Assessing Australia's Sustainable Energy Technology Options: Key Issues, Uncertainties, Priorities and Potential Choices*

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Abstract

Avoiding dangerous climate change will almost certainly require that we achieve large, rapid and sustained reductions in greenhouse emissions from our energy systems. This paper explores some of the key issues, associated uncertainties, priorities, choices and, finally, associated policy implications associated with Australia's different sustainable energy options for achieving such reductions. It presents a possible technology assessment framework for assessing these options that focuses critically on their technical status and hence associated uncertainties in terms of costs, benefits, potential scale and speed of deployment. The limitations of technology assessments undertaken in the Australian context to date are highlighted and the key role of existing energy efficiency, renewable energy and lower-emission fossil fuel technologies discussed. Finally, the paper considers the policy implications of this assessment focusing on the need to implement proven policy measures that have demonstrated success in driving early uptake of these key abatement technologies.

Key words

Climate change, Technology assessment, Scenario studies, Climate and energy policy

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Introduction: New Challenges for Our Fossil-Fuelled World

Fossil fuels — coal, oil and gas — currently dominate the global energy mix providing some 80 per cent of commercial energy supply. Current Business-As-Usual projections suggest little change in the decades to come.[1] The reason is largely one of economics: these fossil-fuels represent relatively low-cost, energy dense, flexible and hence highly convenient energy resources by comparison with present alternatives — renewable energy sources and nuclear power. The last century has seen industrialised economies greatly shaped by the ready availability of these fossil fuels.

Two key sustainability drivers are now challenging this future. One is growing energy security concerns. Recent price increases in internationally traded oil, gas and, to a lesser extent, coal suggest tightening global supply/demand balances. Oil and gas pose particular regional energy security issues — oil due to high global demand and apparently limited supply concentrated in a relatively small number of countries, and gas which has significantly lower global demand and more diversely held reserves in countries around the world, yet is more difficult to transport being still highly reliant on pipeline infrastructure. Coal, by comparison, has far larger identified reserves than oil or gas and these reserves are distributed markedly differently across the world from those countries with oil and gas. In particular, some countries with high and growing energy demand have limited domestic oil and gas but major coal reserves. One outcome of growing energy security concerns is, therefore, renewed interest in coal within countries as diverse as China, the United Kingdom and the United States.[2]

The other driver is of course climate change. While debate continues on what might represent dangerous anthropogenic warming, there would appear to be some consensus of the need to stabilize atmospheric greenhouse gas concentrations so that the likely global temperature increase is no more than 2 °C above pre-industrial levels.[3] Note, however, that the climate change science continues to evolve and some scientists suggest 2 °C warming carries significant risks of runaway climate change.[4]

What is certain is that restricting warming to "manageable" levels is almost certain to require rapid, large and sustained reductions in global greenhouse emissions. Furthermore, the majority of these reductions will have to be achieved by reducing emissions associated with fossil-fuel use. For example, the IPCC suggests that

1 See, for example, IEA *World Energy Outlook* (International Energy Agency, Paris: 2007) 74.

2 Ibid, Chapter 4.

3 This question is discussed in the Working Group III report of the IPCC: *Fourth Assessment Report* (International Panel on Climate Change, Geneva: 2007), although the IPCC does not specifically advise on a particular global temperature target.

4 J. Hansen *Climate Tipping Points: The Threat to the Planet*, presentation at Illinois Wesleyan University, Bloomington, Ill, available at http://www.columbia.edu/~jeh1/ (accessed 20 February 2008).

maintaining global warming to 2.0-2.4 °C above pre-industrial levels will likely require atmospheric stabilisation of greenhouse gases in the atmosphere at 445-490 ppmCO2e. This in turn would seem to require global CO2 emissions to peak within the period 2000 – 2015 and then decline by 50 – 85 per cent (with respect to 2000 emission levels) by 2050.[5] Progress in our understanding of the climate science may well identify a need for even more drastic action. The work of Stern and others has highlighted that the costs of inaction are likely to be far higher than the costs of action.[6] Australia is a relatively small wealthy country considered likely to be particularly adversely impacted by climate change and yet with per-capita emissions more than doubled the average for the developed world, let alone the developing world.[7]

