductions in both the short and longer term. One must not, however, neglect abatement potential on the demand-side of this sector.

The report describes the principal driver of energy sector emissions as increasing energy demand from economic growth, with growth of our energy intensive economy highly dependent on low cost fossil fuels.

The Australian economy is certainly energy intensive in comparison with many other developed countries. However, care needs to be taken in linking Australia’s economic potential to energy intensive industry development as *Beyond Kyoto* does. Over 70% of our wealth and jobs are now in the services sector, while the contribution of manufacturing to the economy continues to fall (Parliament of Australia, 2002).

Over the longer-term it is possible to envisage marked changes in the energy intensity of the Australian economy, particularly if energy users are required to pay for their greenhouse emissions. A policy choice to continue to subsidise and promote energy intensive industry should be taken only after full consideration of its economic and climate change implications.

‘Beyond Kyoto’ bases its assessment of emissions reductions in the energy sector on ABARE projections of electricity use to 2030.

It is important to acknowledge the projected rates of growth for electricity and gas use in Australia over the next two decades. It is also necessary, however, to put projections such as those of ABARE in context. Their methodology generally assumes no significant change in energy policies and measures, major technology developments or other possible ‘surprises’ over the period (Craig et al, 2002). This is unlikely to be a sensible assumption in the medium to longer term. For example, wide international concern on climate change only emerged around a decade ago, yet is clearly beginning to shape energy sector development.

The most appropriate role for projections is to influence our actions now by showing the consequences of failing to act. This point is well made in the latest IEA Energy Outlook (2002) “..the projections in this Outlook raise serious concerns.. Governments will have to take strenuous action in many areas of energy use and supply if these concerns are to be met.” The use of ABARE projections here seems somewhat less thoughtful.

Current policy to support innovation in greenhouse emission abatement

‘Beyond Kyoto’ outlines the objectives and budgets of some of the current Federal government activities and programs for reducing greenhouse gas emissions.

Beyond Kyoto, however, fails to discuss important climate policy measures such as MRET and makes no attempt to assess the success or otherwise of these programs in influencing the continuing growth in emissions. Of even more concern with regard to the longer-term challenge, current measures would seem to have failed to halt major energy infrastructure construction with adverse and long-term impact on growth in emissions – for example, the recent construction of three coal power stations in Queensland.

Further, there is no discussion of present government R&D funding in the energy sector. We now have separate CRCs for black coal, brown coal, geosequestration and ecosystem sequestration yet none for renewable energy. Moreover, direct government support for sustainable energy R&D is low by per-capita standards compared to most developed countries (Australia Institute, 2003). In terms of market-based policy measures, the MRET target for renewable energy is also low in comparison with many other developed countries (BCSE, 2003).

All of these factors might go some way to explaining the apparent failure of Australian climate actions to date to reduce, or even stem the growth, in energy sector greenhouse emissions. Effective policy development for longer-term actions needs to be informed by such an analysis.

Emissions reductions within the energy sector

The ‘Beyond Kyoto’ terms of reference identify three areas where emissions reduction opportunities may lie: existing fossil-fuel based activities, existing non carbon-cycle technologies, and R&D leading to new zero-emission energy sources.

In our view, the report fails to adequately address any of these three areas. Further, its analysis framework for emissions reductions appears inadequate for reasons including:

- inappropriate use of long term electricity demand projections to argue for supply-side measures only: demand-side options to reduce electricity use appear to have been largely neglected,
- excessive focus on $/MWh costs given the difficulties in assessing these for future technologies and the complex set of societal costs and benefits that need to be weighed when assessing different abatement options,
- the failure to properly distinguish between technical and commercial feasibility for some options,

- a poor choice of time horizons (current, near-term and 50+ years), and inappropriate classification and assessment of different generation options within these,
- the consideration of an unreasonably limited set of scenarios for major emission reductions, and
- a near complete failure to consider the varied 'risk profiles' of the different technology options.

Demand-side options: '*Beyond Kyoto' allows little scope to the potential for reductions in Australian energy, and in particular electricity, demand.*

This is despite the far lower energy intensity of many other developed countries. Consider also the many 'no regrets' energy efficiency options identified by the IPCC (2001) that offer both strict economic and greenhouse benefits. Policy measures to promote innovation that exploits such opportunities are vital, yet not covered in *Beyond Kyoto*.

Comparing different technology options: '*Beyond Kyoto' compares energy abatement options on their estimated costs ($/MWh) and their ability to deliver major reductions in emissions.*

This analysis seems inadequate. It is difficult to estimate future costs of technologies that are in early development (with considerable potential for technical breakthroughs yet only a limited understanding of possible risks) or that are yet to achieve economies of scale. It may also be difficult to estimate the potential scale of their emission reduction contribution over the longer term. Thus the temptation to "pick winners" should be avoided, and a range of options should be supported.

In addition, other important societal and environmental values might influence energy choices:

- energy security concerns, leading to a policy to avoid excessive reliance on energy sources that are imported, vulnerable to terrorism or environmentally damaging,
- regional development and employment concerns, which could well modify the ranking of options,
- air, water and solid waste pollutants other than climate change,
- broader resource management questions such as land-use and water consumption, and
- the possibility of assisting the 'energy poverty' challenge in the developing world.

For example, recent work including (MacGill et al, 2002) has highlighted the regional development and job creation of wind and biomass energy projects. *Beyond Kyoto* makes no reference to these wider values.

Technology options for abatement

'Beyond Kyoto' identifies a range of technology options for emission reduction and then classifies these into current, near-term and longer-term time frames.

Unfortunately, this analysis appears to have significant errors for some important technologies.

Conventional Coal: '*Beyond Kyoto' states that incremental efficiency improvements to conventional pulverised fuel plants offers very limited opportunities for major emissions reductions in the longer-term.*

We agree, and would stress that construction of these capital intensive and long-lived plants 'locks in' very significant emissions for decades to come. *Beyond Kyoto* would seem to make a strong case that no more coal-fired generation should be built in Australia unless it incorporates CO2 capture and geosequestration.

A new 1000MW coal fired power station will emit nearly 7 million tCO2 each year – nearly 280 million tCO2 over an average 40 year operating life.

Retrofitting CO2 capture and geosequestration to existing power stations is expected to be more expensive than 'new build' options (IEA, 2001; Freund, 2002).

Natural gas: '*Beyond Kyoto' acknowledges the growing use and increasing sophistication of gas fired combined cycle (CCGT) plants but suggests that their cost of electricity is almost 50% higher than conventional coal plants.*

The recent CoAG (2002) Market Review disagrees, estimating current CCGT generation cost at only 20% greater than black coal and less than brown coal. CCGT plants have lower capital costs and shorter construction lead times than coal fired units, less than half the greenhouse emissions when fuelled with natural gas, more flexible siting and more flexible operating characteristics – none of this is acknowledged in the *Beyond Kyoto* report. Gas fired CCGT has become the preferred choice for electricity generation in much of the world and ABARE modelling has gas CCGT contributing between 5 and 46 per cent of Australian electricity in 2030, even without emissions constraints (Naughten, 2002).

Distributed Energy Systems: *There are classified in 'Beyond Kyoto' as emerging (10 years) small-scale technologies based around combined heat and power close to loads.*

The "emerging" categorisation is curious given the widespread international application of cogeneration technologies today (WADE, 2002). In addition, cogeneration has the advantage of reduced network losses (and possibly network investment savings) and increased security of supply compared to remote generation.

Renewables: '*Beyond Kyoto' classifies renewables as both current and future (50 years) options. Some key technologies are identified as having niche markets yet none are seen as likely to be deployed in significant scale in the near future because of high costs and limited availability.*

This analysis seems flawed. While most renewable technologies are currently not cost-effective in comparison with fossil fuel generation in Australia, costs continue to fall. The cost of wind energy has, for example, fallen 20% over the last five years (EWEA, 2002). Renewable energy can offer other valuable benefits as well, such as job creation and synergies with other environmental objectives.

The growth rates of some key renewables technologies are an order of magnitude greater than those for fossil fuels or nuclear power (WorldWatch, 2001). While this is from a small base, note that oil met only 2% of world energy demand in 1900.

Technology	Avg. annual growth (%) over 1990-2000
Wind power	25
Solar photovoltaics	20
Solar thermal (Europe)	18
Geothermal	4
Biomass	3
Natural gas	1.6
Oil	1.2
Nuclear power	0.6
Coal	**-1.0**

The existing Federal MRET target may see some 3000MW of new renewables installed in Australia by 2010. Increasing the MRET target to +5% could see installation of over 3000MW of wind generation alone (MacGill et al, 2002). This would make a very significant contribution to emissions reductions. Many developed countries have set far more ambitious renewable generation targets than Australia (BCSE, 2003).

Coal IGCC and geosequestration

The main recommendation of 'Beyond Kyoto' is to give national research priority to coal-based integrated gasification combined cycle (IGCC) combined with geosequestration of CO2. The report gives IGCC 'current options' status alongside conventional coal, natural gas, nuclear and renewable energy.