There is also a high price of delay in taking such action, with respect to the required speed and overall level of emission reductions then required. For example, a delay of 15 years in taking action might require emissions to then be reduced each year at four times the rate otherwise required to stabilise atmospheric greenhouse gas concentrations at a given level.[8] Such a delay also limits, and may indeed eliminate, opportunities for achieving lower atmospheric greenhouse gas levels should we later determine this will be required to avoid dangerous warming. The potential implications for a country like Australia are stark — effective global action on climate change seems likely to require near immediate emission reductions with significant reductions achieved within a decade.[9]

In this paper we explore some of the key issues, associated uncertainties, priorities, potential choices and, finally, associated policy implications associated with Australia's various sustainable energy options for achieving rapid and major emissions reductions. We first consider what options are available to us, in particular with respect to energy efficiency and lower carbon technologies for power, heat and transport. The paper then presents a possible technology assessment framework for assessing these options. Key aspects of this framework include the technical status of these options, their delivered benefits, present and possible future costs, potential scale of abatement, potential speed of deployment and wider societal outcomes. Such assessments have scientific, engineering, economic, commercial and social perspectives. We highlight the key role that technical status should play in assessing our sustainable energy options, and describe two dimensions of technical innovation relevant to understanding how emerging technologies can enter widespread

5 See IPCC, note 3 at 23.

6 See, for example, N. Stern *Review on the Economics of Climate Change* (UK Government, London: 2006).

7 I.F. MacGill and H.R. Outhred "Australian Climate Change Policy and its Implications for AP6 Countries" (2007) April *Proceedings of the China Energy Law International Symposium*, Beijing China.

8 See Stern, note 6 at xii.

9 For one of the most recent discussions of this point see R. Garnaut *Climate Change Review Interim Report* (Garnaut Climate Change Review, Canberra: 2008).

deployment. The paper then describes the technology assessments undertaken in the Australian context to date and highlights their limitations. It presents a preliminary high-level technology assessment of sustainable electrical energy options in the Australian context. Finally, we consider the potential policy implications of this assessment, and suggest key policy priorities for Australian governments.

More Sustainable Energy Options

Energy security and climate change concerns represent enormous challenges for our present fossil-fuel based energy systems. Recent price increases and geopolitical tensions have focussed considerable recent attention on energy security, however, climate change almost certainly has far greater implications than fossil-fuel related energy security issues for a sustainable energy future — present fossil-fuel usage and reserves appear more than adequate to seriously damage our climate systems.[10]

Climate change also has far greater uncertainties at present than does fossil-fuel energy security. Furthermore, while there are apparent synergies in some potential sustainable energy options with respect to both challenges, there are also potential conflicts to consider. For example, the use of coal for electricity and heat production is associated with significantly greater greenhouse gas emissions than the use of gas, yet coal reserves are significantly larger and more equally distributed around the world. In this paper we assess the ability of various energy options to help reduce greenhouse gas emissions, including:[11]

- Reducing demand for emissions-intensive goods and services; that is, energy conservation and frugality
- Increased efficiency; particularly end-use efficiency but also efficiency of energy supply and distribution
- Action on non-energy emissions; land-use, agriculture, waste and non-CO2 industrial emissions, and
- Switching to lower-carbon technologies for power, heat and transport; renewables, nuclear, natural gas-fired generation and cogeneration, and potentially Carbon Capture and Storage.