This assessment of IGCC seems overly optimistic. For example, the IEA (2001) notes that "IGCC has been successfully demonstrated but the capital cost needs to be reduced and the reliability and operating flexibility needs to be improved to make it widely competitive in the electricity market."

Geosequestration: '*Beyond Kyoto' classifies geosequestration for coal fired generation as an emerging option that "will happen within 10 years."*

This is not supported by international work to date. It will require considerable technical progress in order to capture CO2 from electricity generation and then sequester it in the geological formations available to such power stations (IEA, 2001). There are a number of technical unknowns and risks associated with this. While there is general agreement as to the technical feasibility of at least some geosequestration, its potential wide-scale application with coal IGCC technologies is currently unproven.

‘Beyond Kyoto’ quotes cost estimates ranging from A$10 (unpublished data from Roam Consulting) to $50 (IEA, 2001) per tonne of CO2 abated. The report uses the A$10 figure in its technology comparisons.

One key question for IGCC and geosequestration, should its technical feasibility be proven, is how the cost compares with other abatement options. There are particular challenges in estimating these costs given the immature status of the technology. It is not possible to verify the unpublished data on which the *Beyond Kyoto* estimate is based. Nevertheless, it falls well below other published estimates.

Study	Est. abatement costs for coal gen. with geosequestration (A$/tCO2)
IPCC (2002)	$52-86
GEODISC (2002)	$17-27 (not including capture)
IEA (2001)	$69-103
DoE (2003)	$46-140
Beyond Kyoto	**$10**

‘Beyond Kyoto’ frequently uses the term ‘zero emissions coal’ to describe coal IGCC with sequestration. Elsewhere, however, the report notes that the technology “results in major reductions in greenhouse emissions but for technical reasons does not equate to zero emission”.

The IEA (2001) reports that future IGCC with sequestration will likely have CO2 emissions per MWh some 40% of gas-fired CCGT plant – hardly a zero-emission technology. Moreover, the term ‘zero emissions coal’ implies that geosequestration of CO2 is equally secure as carbon sequestered in coal - hardly likely in the long term.

Generation cost for ‘zero emissions coal’: ‘*Beyond Kyoto’ bases its assessment of abatement options on estimated generation costs ($/MWh) for conventional coal, CCGT, ‘zero emissions coal’ and a range of renewable energy resources.*

The source of these cost estimates is not clear. The costs quoted appear to be too low for current wind, biomass and PV electricity. The gas CCGT costs seem wrong as noted earlier, while the ‘zero emissions coal’ cost of $41/MWh – or only 20% more than conventional coal fired plant – is based on a geosequestration cost that is around one fifth of the average of the other published estimates shown above.

Australian sequestration potential: ‘*Beyond Kyoto’ makes reference to the GEODISC program of the Australian Petroleum CRC and its investigation of Australian geosequestration potential in support of its recommendations.*

The GEODISC (2002, 2002b) program has made an important contribution to our understanding of geosequestration potential in Australia. Some of this work has matched potential geosequestration sites around Australia against those regions with high greenhouse emissions. Although this work is somewhat preliminary and subject to considerable uncertainty, it is estimated that Australia may have the potential to store a maximum of 25% of our total annual net emissions, or approximately 100 - 115 Mt CO2 per year.

The studies to date also suggest that some of the major existing electricity generation regions are unsuitable for geosequestration. NSW black coal fired power stations are far from suitable sites and are predicted to face very high sequestration costs. Queensland, however, would appear to have moderate sequestration possibilities.

These studies also acknowledge that “Broad brush style estimates of CO2 storage potential at the global and continent scale are probably of limited value for future research programmes, and more sophisticated storage capacity estimates are required that integrate economics, source to sink matching and technical viability.”

Comparison of Energy Abatement Options

‘Beyond Kyoto’ assesses the energy abatement opportunities for each of the technologies considered on the basis of their potential to contribute large-scale emissions reductions and comparative costs of abatement.

The report gives three scenarios of future emissions from the electricity sector where all future generating capacity is either conventional coal, gas CCGT or IGCC with geosequestration.

From this, Beyond Kyoto concludes that "within the foreseeable future only carbon capture and geosequestration has the potential to radically reduce Australia's greenhouse signature". Also, "existing renewable alternatives can only be expected to make up a small proportion of the total energy mix in the near future"

We agree with the implicit finding of *Beyond Kyoto* that new conventional coal fired plant should not be built. The report's analysis of other scenarios, however, would seem flawed. IGCC with geosequestration can hardly be expected to provide significant abatement in the near future given that it hasn't yet even been shown to be technically feasible. There are considerable challenges still to be resolved prior to practical implementation.

By contrast, there is already widespread deployment of some renewable energy generation and energy efficiency technologies internationally. The potential scale of IGCC with geosequestration must also be considered. Some major coal generation regions appear to have poor geosequestration potential.

Further, the *Beyond Kyoto* scenarios take only a very limited view of longer-term abatement possibilities. There is broad consensus that approaches combining energy efficiency, distributed cogeneration, renewable energy and low-emission fossil fuelled generation hold perhaps the greatest potential for large scale emission reductions (IPCC, 2001). The report considers only 'IGCC with geosequestration' and gas CCGT scenarios.

***Beyond Kyoto* recommendations**

The Beyond Kyoto recommendations for action in the stationary energy sector are driven by the view that of the available abatement options, "the production of electricity using coal gasification and sequestration of CO2 in geological structures appears to offer the best chance of large scale GHG mitigation."

The report recommendations therefore are to:

- *establish a national program to scope, develop, demonstrate and implement zero emissions coal,*
- *identify energy options resulting in low greenhouse emissions as a national research priority,*
- *provide incentives for the adoption of abatement measures along MRET lines, and*
- *accelerate the adoption by energy consumers of energy efficiency and cost effective alternative energy sources.*

We support the recommendation to accelerate the adoption by energy consumers of energy efficiency options and the use of cost effective alternative energy sources. Who could oppose it.

The challenge is in how this should be done, and *Beyond Kyoto* doesn't address this. In particular, the failure of present energy markets to even take advantage of many strictly cost-effective energy efficiency options has to be addressed.

The most specific recommendations of *Beyond Kyoto* are the establishment of a national 'near zero emissions coal generation' development and demonstration program, and the need for market instruments to drive such low emission generation.

We would certainly agree with the IEA (2001) that "In view of the many uncertainties about the course of climate change, further development of CO_2 capture and storage technologies is a prudent precautionary action."

However, this would seem to be only one part of any broad innovation based program to create and further develop a range of abatement technologies for the medium to longer term.

A more diversified national research strategy on a wide range of abatement technologies would seem warranted. The absence of significant Federal support for renewable energy R&D is concerning in this regard. Market based measures to drive adoption of new abatement technologies would also seem to need to be greatly strengthened.

TABLE OF CONTENTS

1 Introduction

The Australian Prime Minister's Science, Engineering and Innovation Council[3] has recently tabled a report, *Beyond Kyoto – Innovation and Adaptation* (PMSEIC, 2002) prepared by a working group established by the Council and given the task of assessing how science, engineering and technology can help identify:

- opportunities to utilise and develop emission reduction technologies appropriate to Australia's energy sector, and
- strategies and research activities to help Australian industries and communities adapt to the expected impacts of climate change.[4]

There is an urgent need to consider how Australia might be able to make the very significant greenhouse gas emissions reductions that will be required to protect the climate. Technical innovation will clearly play a vital role in such a transformation. The *Beyond Kyoto* report is one of the first public Australian government efforts to explore this role for innovation. Further, it makes some major recommendations for government action. Recent policy developments also suggest growing Federal Government support for actions that fall within these recommendations.[5]

This critique paper reviews the *Beyond Kyoto* report with particular focus on its analysis and recommendations on emissions reduction opportunities within the Australian stationary energy sector. This sector presently contributes almost half of Australia's total emissions, with two thirds of these arising from electricity generation.

Unsurprisingly, therefore, *Beyond Kyoto* focuses a great deal of attention on electricity supply. The report would actually seem to devote more attention to the stationary energy sector than adaptation, transport,[6] agriculture and land management combined.[7] Our review therefore covers a significant proportion of the report's analysis and recommendations.

In Section 2 we consider the longer-term GHG target of 50% emissions reductions taken by *Beyond Kyoto*. This is followed by a discussion of how the report considers the innovation process and, in particular, the role of governments in inducing technological change.

Section 3 critiques the report's assessment of stationary energy sector emissions and trends, and current government abatement policies and measures.

Section 4 then focuses on the *Beyond Kyoto* assessment and comparison of different emissions reductions options in the stationary energy sector. In particular, we critique the main recommendations of the report for the stationary energy sector. This is followed in Section 5 with a discussion of the strengths and weaknesses of the *Beyond Kyoto* report.

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[3] The PMSEIC Executive Officer is Dr Robin Batterham, Australia's part-time Chief Scientist and also the Chief Technologist for Rio Tinto Corporation. The *Beyond Kyoto* working group included members from the Universities of NSW and Queensland, CSIRO, Bureau of Rural Sciences and Rio Tinto Corporation.

[4] See the terms of reference provided to the working group (PMSEIC, 2002 p. 5).

[5] See, for example, (ABC, 2002) and also the Government's (2002) Climate Change Action Agenda - "we will continue to encourage the development of promising low emissions technologies such as coal gasification, geological sequestration, coal gas to liquids and the hydrogen economy."

[6] It is to be hoped that others will be able to review how 'Beyond Kyoto' has addressed transport. For example, we are surprised that public transport receives no attention at all in the report despite clear international evidence of its potential contribution to reducing transport related greenhouse emissions.

[7] As estimated from the number of pages devoted to each of these topics in 'Beyond Kyoto'.

2 Looking *Beyond Kyoto* and the role of innovation

2.1 Beyond Kyoto emissions reductions

The question of longer-term policy to address climate change, and the role of innovation and technology in this, is of critical importance. Effective mitigation of dangerous climate change will require concerted, wide ranging long-term action over decades. It is likely that many sectors of the economy, in particular the energy sector, will need to be entirely transformed.

The term 'Beyond Kyoto' is often used when considering large-scale global emissions reductions over the longer-term – beyond the moderate reductions over the short-term agreed within the Kyoto Protocol (an average 5% reduction from 1990 levels of emissions across ratifying developed countries by 2008-12).

As acknowledged in the *Beyond Kyoto* report, IPCC emission scenarios for stabilising atmospheric concentrations of CO2 gases at levels that would prevent dangerous interference with the climate system, indicate that global emissions may have to be reduced by 50-60% from present levels over this century. This objective has been widely acknowledged by national governments including that of Australia.[8]

It should be noted that the Kyoto Protocol is more than an agreed target for the 2008-12 commitment period. It is also a framework for international agreement, collaboration and enforcement of global climate action. Negotiations on targets and timelines for the second commitment period are scheduled for 2006. Longer-term action for decades to come may well be undertaken within this general framework. and in this case would clearly not be 'Beyond Kyoto', despite the possible political attractiveness of the term.

The 'Beyond Kyoto' report takes as its target, a 50% reduction in Australian emissions by 2100.[9]

We agree that there is considerable value in setting a longer-term goal beyond the average 108% emissions target for Australia for the 2008-12 commitment period established within the Kyoto Protocol. Given this modest objective and the generous land-use provisions allowed specifically for Australia, this target may yet be met without any significant change in the energy sector.[10]

Failure to develop a longer-term strategy now may impede our ability to make more substantial emissions cuts in the future, as discussed later in this paper.

Note also that Australia at present has the highest per-capita greenhouse emissions of any industrialised nation.[11] An equitable international framework for global emissions reductions (contraction and convergence) may therefore require Australia to make greater cuts than 50% over a shorter time frame than 2100.

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[8] For example, the Australian Federal Environment Minister has been quoted (ABC, 2002) as saying "..we have got to cut globally greenhouse gas emissions by some 60 per cent if we are going to stabilise greenhouse gasses in the atmosphere. That is a very long way to go."

[9] *Beyond Kyoto*, p. 23.

[10] See (Australia Institute, 2003) for a discussion of this possibility.

[11] Australia's per capita emissions are some 25% higher than the second country Canada, 35% higher than the US and over twice the per-capita average for industrial countries (Australia Institute, 2002b). Despite our relatively low population, Australia's total emissions therefore exceed all industrial countries other than the USA, Japan, Russia, Germany, the United Kingdom and Canada.

2.2 The role of technology and innovation

As well as the long time frame of climate change impacts, the other great challenge for policy development on global warming is the fundamental transformation of our economy that seems to be required. Energy, in particular, underpins just about every activity we undertake in our society, and our present energy systems are based largely on greenhouse gas emitting fossil fuels.

Technology innovation will play a critical role in transforming the energy sector. The Intergovernmental Panel on Climate Change has identified “technology as a more important determinant of future greenhouse gas emissions and possible climate change than all other driving forces put together” (IIASA, 2002).

The terms technology and innovation are used in many different, and potentially confusing, ways and contexts. We will take innovation to mean the *practical application of new ideas*. Its key themes are, from this definition, *invention* and *application.* Both of these will be essential in any fundamental transformation of our energy systems.

Similarly, technology is often thought of as meaning hardware. For our purposes, however, technology can be more usefully considered as having hardware, software and orgware dimensions (IIASA, 2002). Here, hardware refers to manufactured technology, software to the knowledge required to design, manufacture and use hardware, and ‘orgware’ to the institutional settings and rules for generating technological knowledge and governing its use. All three aspects have a key role in transformative technological change as required to address climate change. Undue emphasis on the hardware dimension alone has reduced the effectiveness of much innovation.[12]

A great deal of work is underway to improve our understanding of the dynamics of technological change and innovation, and the role that policy can play in driving this change.[13] Much, however, remains to be learned. One important factor is certainly the technology development cycle from invention through to widespread application. Research and development efforts are key components of the invention phase. Demonstration and commercialisation are key steps in moving from invention to widespread adoption.

Many would argue that commercialisation is the great challenge as a technology is taken from proven technical feasibility to cost-competitive commercial viability and success. Terms such as the ‘valley of death’ and the ‘mountain of death’ highlight the challenges of successful commercialisation given the learning costs and efforts in doing something the first time (Norberg-Bohm, 2000).

Niche markets and special advantages of new technologies can allow them to move from limited high-cost applications to widespread low-cost applications. Another important factor is the ‘maturity’ of a particular technology. For mature technologies, it is likely that cost reductions will arise from up-scaled manufacturing rather than technical breakthroughs. Other technologies, however, may still be undergoing rapid innovation with great potential for breakthroughs that reduce costs.

2.3 Induced technical change

If our understanding of technical innovation is limited, determining the role of Government in driving such innovation is even more difficult. Its role in supporting R&D in basic research that is high risk and directed to the public good seems clear.[14] Determining the Government’s role in commercialisation, however, is more complex. Nevertheless, there are good reasons to accept, and

[12] See, for example, the findings of the Australian Innovation Summit (DITR, 2000).

[13] See, for example, (IIASA, 2002) and (IPCC, 2001).

[14] See, for example, the discussion in (DTI, 2001).

experience confirms, the important role that governments should play in supporting emerging greenhouse 'friendly' energy technologies. Support for demonstration projects and market interventions all have a role. [15]

One of the key general policy questions in this area is that of 'induced technical change' – the view that policy driving early emissions reductions action can stimulate technological change and rapidly reduce the costs of technologies providing such reductions. This ties into the question of 'dynamic efficiency' in how we can best (most efficiently) achieve our long-term climate change policy objectives, and the key role of appropriate choices now in expensive and long lived energy infrastructure.[16] It also links to the question of how economic performance might be linked to climate change action. There is growing evidence that strong environmental performance may positively support economic competitiveness (Esty and Porter, 2002).

The IEA (2003) has recently reported on the development of markets for new energy technologies. It describes three perspectives that are all important in the market success of such new technologies:

- Research, Development and Deployment, focussing on the innovation process, industry strategies and the learning that is associated with new technologies. This perspective focuses on technology costs and performance, and strategies for market entry,
- Market Barriers, focussing on decision making by investors and consumers through economic analysis, and
- Market Transformation, focussing on the distribution chain from producer to user, using management science tools (Executive summary, p. 2).

'Beyond Kyoto' does not make any detailed reference to the innovation process, and the role of policy in inducing technological change. For the stationary energy sector, the report focuses largely on the R&D and Deployment perspective of technology innovation for developing new 'zero emission coal' technologies.

Driving technical innovation in order to protect the climate is likely to require careful and thoughtful policy development. A policy framework that focuses on short-term 'least cost' emissions reductions may not drive the innovation required over the longer term.

The PMSEIC would seem to have an important role to play as "…the Government's principal source of independent advice on issues in science, engineering and innovation.." (PMSEIC, 2003). It could be expected that the PMSEIC would take the Research, Development and Deployment perspective, and this is clearly of vital importance in contributing to our understanding of climate change and technological innovation. Unfortunately, its report focuses almost entirely on the R&D and Deployment perspective of technological innovation only, and this for just one technology option – zero emission coal.

It is our view that one of the major weaknesses of *Beyond Kyoto* is its failure to adequately consider and incorporate the growing understanding of the process of technical innovation and induced technical change, and how it applies to climate change policy development for the Australian energy sector.

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[15] See, for example IEA (2002b) *Dealing With Climate Change - Policies and Measures in IEA Member Countries*. The latest volume details more than 200 new policies and measures undertaken in the year 2000 to address energy-related emissions in IEA member countries.

[16] The term dynamic efficiency refers to the processes of technological and organization innovation responding to longer-term market developments. It is very different from the productive and allocative efficiencies that much policy development focuses on. For example, dynamic efficiency is clearly the most relevant efficiency for long-term climate action in the energy sector where many of its key technologies require high capital investments and have very long asset lives.

Further, the report fails to explain the importance of addressing market barriers and driving market transformation as well as R&D and deployment in order to successfully transform the Australian energy sector through new technologies.