In this paper we focus on energy efficiency and lower-carbon energy technologies. Conservation and frugality are vitally important and may well hold the key to effective action on climate change. However, they have not yet been seriously addressed in policy debate and efforts to date. Non-energy emission reduction

10 Hansen, note 4.

11 These options are classified in many ways. Here we follow the approach taken by Stern, note 6.

options have a vital role to play, but can not substitute for effective emissions reductions within our energy systems. In Australia, for example, around 70 per cent of total estimated emissions are energy related.[12]

Assessing our Sustainable Energy Options

The wide range of energy-related abatement options exhibit diverse and complex characteristics. It is not immediately clear what their respective potential contribution might be, and which we should prioritise. Hence, there is an important need for formal assessment tools. Clearly such assessments must focus on the ability of these different options to contribute to large, rapid and sustained global emission reductions while maintaining energy security and other economic and social sustainability outcomes. Key assessment issues include:

- Technical status; from unproven to technically mature and from niche to widespread deployment
- Delivered benefits; greenhouse emission reductions of course yet also other characteristics including, for example, flexibility and dispatchability
- Present costs where known, and possible future costs
- Potential scale of deployment and hence emissions abatement; including possible physical, technical and cost constraints
- Potential speed of deployment; the time and effort required to achieve scale including possible technical and other constraints
- Other possible societal outcomes; for example other environmental impacts, energy security implications and issues of social acceptance.

There are clearly considerable uncertainties associated with many of these issues for many of our potential sustainable energy options. An appropriate technology assessment framework requires explicit and transparent management of associated risks, uncertainties and, to the extent possible, ambiguities.

It is increasingly accepted that the risks of dangerous global warming are higher than previously believed and that the direct and wider social costs of failing to effectively respond to climate change are likely to greatly exceed the costs of action. This highlights the importance of robust environmental effectiveness over economic efficiency, and suggests that the highest priority issues are those of delivering rapid and major emissions reductions rather than focusing on minimising the costs of abatement. Such emission reductions have to be robust against the many uncertainties in the assessment criteria noted above.

12 Australian Government *Tracking to the Kyoto Target* (Australian Greenhouse Office, Canberra: 2008).

Appropriate technology assessment frameworks also need to explicitly recognise the different perspectives involved in attempting to answer these criteria:

- Scientific; for example the impact of physical resource limits on potential scales of deployment
- Engineering with respect to our ability to develop socio-technical systems; for example, engineering limitations to the speed with which particular technology industries can grow
- Economic in the "social welfare" sense; for example the full and direct externality costs of different options
- Commercial; recognising the role of commercial market "settings" in driving individual decision making in areas such as technology innovation
- Societal including questions of social expectations and the various forms of governance required to deliver these including policy, mechanisms, measures and regulation; for example the social acceptability of nuclear power and the reflection of this in government policies.

It can be argued that scientific and engineering perspectives are particularly critical given the scale of the global warming crisis we face — they define key aspects of what is physically possible. The major emission reductions likely required to avoid dangerous global warming will also certainly require societal transformation, highlighting the key importance of achieving social consensus in support of such a transformation. In contrast, economic and commercial perspectives will to at least some extent emerge from our broader societal choices. These reductions will also certainly require societal transformation, highlighting the key importance of societal outcomes that support consensus of the need for such major changes.

The Key Role of "Technical Status" in Technology Assessment

Most of the key uncertainties in assessing possible sustainable energy options with respect to key issues and perspectives against options hinge on their technical status. A typical model of technical innovation includes stages of invention, through commercialisation onto potential widespread deployment and uptake. Another useful set of perspectives for technology innovation developed by IIASA distinguishes between technology:[13]

13 IIASA (International Institute for Applied Systems Analysis) What is Technology? at http://www.iiasa.ac.at/Research/TNT/WEB/Page10120/page10120.html?sb=5 (20 February 2008).

- Hardware; manufactured objects
- Software; knowledge required to design, manufacture and use technology hardware
- Orgware; institutions and rules for the generation of technological knowledge and for the use of technologies.

Technical status and, more generally, the technical innovation process has two key dimensions within these two perspectives:

- From technically unproven (for example, not yet demonstrated at scale or in an integrated manner) through to technically mature (considerable experience, fairly stable technical form and commercial products even if only in niche markets)
- From niche markets through to widespread deployment requiring a large and well established industry associated infrastructure and institutional capacity; ie. "orgware".