2.4 Analysis tools

One major difficulty with the *Beyond Kyoto* report is its failure to explain and defend its assessment methodology for the Australian context, and emissions reductions opportunities. Beyond the absence of suitable models for innovation and induced technical change as outlined above, there would seem to be weaknesses in the report's:

- linkage of economic growth and competitive advantage with the existing energy sector,
- use of projections for assessing Australia's longer-term energy needs,
- choice of time frames when assessing energy sector emissions reduction options,
- assessment of prospective, emerging and established technology options including the failure to recognise that what already exists is, by definition, possible,
- inadequate consideration of the dangers to long-term climate objectives in making large scale investments in capital intensive, long lived energy assets that have high greenhouse emissions, and
- an almost complete failure to consider the varied 'risk profiles' of the different technology options.

3 Australian greenhouse emissions and the energy sector

3.1 Stationary energy sector emissions sources and trends

'Beyond Kyoto' highlights the Australian stationary energy sector's contribution to overall greenhouse emissions (49.3%) with two thirds of this contribution arising from electricity generation. The sector has also had the highest rate of emissions growth over the last decade.

We agree with the report's conclusion that the high emissions, high growth rates and relatively uniform technology mix of the stationary energy sector makes it a principal target for emissions reductions (p. 14). One must not, however, neglect abatement potential on the demand-side of this sector.

Given the long-term timeframe for *Beyond Kyoto* it is necessary to consider the present drivers for energy related emissions, and emissions growth, and how these may change over the coming decades. Emissions arise, of course, from physical energy consumption that is largely supplied by fossil fuels. Australia's emissions can be expected to depend on our population, the energy services we use (both directly and in the provision of goods and services) and the primary energy resources and physical infrastructure that delivers these.

'Beyond Kyoto' sees the principal driver of emissions as increasing energy demand from economic growth (p. 21) and that growth of our energy intensive economy is highly dependent on low cost fossil fuels (p. 1).

The Australian economy is certainly energy intensive in comparison with many other developed countries. However, care needs to be taken in linking our economic potential to energy intensive industry development.

For example, the Aluminium smelting industry consumes almost 15% of Australia's electricity generation yet contributes only 0.15% of Australian GDP (AGO, 2002) while receiving electricity price subsidies estimated at A$210 million to more that $250 million a year (Australia Institute, 2002).

Over 70% of Australia's wealth and jobs are now in the services sector and this is growing, while manufacturing's contribution continues to fall (Parliament of Australia, 2002). A policy choice to continue to subsidise and promote energy intensive industry should be taken only after full consideration of its economic and climate change implications.

Over the longer-term it is possible to envisage marked changes in the energy intensity of the Australian economy, particularly if energy users are required to pay for their greenhouse emissions. Australian per-capita energy consumption is, after all, over 50% greater than the average for Western Europe, although some 37% less than that for the US.[17]

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[17] Data obtained from tables of Per Capita (Person) Total Primary Energy Consumption provided on the US EIA website, http://www.eia.doe.gov/emeu/international/total.html#IntlConsumption

3.2 The use of ABARE projections

'Beyond Kyoto' bases its assessment of emissions reductions in the energy sector on ABARE projections of future electricity use to 2030.

It is important to acknowledge the projected rates of growth for electricity and gas use in Australia over the next two decades. It is also necessary, however, to put projections such as those of ABARE in context. Their methodology generally assumes no significant change in energy policies and measures, major technology developments or other possible 'surprises' over the period. This is unlikely to be a sensible assumption in the medium to longer term. For example, wide international concern on climate change only emerged around a decade ago, yet is clearly beginning to shape energy sector development.

The accuracy of longer term projections has certainly proven to be questionable.[18] For example, Craig et al. (2002) reports that "Energy forecasters working in the aftermath of 1970s oil shocks expended enormous effort in projecting future energy trends… Actual U.S. energy use in 2000 was at the very lowest end of the forecasts. Energy use turned out to be lower than was considered plausible by almost every forecaster." Note that these projections where made *after* the first oil shock had occurred.

Closer to home, difficulties with ABARE projections have been noted. One relevant example is that of ABARE's changing projections of future Australian gas consumption over the last decade as shown in Figure 1. ABARE's 1993 projection had 2003 gas consumption at around 800 PJ, its 1995 projection was just over 1000 PJ, its 1997 projection was well over 1300 PJ while its 1999 projection saw 2003 consumption back down at around 1100 PJ. Over six years, ABARE's projections of 2003 gas consumption – never more than a decade away – varied between 800 to 1300 PJ, or around 50%.

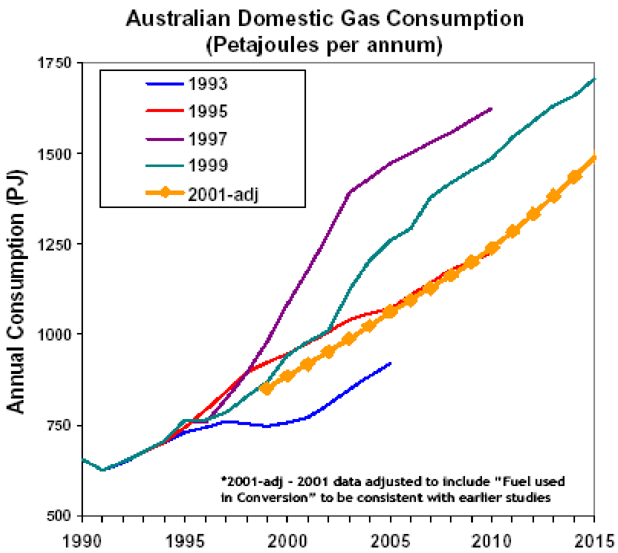

Figure 1. ABARE projections of Australian gas consumption from 1993 to 2001 (taken from Origin Energy, 2002).

The key, then, is in how projections are actually used. Their most important role is to influence how people act by showing the consequences of failing to act. This point is well made in the most recent IEA Energy Outlook – "The projections in this Outlook raise serious concerns… Governments will have to take strenuous action in many areas of energy use and supply if these concerns are to be met." (IEA, 2002; Executive Summary, p. 1). The use of ABARE projections in *Beyond Kyoto*, however, seems rather less thoughtful.

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[18] Forecasts… "should be seen as no more than approximate outcomes centred on a range of plausible possibilities, conditional on a number of assumptions" according to the Australian Treasury (Commonwealth of Australia, 1985).

There is no doubt that significant action and investment in the energy sector is required now and over the longer term. However it may not be driven as much by ever increasing demand, as argued in *Beyond Kyoto,* as by other imperatives including demand management.

3.3 Current abatement activities

'Beyond Kyoto' outlines some of the current federal government activities and programs for reducing greenhouse gas emissions (p. 15).

As discussed earlier, policy choices taken now can have marked impacts on our longer-term technology options. Unfortunately, *Beyond Kyoto* makes to attempt to assess the success or otherwise of these programs, and omits discussion of some of the potentially most important measures such as the Federal Government's Mandatory Renewable Energy Target.

Such analysis would have identified the clear failure of measures to date to reduce energy sector emissions or even end their growth. Of even more concern with regard to the longer-term challenge of effective climate change action, current measures do not seem to be directing major energy infrastructure investment decisions away from choices that will have very marked adverse impacts on longer-term emissions (perhaps three or more decades). There is, for example, the recent construction of three coal fired power stations in Queensland.

Further, there is no discussion of present government R&D funding in the energy sector. We now have CRCs for black coal, brown coal, geosequestration and ecosystem sequestration (the CRC for Greenhouse Accounting) yet none for renewable energy and only one federally funded research centre (Photovoltaics).

In overall funding terms, direct government support for sustainable energy in Australia is low by per-capita standards with many other developed countries as shown in Figure 2. There are, of course, market-based policy measures that governments can implement that have energy consumers 'fund' sustainable energy development. MRET is, of course, an example of this. Again, however, Australian targets for renewables are low in comparison with numerous other developed countries (BCSE, 2003).

All of these factors might go some way to explaining the apparent failure of Australian climate actions to date to reduce, or even stem the growth, in energy sector greenhouse emissions. Effective policy development for longer-term actions needs to be informed by such an analysis.

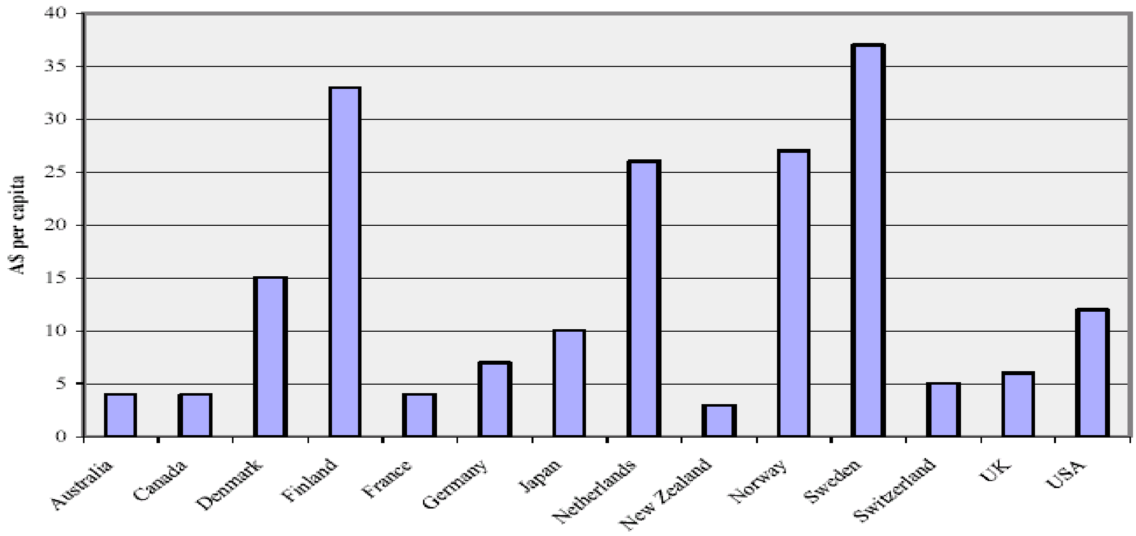

Figure 2. Indicative annual per-capita government spending on sustainable energy (taken from Australia Institute, 2003).

4 Emissions reductions within the energy sector

The ‘Beyond Kyoto’ terms of reference identify three distinct areas where emissions reduction opportunities may lie (p. 5):

- *reductions from existing fossil-fuel based activities*
- *existing non carbon-cycle technologies, and*
- *R&D leading to new zero-emission energy sources.*[19]

The report focuses on electricity supply and its two thirds contribution to stationary energy sector emissions. Its analysis framework seems largely based around (p. 22-23):

- *ABARE projections of greatly increased future electricity demand,*
- *the supply gap arising from this growth and declines in existing generation capacity over the next three decades,*
- *the need to assess the different low emissions generation options with regard to generation costs and their ability to deliver major emissions reductions,*
- *the use of three time horizons – “technologies which are currently available, technologies which could be commercialised with 10 to 20 years, and technologies which may be 50 or more years away.”, and*
- *three scenarios of possible emissions reductions.*

In our view, this framework is inadequate for reasons including:

- as discussed earlier, the great care required when using longer-term projections for analysis – demand-side options to reduce electricity demand appear to have been neglected,
- the multi-dimensional and complex set of costs societal costs and benefits associated with different generation options beyond strict $/MWh comparisons – for example, energy security concerns,
- little if any consideration of the different risk profiles for major technological progress with any of these technologies,
- the failure to properly distinguish between technical and commercial feasibility when assessing different technical options,
- the incorrect classification and assessment of different generation options within the reports three time horizons, and
- the choice of an unreasonably limited set of scenarios for major emission reductions.

We will address each of these concerns in turn, with particular attention to the *Beyond Kyoto* report’s assessment of zero-emission coal technology, distributed generation and the different renewables. For the above and other reasons, we believe that the recommendations of *Beyond Kyoto* are inadequate and potentially misleading.

4.1 Demand-side options

‘Beyond Kyoto’ allows little scope to the potential for reductions in Australian energy, and in particular electricity, demand.

This is despite the far lower energy intensity of many other developed countries. Consider also the many ‘no regrets’ energy efficiency options that offer both strict economic and greenhouse benefits, as identified by work including the IPCC (2001) *Third Assessment Report*.

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[19] ‘Beyond Kyoto’ terms of reference, p. 5.

Closer to home, a recent Allens Consulting (2002) report states that mandatory 4 or 5 star energy ratings for new houses in Victoria "would have many positive economic benefits for the State of Victoria in a range of areas including Gross State Product (GSP), employment and economic welfare".

The technical feasibility and economic attractiveness of many demand-side technologies is well established. Policy measures to ensure that energy infrastructure and equipment investments take advantage of these technologies are vital, yet not covered in *Beyond Kyoto*.

4.2 Valuing different technology options

'Beyond Kyoto' compares energy abatement options largely on their:
- *likely cost effectiveness, in terms of $/MWh, and*
- *ability to deliver major reductions in emissions.*

We will first consider the question of comparing direct ($/MWh) energy costs. We explore the issue of how the various technology options have widely different abilities to deliver very significant emissions reductions in a later section on scenario analysis.

Among Australia's existing generation options, thermal coal fired plants offer the lowest direct energy costs in many regions. As *Beyond Kyoto* notes, this reflects the low cost of Australian coal and modern large-scale coal fired power plants. It also reflects to some extent, earlier policy choices such as historical subsidies to centralised generation, around 100 years of experience with the technology, economies of scale, the immature status of Australian gas markets and more.

It is difficult to estimate future costs of technologies in early development with considerable potential for technical breakthroughs, and established technologies that have not yet achieved economies of scale. For example, the IPCC *Third Assessment* (2001) reports that "Significant technical progress relevant to greenhouse gas emissions reduction has been made since the Second Assessment Report in 1995 and has been faster than anticipated. Advances are taking place in a wide range of technologies at different stages of development…" Given this, there are reasons to be cautious when making cost comparisons, and reasons to support a range of prospective options.

More broadly, the accepted need to reduce emissions from electricity generation identifies climate change as a negative industry externality – that is, a societal cost associated with high emissions generation that is not 'seen' by the power producer. There are other externalities that might also shape our energy choices including:

- energy security concerns associated with high reliance on imported, vulnerable or potentially unacceptable energy sources,
  - the highly favorable economic development and job creation potential of some technologies,
- other possible air, water and solid waste pollutants,
- the different types of risks associated with the various technologies,
- broader resource management questions such as land-use and water consumption, and
- the possibility of assisting the 'energy poverty' challenge in much of the developing world.

Many of these other types of externalities can be quite significant for energy technologies. For example, earlier work by MacGill et al (2002) amongst others has highlighted the regional development and job creation potential of wind and biomass energy projects.

These wider societal opportunities and risks with the different abatement options all need to be considered along with cautious estimates of direct energy costs when determining appropriate policies and measures.

4.3 Technology options for abatement

'Beyond Kyoto' identifies a range of technology options for emissions reductions and then classifies these into current, near-term and longer-term time frames.

This analysis appears to have significant inconsistencies and inaccuracies for some important technologies as outlined below.

Conventional Coal:
'Beyond Kyoto' states that incremental efficiency improvements to conventional pulverised fuel plants offers very limited opportunities for major emissions reductions in the longer-term.

We agree, and would stress that construction of these capital intensive and long-lived plants 'locks in' very significant emissions for decades to come. *Beyond Kyoto makes* a strong case that no more coal-fired generation should be built in Australia unless it incorporates CO2 capture and geosequestration.

For example, the Federal MRET scheme is expected to provide greenhouse abatement of around seven million tCO2-e each year by 2010. One new conventional 1000MW coal fired base-load generator would emit almost seven million tCO2 each year alone.[20] Over a 40 year life, such a plant would emit nearly 280 million tCO2.

The IEA (2001) and Freund (2002) have noted that the additional cost of capturing CO2 tends to be higher for retrofitting of CO2 capture equipment than for fitting such equipment as part of a new plant.

Natural gas:
'Beyond Kyoto' acknowledges the growing use and increasing sophistication of gas fired combined cycle (CCGT) plants but suggests that their cost of electricity is almost 50% higher than conventional coal plants.[21]

By comparison, the recent CoAG (2002) Market Review estimates current CCGT generation cost at only 20% greater than black coal and less than brown coal. The CoAG review also recommended significant changes to the still immature Australian gas market to increase gas supply and reduce longer-term gas costs.

Furthermore, CCGT plants have lower capital costs (hence lower sunk investment) than conventional or IGCC coal fired unit. They also have less than half the greenhouse emissions of conventional coal plants when fuelled with natural gas, more flexible siting with respect to fuel supply and network constraints and more flexible operating characteristics. These advantages have not been acknowledged in the *Beyond Kyoto* report.

In many countries including the US and much of Europe, CCGT plants are the preferred option for new generation. In the US, for example, over 90GW of new gas generation capacity was brought on line in 2001-2 yet no coal fired generation was commissioned over that period (EIA, 2002).

ABARE modelling for Australia estimates the CCGT share of electricity production by 2030 as between 5 and 46 per cent, and this for a range of scenarios without emissions constraints (Naughten, 2002).

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[20] A 1000MW plant with emissions of 850kgCO2-e/MWh operating at 92% capacity factor will emit around 6.85 million tCO2-e each year.

[21] *Beyond Kyoto* estimates CCGT electricity generation costs at approximately $50/MWh versus $34/MWh for black coal electricity generation (p. 31).

Distributed Energy Systems:
There are classified in 'Beyond Kyoto' as emerging (10 years) small-scale technologies based on combined heat and power close to loads.

Beyond Kyoto classifies distributed energy as "emerging", which is curious given the widespread international application of cogeneration technologies today as shown in Figure 3 (WADE, 2002).