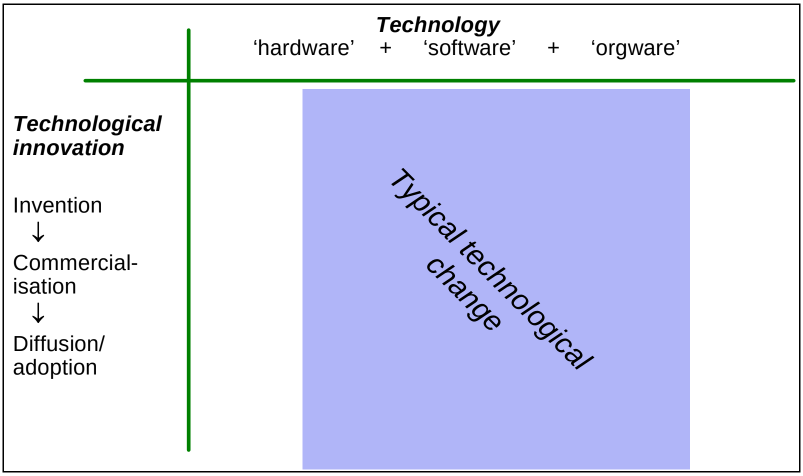


Figure 1. Two dimensions of major technological change.

For unproven technologies there can be little certainty in questions of potential scale of abatement, speed of deployment, costs and wider societal implications. For technically mature technologies that have only been deployed in niche markets there are likely to be remaining yet lesser uncertainties with respect to these questions. uncertainties related largely to "learning by doing" and other "orgware" issues. Engineering perspectives are particularly critical in terms of the times taken to take technologies from the laboratory through to demonstration and then commercial products, and in the ability to scale up manufacturing and deployment of commercial products. There are particular challenges in establishing the "orgware" — institutional capacities yet also social awareness and norms — necessary for widespread deployment of technologies.

These and other uncertainties represent key challenges in formulating a climate change response that is robust against unfortunate outcomes such as, for example, unforseen technical problems in carbon capture and storage or a nuclear accident at a civilian power plant. While some uncertainties may resolve to make problems less challenging than first believed, the key to policy making is to manage such downside risks.

Potential policy implications are explored later in this paper but clearly include the need to focus foremost on proven lower risk options because emerging options can not be relied upon to play a major role in the timeframe required for action. Furthermore, "orgware" or institutional and industrial capacity is vital to achieving the wide deployment of new sustainable energy technologies and can be supported through appropriate policy measures.

Technology Assessment of Key Sustainable Energy Options

One might expect that there would be a formal Government technology assessment framework in place to drive policy discussion and formulation. Certainly in the Australian context, one would be sadly mistaken. There are no formal, public and transparent technology assessments available that explicitly address these key issues of technical status, delivered benefits, costs, potential scale and speed of deployment and wider societal outcomes for all our sustainable energy options.

The Australian Government's Energy White Paper of 2004[14] included a brief technology assessment "outcome" table with respect to R&D and demonstration needs but provided no information on the underlying assessment. Government led reports into particular technologies have not generally presented formal technology assessments. These have ranged from the farcical such as the Prime Minister's Science, Engineering and Innovation Council report into Carbon Capture and Storage options[15] through to the detailed but questionable government directed report on Uranium Mining, Processing and Nuclear Energy Inquiry.[16] More reputable efforts have included the assessment established in the development of the National Framework for Energy Efficiency.[17]

14 Australian Government *Securing Australia's Energy Future* (Commonwealth Government, Canberra: 2004) 170.

15 PMSEIC *Beyond Kyoto – Innovation and Adaptation, Report to the PMSEIC Ninth Meeting* (Australian Government, Canberra: 2002).

16 UMPNER *Uranium Mining, Processing and Nuclear Energy – Opportunities for Australia?* (Uranium Mining, Processing and Nuclear Energy Review Commonwealth Government Canberra: 2006).

17 National Framework for Energy Efficiency at www.nfee.gov.au (20 February 2008).

Questions regarding the future of particular technologies are inherently questions of judgement. The challenge is to establish formal, transparent frameworks for establishing what the key issues are, and areas of agreement and disagreement within these. It is also necessary to have such assessments available for the range of options in order that comparisons can be made. In the absence of such work, in the public sphere anyway, a very high-level and preliminary technology assessment for Australian electricity industry abatement options is briefly outlined below in Table 1.