We believe that *Beyond Kyoto* is correct in assessing smaller-scale technologies such as micro-turbines and fuel cells as not yet commercial. However, it is possible to take advantage of larger-scale cogeneration and CHP opportunities in Australia now.

The benefits of such technology options are many including very high energy efficiency, potentially lower costs, low greenhouse emissions compared with conventional energy supply, reduced T&D losses, the potential to defer network investments and possible supply security advantages for high 'value' loads.

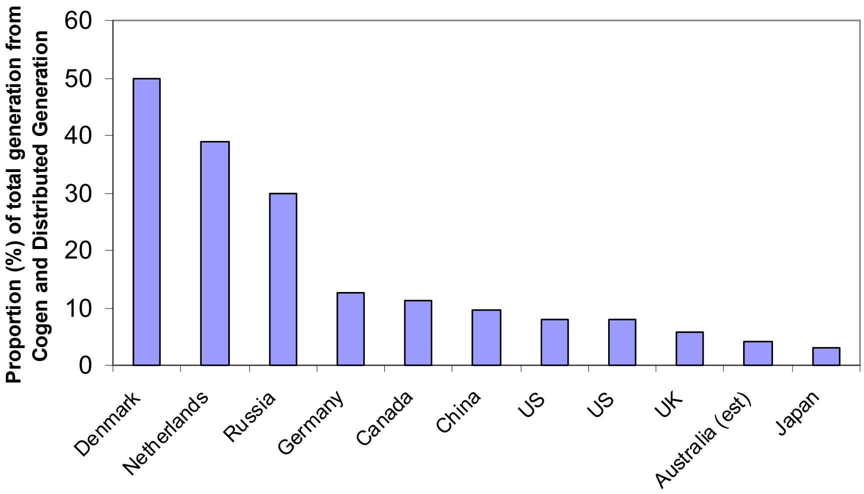

Figure 3. Contribution of Cogeneration, CHP and Distributed generation to overall electricity generation for selected countries.[22]

Renewables:
'Beyond Kyoto' classifies renewables in both the current options and future (50 years) possibilities categories. Some key technologies are identified as having niche markets yet none are seen as likely to be deployed in significant scale in the near future (p. 24). This is due to high costs and, in the case of wind, limited availability of sites with access to the grid (p. 25). So called 'advanced renewables' including new PV materials, lighter and more efficient wind turbines and artificial photosynthesis are identified as possible future options 50 years or more away (p. 29).

We consider this analysis flawed. While some key renewable technologies are currently not cost-effective in comparison with current fossil fuel generation they can have other valuable benefits, and costs continue to fall markedly as their industries grow.

Energy security is a growing driver for renewables, as is the economic growth and job creation potential of the rapidly growing renewables industry. Some renewables have other 'valuable' characteristics that should be considered. For example, photovoltaics can be deployed in the urban environment as building integrated products. Here, the relevant cost comparison may be against commercial and retail tariffs rather than base load coal generation. There are also potential network advantages from reduced distribution losses and deferred 'wires' investment.

[22] Adapted from (WADE, 2002). The Australian estimate is from installed cogeneration capacity with respect to total power plant (ESAA, 2001).

Wind power has made remarkable progress over the last decade with over 27GW installed worldwide in Autumn 2002, up nearly 40% for the year (EWEA, 2002b). Wind farms at good sites in the US are now able to generate electricity at around the same cost as coal-fired plant (EWEA, 2002). Wind now supplies almost 20% of Denmark's and 4% of Germany's electricity generation.

The growth rates of some key renewable industries over the last decade are an order of magnitude greater than that for fossil fuels as shown in Table 1. It is true that these high growth rates are from a very small base in comparison to coal, oil and gas. Nevertheless, oil supplied only 2% of world energy demand in 1900, yet went on to dominate world energy supply in a little over 60 years (WorldWatch, 2001).

Table1. Some global trends in energy over the last decade 1990-2000 (Worldwatch, 2001).

Source	Average annual growth rate* (%)
Wind power	25
Solar photovoltaics	20
Solar thermal (Europe) #	18
Geothermal @	4
Biomass &	3
Natural gas	1.6
Oil	1.2
Nuclear power	0.6
Coal	**-1.0**

* Based on installed capacity for wind and nuclear power, shipments for solar PV, and consumption for natural gas, oil, and coal.
# The solar thermal market in Europe has been growing at an annual 18% over the decade 1989-99 (IEA, 1999) although the US market has been shrinking.
@ Annual geothermal energy production growth over 1995-2000 (REW, 2001).
& Annual biomass energy production growth over 1995-2000 (REW, 2001).

In the near future, it is expected that renewable generation costs for many technologies will continue to fall as their markets grow. For example, wind power costs have fallen some 20% over the last five years (EWEA, 2002).

For Australia, Redding (2002) estimates that wind generation might contribute one third of the present MRET requirement for 9500GWh of new renewable electricity by 2010, representing some 1000 MW of installed wind capacity. Recent concerns with the integrity of MRET with respect to pre-existing hydro suggest the wind contribution may be considerably lower (AEA, 2002). It has been estimated that a +5% MRET target could see installation of over 3000MW of wind generation alone by 2010 (AEA, 2001). This would represent some 7% of present total installed generating capacity.[23]

Other countries are showing far more faith in the potential of renewable energy than Australia. MRET currently has a target of less than 2% new renewables in 2010. In contrast, other countries are setting far higher targets for *new* renewable generation. For example, the EU target is 8.2% by 2010 (BCSE, 2003).

Beyond Kyoto refers to possible advanced renewables over the longer-term (50 years or more). This discussion (p. 29) is unduly pessimistic given present rates of technology progress, for example wind turbines.

[23] See MacGill et al (2002b) for more details on possible wind generation scenarios for Australia to 2010.

4.4 Coal IGCC and geosequestration

'Beyond Kyoto' devotes considerable attention to coal fuelled integrated gasification combined cycle power generation (p. 23) and its potential role in zero emission coal generation using geosequestration.

This analysis seems flawed, and particularly troubling, given that the main recommendation of the report is that zero emission coal be made a national research priority.

Coal IGCC generation:
This technology is given 'current options' status alongside conventional coal, natural gas, nuclear and renewable energy. The report claims that 'IGCC plants are in operation in a number of countries.." and that "... it is understood that the process is approaching cost competitiveness with conventional coal technologies."

This claim seems to overstate the case. SKM (2000) reports that the US is at the forefront of developing this technology with several operational 250MW plants, yet notes that these "…are essentially demonstration plants and are not able to be operated on a fully commercial basis. There are also similar plants operating in Europe but again not on a fully commercial basis."

The IEA (2001) notes that "IGCC has been successfully demonstrated but the capital cost needs to be reduced and the reliability and operating flexibility needs to be improved to make it widely competitive in the electricity market."

Thus coal IGCC is potentially a commercially viable technology, but at present it is only in the demonstration phase. This is briefly acknowledged later in *Beyond Kyoto* when IGCC is classified as an emerging technology in the discussion of geosequestration (p. 27).

Geosequestration

'Beyond Kyoto' classifies geosequestration as an emerging option ("will happen within 10 years", p. 25). It notes the existing application of sequestration for enhanced oil recovery and disposal of CO2 generated through oil and gas extraction (p. 26).

This is not supported by international opinion. For example, an IEA report states that it would require considerable technical progress in order to capture CO2 from electricity generation and then sequester it in the geological formations available to such power stations (IEA, 2001). There are a number of technical unknowns and risks associated with this.

While there is general agreement as to the technical feasibility of at least some geosequestration, its potential wide-scale application with coal IGCC technologies is currently unproven.

Abatement costs of geosequestration:
One key question is how the cost of geosequestration (if feasible), would compare with other abatement options. There are particular challenges in estimating these costs, particularly in the medium to longer-term given potential technical advances. Nevertheless, the present demonstration and even commercialization of some of the key technology components provides some guidance (IEA, 2001). Other important considerations are the use of 'net present value' or 'levelised' costs and the discount rate applied. Freund (2002) shows that choices here can change $/tCO2e estimates by a factor of 3.6. The IEA Greenhouse Gas R&D Programmes use levelised costs in their comparisons and this moves cost estimates to the higher range.

'Beyond Kyoto' quotes cost estimates ranging from A$10 (unpublished data from Roam Consulting) to $50 (IEA), 2001) per tonne of CO2 abated. The report uses the A$10 figure in its technology comparisons.

It is not possible to verify the unpublished Roam Consulting data and judge the estimations and assumptions made in its calculation. However, the quoted IEA (2001) estimate of $50/tCO2 tonne comes from an authoritative and well regarded IEA program. There would appear to be some confusion in *Beyond Kyoto* concerning this IEA report as it actually gives estimated abatement costs for coal fired generation with geosequestration of around US$40-60/tCO2, equivalent to A$70-100/tCO2 or more (see Figure 4).