Key outcomes that it highlights include the very valuable role that energy efficiency can play in achieving rapid, major emission reductions. There is a wide range of well proven end-use energy technologies that enhance energy efficiency in comparison with standard options, they can offer improved energy services, many are already cost effective, their potential scale and speed of deployment is significant and they can offer wider social benefits including energy security and job creation.

A number of well proven yet still emerging renewable energy technologies such as wind and advanced biomass also offer significant abatement potential in the short to medium term. Direct costs are greater than conventional fossil-fuel options, however, these are falling. Australia has world class primary renewable resources and the renewable energy industry is growing in scale and capabilities.

Efficient Combined Cycle Gas Turbine (CCGT) generation is a well proven technology that produces less than half the greenhouse emissions of coal-fired generation. There are considerable, relatively low-cost, gas reserves available on the East Coast of Australia although longer term energy security questions have been raised. These technologies offer low cost abatement and could be rapidly deployed.

In contrast, Carbon Capture and Storage technologies in power generation have still not been demonstrated in an integrated manner or at scale. CCS should therefore be considered as a promising, but still somewhat unproven, option that potentially offers significant abatement potential and might allow the continued use of coal for electricity generation in Australia and around the world. There is currently considerable uncertainty regarding its likely effectiveness and safety and potential costs, scale and speed of deployment. In particular, it is likely to well over a decade or more before CCS can deliver significant emission reductions as the technology is proved up and then refined.[18]

Nuclear power in the Australian context has some similar characteristics. While nuclear power is a proven generation technology elsewhere in the world the new generation of power plants intended for the developed world are still being proven up. Australia also lacks the institutional framework, industrial capabilities and social acceptance that will be required for wide-scale uptake of the technology. It is also unlikely to offer significant abatement potential for well over a decade here.

18 I.F. MacGill, T. Daly and R. Passey "The Limited Role for Carbon Capture and Storage Technologies in a Sustainable Australian Energy Future" (2006) 63(4) *International Journal of Environmental Studies* 751–763.

	Technical status	Delivered benefits	Current + possible future costs	Potential scale of deployment	Potential speed of deployment	Other possible societal outcomes
Energy Efficiency	Many off-the-shelf high efficiency equipment + appliances available but not yet widely deployed. Considerable potential for technical progress	Large emission reductions where emissions-intensive energy supply, distributed benefits wrt networks etc	Many options offer net cost savings independent of abatement value	Potentially very large (Factor 4, Factor 10), but inherently limited + competing against economic growth	Some options can be rapidly deployed, others have longer capital stock turnover (eg. Building stock)	Very promising employment + investment opportunities. Low societal risks, generally no direct environmental impacts. **High energy security value**.
Renewables	Mix of very mature (eg. Hydro) established yet continuing to evolve (eg. Wind) and emerging (eg. Hot Rock).	Very secure CO2 abatement (as fossil fuels), some potential distributed benefits, intermittency issues for some technologies including wind	'new' biomass + wind costs generally falling but still significantly more expensive than conventional options, high uncertainty for emerging technologies	Most individual technologies limited by available fuel supply (hydro, biomass) or face important intermittency issues (wind, PV). In combination, however, potentially large. High present uncertainty for Hot Rocks.	Key technologies including Wind and PV growing fast from relatively small base and experiencing some supply constraints. Some other technologies still requiring successful demonstration	Promising employment + investment opportunities, including regional areas for many techs. Some env. impacts for some technologies – eg. biomass. Land-use issues for wind. **High energy security value**
Lower emission fossil-fuel technologies	Off-the-shelf CCGT and Cogen plants are widely deployed in some parts of the world – micro cogen technologies still emerging	Limited abatement with advanced coal generation but CCGT + cogen have < half emissions of coal, good fit with existing infrastructure, cogen offers distributed benefits	Costs of gas plant very dependent on gas prices – not cost competitive for baseload in Australia at present	Potential for CCGT driven by likely available gas supplies (possible issues in Eastern Australia although considerable potential to expand supply), CHP has high penetrations (40%) in some countries	Very fast for CCGT and fast for cogen – well established technologies backed by large industries	A range of direct air, water + land environmental impacts with fossil fuels. **Energy security a possible issue** with gas for many countries, coal with some countries