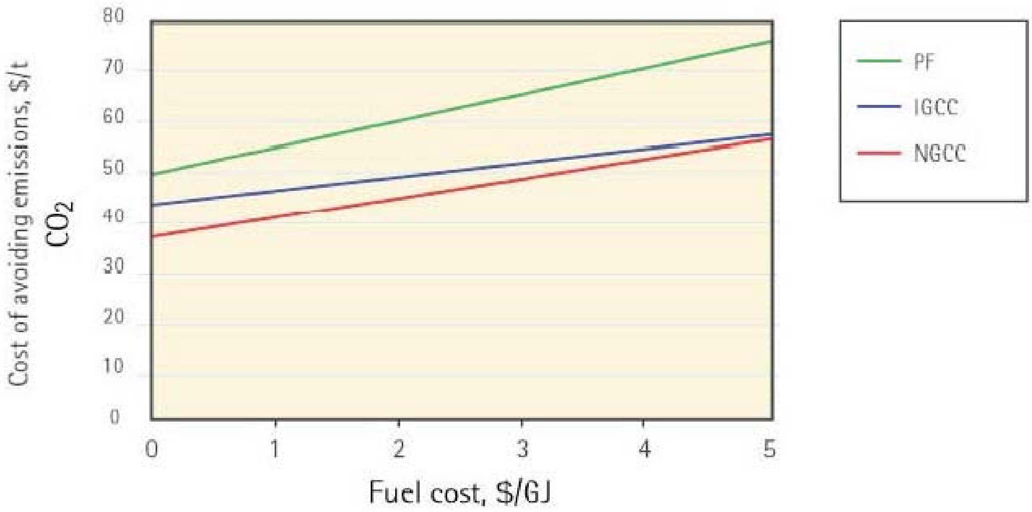

Figure 4. Estimated cost in US$ of 'avoided emissions' for different generation options with geosequestration – PF (conventional pulverized fuel), IGCC and NGCC (Natural Gas Combined Cycle). (Graph is taken from IEA, 2001).

This later figure is in accordance with other estimates including the IPCC (2001) estimate of US$30-50/tonne (A$52-86/tonne). The US Department of Energy (2003) estimated sequestration costs for coal fired generation in the range of US$100 to US$300/ton of carbon emissions avoided (equivalent to US$27-80 /tCO2 or A$46-140/tCO2).

The US has recently announced a A$1.7billion project to build a 275MW demonstration IGCC plant (DoE (2003b) with geosequestration. This capital cost (per MW of capacity) is well over three times present capital costs for coal fired generation in Australia

Beyond Kyoto references ongoing work into the potential Australian geosequestration resource under the GEODISC program (p. 26). Interestingly, this program has recently estimated that the real breakeven carbon credit required for sequestration is between US$10.1 and US$15.5 per tonne of CO2 avoided with a mean of US$12.5 per tonne avoided. This cost range from A$17-27 per tonne CO2 avoided is only for the sequestration and does not include capture costs (GEODISC, 2002).

Zero-emissions coal:

'Beyond Kyoto' frequently uses the term 'zero emissions coal' to describe coal IGCC with sequestration. Elsewhere, however, the report notes that the technology "results in major reductions in greenhouse emissions but for technical reasons does not equate to zero emission".

The IEA reports that future IGCC with sequestration will likely have CO2 emissions per MWh some 40% of existing gas-fired CCGT plant – hardly a zero-emission technology. Moreover, the term 'zero emissions coal' implies that geosequestration of CO2 is equally secure as carbon sequestered in coal - hardly likely in the long term.

Zero emissions generation costs:
'Beyond Kyoto' bases its assessment of abatement options on estimated $/MWh generation costs of conventional coal, CCGT, zero emissions coal and a range of renewables ("Electricity cost for a range of technologies – Figure 11", p. 31).

The source of these cost estimates is not clear. The costs quoted appear to be too low for current wind, biomass and PV electricity. The gas CCGT costs seem wrong as noted earlier, while the 'zero emissions coal' cost of $41/MWh – or only 20% more than conventional coal implies a cost of geosequestration that is about one fifth of the average of the other published estimates discussed above.

The zero emissions coal generation cost of A$41/MWh is referenced to unpublished data from Roam Consulting without explanation. It is not in accord with cost estimates from IEA (2001) which estimate that capture and sequestration (either from pre-combustion capture with IGCC or post-combustion capture with conventional PF plant) will increase electricity costs some 90% with respect to conventional plant.

The US DoE's National Energy Technology Laboratory (2002) estimates 'capture and sequestration' electricity prices of A$95/MWh with IGCC and A$120/MWh with pulverised coal plant.

In start contrast, *Beyond Kyoto* suggests that capture and sequestration will add only a little more than 20% to current coal generation costs. This represents an approximate abatement cost (factoring in the low but still significant emissions of IGCC with sequestration in comparison with conventional coal) of A$10/tCO2 abated – one quarter of most other estimates and less than half the GEODISC average estimates for Australia for sequestration alone (that is, not including the costs of capture or transport?).[24]

Australian sequestration potential:
'Beyond Kyoto' makes reference to the GEODISC program of the Australian Petroleum CRC and its investigation of Australian geosequestration potential in support of its recommendation to pursue zero emissions coal options.

The GEODISC (2002, 2002b) program has made an important contribution to our understanding of geosequestration potential in Australia. Some of this work has matched potential geosequestration sites around Australia to regions with high greenhouse emissions. Although this work is somewhat preliminary and subject to considerable uncertainty, it is estimated that Australia may have the potential to store annually a maximum of 25% of our total annual net emissions, or approximately 100 - 115 Mt CO2 per year.

The studies to date suggest that some of the major existing electricity generation regions are unsuitable for geosequestration. NSW black coal fired power stations are far from suitable sites and are predicted to face very high sequestration costs. Queensland, however, would appear to potentially have moderate sequestration possibilities. See Figure 5 for more details.

These studies also acknowledge that "Broad brush style estimates of CO2 storage potential at the global and continent scale are probably of limited value for future research programmes, and more sophisticated storage capacity estimates are required that integrate economics, source to sink matching and technical viability."

[24] Conventional coal plant emissions of 850kgCO2/MWh versus 'IGCC with sequestration' emissions of 150ktCO2/MWh.

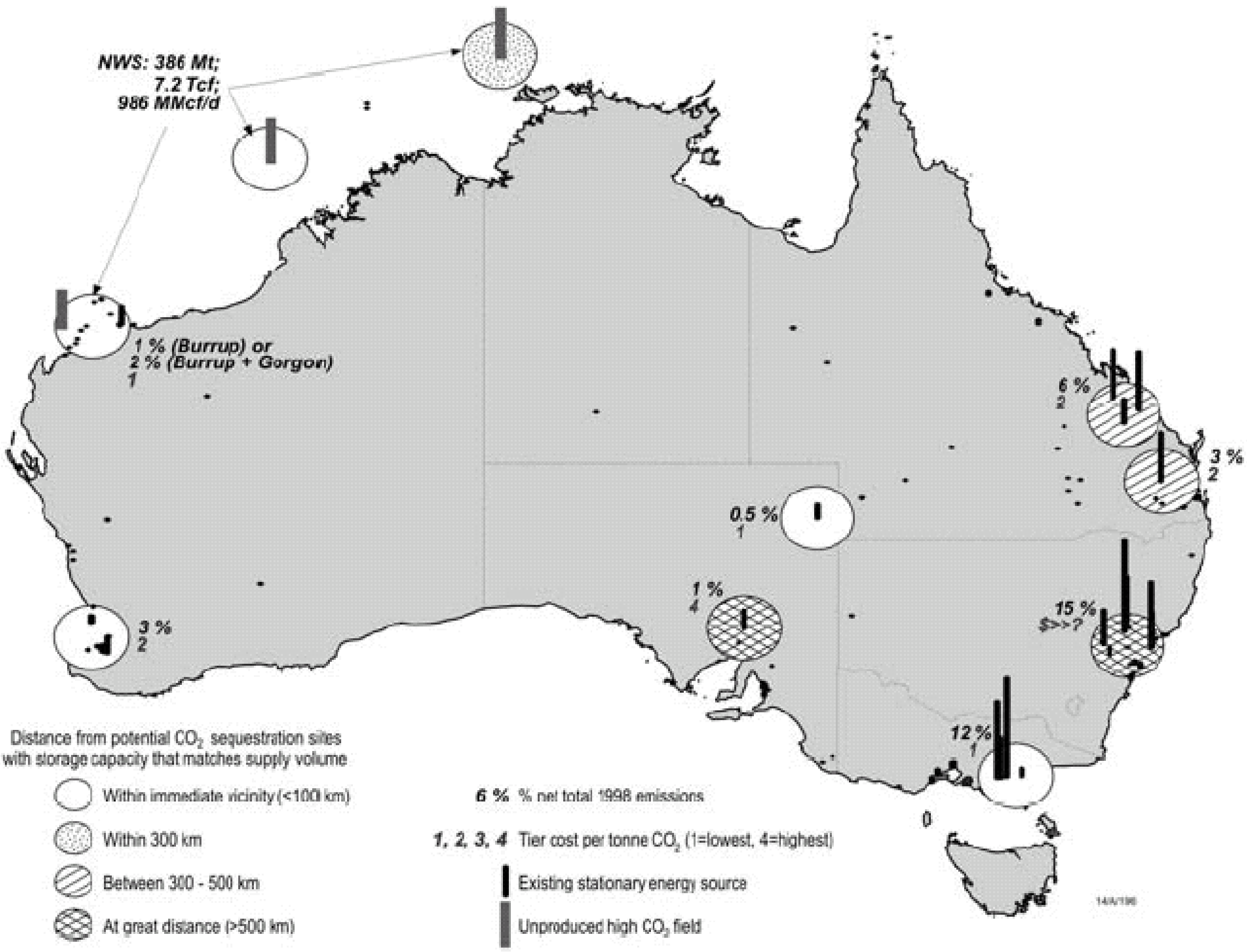

Figure 5. "Map of each major emission node, their relative emissions that could be sequestered compared to the net total 1998 CO_2 emissions, the distance to nearest viable geological sequestration site and an estimate of the cost based on a 4 tiered ranking." (taken from GEODISC, 2002b).

4.5 Comparison of Energy Abatement Options

'Beyond Kyoto' assesses the energy abatement opportunities for each of the technologies considered on the basis of:

- *potential to contribute large-scale emissions reductions, and.*
- *comparative costs of abatement.*

Large scale emissions reductions:

The report gives three scenarios of future emissions from the electricity sector where all future generating capacity is either conventional coal, gas CCGT or IGCC with geosequestration. From this, Beyond Kyoto concludes that "within the foreseeable future only carbon capture and geosequestration has the potential to radically reduce Australia's greenhouse signature" (p. 31). Also, "existing renewable alternatives can only be expected to make up a small proportion of the total energy mix in the near future.." (p. 30).

We believe that this analysis is flawed for several reasons. IGCC with geosequestration can hardly be expected to provide significant abatement in the near future because it has yet to be shown to be technically feasible. There are no such power stations yet in existence and while they are expected to be technically possible, there are considerable challenges still to be resolved.

By contrast, there is already widespread deployment of some renewable energy generation and energy efficiency technologies internationally. Denmark already gets nearly 20% of its electricity from wind, Germany will soon achieve 5%. These and other countries are also setting substantial '*new* renewables' energy generation targets for the near term (2010) including, for example, Germany with an +8% target, Spain with a +9.5% target and the UK with a +8.3% target. A number of US states have set similar or even greater targets including California, New Jersey and Nevada (BCSE, 2003). If achieved, these national renewable targets will greatly reduce greenhouse emissions from their electricity industries.

The potential scale of IGCC with geosequestration must also be considered. Some of Australia's major coal generation regions appear to have poor geosequestration potential.

A second flaw in the report's scenario analysis is its limited view of longer-term abatement possibilities. Amongst other commentators, there is broad consensus that approaches combining energy efficiency, cogeneration, renewable energy and low-emission fossil fuelled generation hold the greatest potential for large scale emission reductions.[25] *Beyond Kyoto* considers only IGCC with sequestration and gas CCGT futures.

Cost comparison:
It is important to compare the costs of different abatement technology options. As noted previously however, the cost estimates ($/MWh) for 'zero emissions coal' (Figure 11 in *Beyond Kyoto*) are not supported by reputable assessments of 'IGCC and sequestration' technologies.

The technology has yet to be demonstrated to be technically feasible so cost comparisons with established and commercially available technologies are premature. The assumed sequestration cost of around A$10/tCO2 is around one fifth of other authoritative estimates, as shown in Table 2 and Figure 6.

Finally, some key abatement options are missing from the cost comparisons altogether. Demand-side abatement (DSA) is generally agreed to offer some of the lowest cost abatement options. DSA technologies may offer direct cost savings more than sufficient to pay for their implementation and therefore have negative abatement cost.

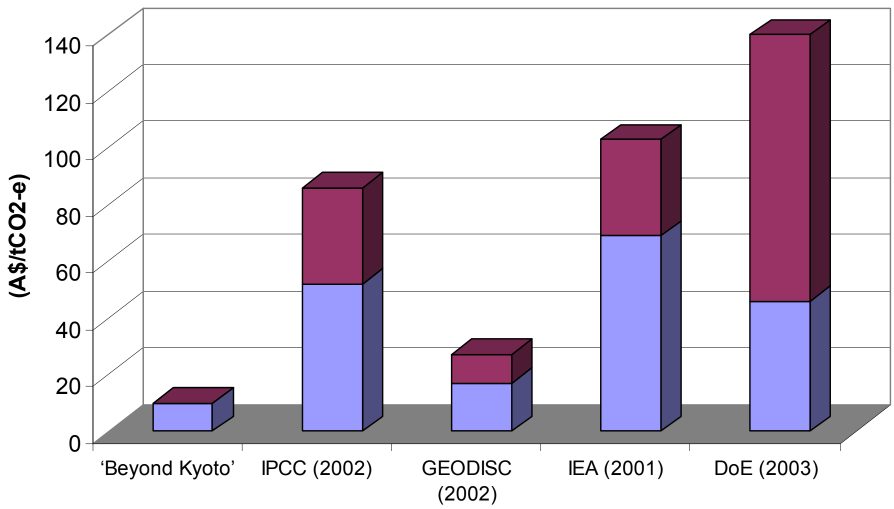

Figure 6. Estimated abatement costs (A$/tCO2) for CO2 capture and geosequestration from coal fired electricity generation from studies in Table 2. The uncertainty rage in these estimates is also shown. Note that the GEODISC estimate does not include CO2 capture.

[25] See for example the IPCC (2001) Third Assessment Report.

Table 2. Estimated abatement costs (A$/tCO2) for CO2 capture and sequestration from coal-fired electricity generation from a number of different studies.

Study	Estimated abatement costs for coal power plants with geosequestration (A$/tCO2)
IPCC (2001)	$52-86
GEODISC (2002)	$17-27 (not including capture)
IEA (2001)	$69-103
DoE (2003)	$46-140
Beyond Kyoto	**$10**

4.6 Beyond Kyoto *recommendations*

The ‘Beyond Kyoto’ report’s recommendations for action in the stationary energy sector are driven by the conclusion that of the available abatement options “… the production of electricity using coal gasification and sequestration of CO2 in geological structures appears to offer the best chance of large scale GHG mitigation.” (p. 1).

The report recommendations are:

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

We welcome the recommendation to identify energy options resulting in low greenhouse emissions as a national research priority. However we also need to improve our understanding of how innovation can invent and apply such options.

We also support the recommendation to accelerate the adoption by energy consumers of low energy use devices and processes and the use of cost effective alternative energy sources. Again, the challenge is in how this should be achieved.

Considerable work is being undertaken to answer the question of how new energy technologies can be successfully introduced into the marketplace, and to better understand R&D and deployment, market barriers and market transformation (IEA, 2003). This analysis could be of great assistance in exploring the possible roles on innovation in effective longer-term climate action. *Beyond Kyoto*, however, does not appear to have taken advantage of such work.

The most specific recommendations of *Beyond Kyoto* are the establishment of a national ‘near zero emissions coal generation’ development and demonstration program, and the need for market instruments to drive such low emission generation.

We would certainly agree with the IEA (2001) that “In view of the many uncertainties about the course of climate change, further development of CO_2 capture and storage technologies is a prudent precautionary action.”

However, this should be only one part of a broad innovation based program to create and further develop a range of abatement technologies for the medium to longer term. This broader view is missing from *Beyond Kyoto*.

5 Discussion

We believe that the *Beyond Kyoto* report has important strengths. It recognises the growing risks that climate change poses for Australia and our present status as one of the world's highest per-capita greenhouse emitters.

It establishes a target of reducing Australia's greenhouse emissions to 50% of present levels by 2100 and recognises the critical importance of the stationary energy sector in achieving such reductions. *Beyond Kyoto* argues the need for government to promote the major technical innovation in the stationary energy sector that will be required. It also makes a strong case that no more coal-fired generation should be built in Australia unless it incorporates CO2 capture and geosequestration.

However, *Beyond Kyoto* also has serious weaknesses. Its methodology for analysis seems weak. Its recommendations are either too general to be of practical application, or, in the case of zero emissions coal, extremely specific yet not supported by the evidence.

Beyond Kyoto places extraordinary emphasis on geosequestration as Australia's key emission reduction strategy and, in doing so, ignores the fact that the safest way to sequester carbon is to leave fossil fuels in the ground. The report therefore undervalues the crucial role of end-use energy efficiency, distributed generation and renewable energy in a prudent response to climate change.

It also relies on cost estimates for CO2 geosequestration that are substantially lower than those in other studies and fails to consider other environmental impacts or social values.

By attempting to pick a winner in this way, *Beyond Kyoto* actually flies in the face of stated energy sector policy restructuring objectives aimed at implementing a 'level playing field' for all the technical options that might help meet desired societal outcomes.

To maximise the benefits while minimising the costs and risks of our climate change response, geosequestration should be only one of a broad range of options supported by a coherent innovation strategy. This strategy should be carefully integrated within a wider policy framework for climate change and energy, and be compatible with a competitive stationary energy sector.

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