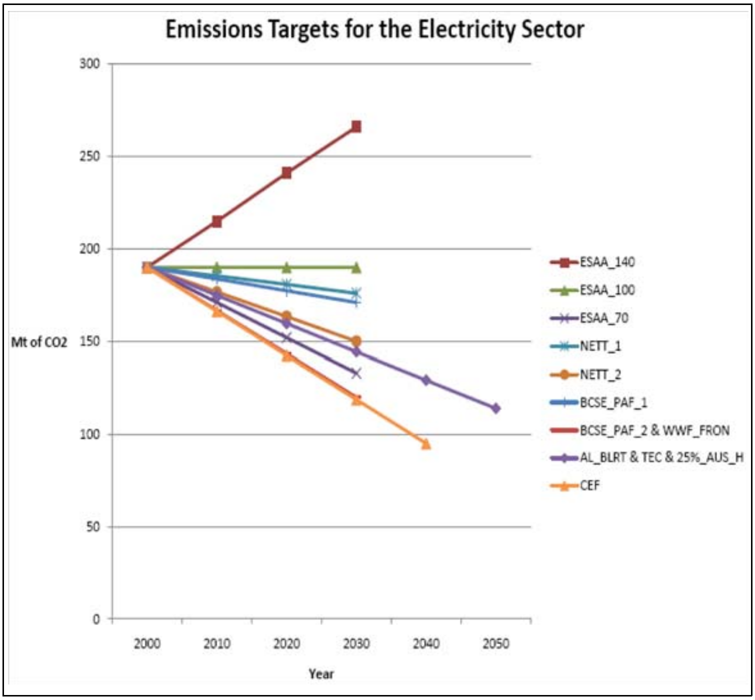
	Technical status	Delivered benefits	Current + possible future costs	Potential scale of deployment	Potential speed of deployment	Other possible societal outcomes
Energy Efficiency	Many off-the-shelf high efficiency equipment + appliances available but not yet widely deployed. Considerable potential for technical progress	Large emission reductions where emissions-intensive energy supply, distributed benefits wrt networks etc	Many options offer net cost savings independent of abatement value	Potentially very large (Factor 4, Factor 10), but inherently limited + competing against economic growth	Some options can be rapidly deployed, others have longer capital stock turnover (eg. Building stock)	Very promising employment + investment opportunities. Low societal risks, generally no direct environmental impacts. **High energy security value**.
Nuclear	Established Generation II plants however the Gen III designs proposed for much of the developed world are still being proven up – 'first of kind'	Reasonable fit with existing infrastructure – existing plants relatively inflexible operation	Very difficult to fully cost given externalities of safety + waste disposal. Emerging designs claim cost reductions….	Potentially very large but questions of longer-term uranium supply	Long lead and build times – unlikely in Australia before 2020. Requires major institutional capacity	**Fraught!**
Carbon Capture + Storage	Not yet demonstrated at scale and fully integrated for electricity generation – demonstration projects not yet implemented. Proving 'storage' will take time.	IGCC+CCS approx. 20% emission of conventional coal plant but long-term storage needs to be proved, reasonable fit with existing centralised infrastructure	CCS for electricity generation has highly uncertain + potentially variable costs depending on capture + sequestration. Some potential for cost reductions with learning	Potentially very large, although difficult to estimate given present uncertainties on long-term storage – particularly in saline aquifers & coal seams	Technologies for electricity generation still not demonstrated, institutional capacity and social acceptance still key issues	Direct env. risks from sudden or slow escape of CO_2 to atmosphere or ground waters. Coal an important contributor to Australian economy + offers high energy security

Table 1. A high-level preliminary technology assessment of our sustainable electrical energy options in the Australian context. Note that CCGT refers to Combined Cycle Gas Turbines; Cogen to Cogeneration or Combined Heat and Power (CHP) plants; IGCC to Integrated Gasification Combined Cycle Coal-fired plants, PV to photovoltaic systems; Hot Rock to non-conventional deep geothermal energy systems.

Scenario Studies of Sustainable Australian Energy Futures

While there are no public, transparent formal technology assessment frameworks for Australia along the lines outlined earlier, there is no shortage of scenario studies undertaken by organisations ranging from government agencies, energy industry associations, research groups such as CSIRO through to environmental groups. They consider a range of emission reductions over time-scales up to 2050. Such studies are invariably underpinned by a technology assessment encompassing at least some of the key issues raised above. Typically, however, there is relatively little transparency in what assumptions – technical, economic, commercial, social and policy related – have been made. Furthermore, the many uncertainties associated with these assumptions are generally poorly presented.

The transparency of assumptions involved in the Australian studies to date is mixed and, as shown in Figure 2, it is evident that the results of scenarios — even those with similar emission reduction targets and timeframes — can vary markedly with respect to questions such as the future role of renewables. As such, interpretation of presented scenario outcomes is difficult. In addition, there is widespread disagreement between studies and models in some cases.



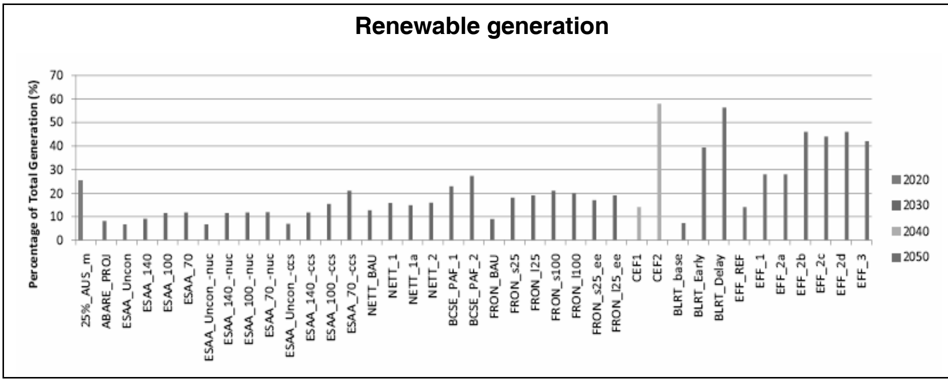


Figure 2. A comparison of some recent Australian energy "futures" studies showing their future emission trajectories and projected contribution of renewable energy to the electricity generation mix.[19] It includes Scenarios from the Australian Bureau of Agricultural and Resource Economics (ABARE), Energy Supply Association of Australia (ESAA), National Emissions Trading Taskforce (NETT), Business Council for Sustainable Energy (BCSE), Frontier Economics, Business Leaders Round Table (BLRT) and CSIRO led Energy Futures Forum (EFF).

The scenarios range from Business-As-Usual (BAU) through to relatively significant emission cuts and show wide disagreement on the respective potential roles of energy efficiency, gas generation, renewables, CCS and nuclear. No current publicly available scenarios in Australia explore the implications of emissions reductions of the scale and speed likely required for Australia to play its appropriate role in avoiding dangerous climate change. Their value is also limited by the generally non-transparent technology assessment underlying the scenarios.

In the global context, some of the most valuable modelling work is that presented in the IPCC WGIII Fourth Assessment Report which presents scenarios from four models of global energy futures to 2030 and 2100 under different emission reduction targets. The results for 2030 are far more relevant for policy and highlight that energy efficiency, renewables and lower emission fossil fuels are likely to make a far greater contribution to emission reductions over the next 25 years that emerging carbon capture and storage technologies or nuclear power.

Another important study is that undertaken by WWF in 2007.[20] This study addresses a relatively narrow question of the technical feasibility of meeting growing global energy demand using sustainable energy technologies that will protect the

19 K. Morris *An Assessment of Australian Energy Scenarios* (UNSW School of Electrical Engineering Fourth Year Thesis, Sydney: 2007) 82.

20 WWF *Climate Solutions – WWF's Vision for 2050* (World Wildlife Fund Gland: 2007).

global climate. The model does not assume technology costs or a carbon price — the costs of dangerous climate change are assumed to far exceed the costs of avoiding it. Instead, it focuses on key questions of the physical resources, the capacity of the technologies themselves and the rate of industrial transitions. Uncertainties are explicitly modelled. The results suggest that there is a reasonable chance of success however physical and engineering constraints, regardless of a carbon price or other policy measures, limit the rate at which emissions can be bought down and that some overshoot of emissions may be inevitable.

Policy Implications

Energy and climate policy-making must manage the inherent uncertainties regarding both the problem and our options for solving it. The process is currently hampered by a lack of public, transparent and consultative technology assessments on a global, regional and, certainly in the Australian context, national scale. Existing scenario studies often ask the wrong questions, make questionable assumptions, conceal uncertainties and therefore provide only limited policy guidance. There is an urgent need for a transparent, public technology assessment to be undertaken for the Australian context with a process by which the necessary judgements involved in such an exercise can be explored by different stakeholders. This then needs to be input into scenario studies that model the emissions reductions now seen as likely required to avoid dangerous global warming, and allow exploration of key uncertainties and sensitivities in determining our policy response.

More general principles that might also better guide policy efforts include:

- What exists is possible; existing off-the-shelf energy efficiency, gas and renewable options have demonstrated capabilities in reducing emissions at reasonably understood costs
- What does not yet exist may or may not be possible, and while these options should be pursued they shouldn't be relied upon — for example, a strategy of waiting for carbon capture and storage technologies to be developed before taking serious action on climate change has very high risks
- It takes time to bring technologies from the laboratory to commercial products — additional money can shorten but generally can't eliminate such delays
- It takes further time to develop the industrial, infrastructure and institutional capacities that take technologies from niche applications to widespread deployment. Policies that support development of appropriate sustainable energy "orgware" have a vital role to play.

The key policy priority is not to develop new technologies but bring existing options — energy efficiency, lower emission fossil fuels and renewables — into widespread deployment through rapid development of the necessary industrial, infrastructure and institutional capabilities.

With respect to CCS and other emerging options such as "hot rocks", and nuclear power in the Australian context, we need to deploy existing options to buy these options time to be proven up (or otherwise) and for the necessary industrial, infrastructure and institutional capacities to be established. The key for CCS progress are the current demonstration proposals and the current delays in implementing these projects in Australia and worldwide is greatly damaging CCS's potential role in protecting the climate.

International and national policy efforts to date have not come close to the scale of the challenge that we face. There is only limited experience and even less success to date on determining what policies will work most effectively to drive such transformations. With climate change, the necessary change must be driven against a well established, existing energy infrastructure with low direct costs and considerable private benefits — a very different challenge from that seen with technical transformations in areas such as IT where new technologies offer additional end-user value.

There are some interesting parallels between the risks of novel technologies and novel policies in tacking climate change. For instance, there should be greater focus on existing proven policy approaches, and greater acknowledgement of the risks associated with using novel policy approaches whose effectiveness has not yet been demonstrated, and for which it will take time to build up our understanding and institutional capacity to implement.

Some climate and energy policy successes to date include Mandatory Energy Performance Standards (MEPS) in countries including Australia and the development of the renewable energy industry in Europe, and now a growing number of countries around the world. Arguably some key policy failures to date have been in the use of emissions trading such as seen with the EU ETS and, within Australia, the NSW Greenhouse Gas Reduction Scheme.[21] Carbon pricing through emissions trading is still a somewhat experimental approach and evidence to date suggests it should not be relied upon to play the primary role in energy and climate policy.

21 See, for example, I.F. MacGill, H.R. Outhred and K. Nolles "Some design lessons from market-based greenhouse regulation in the restructured Australian electricity industry" (2006) 34(1) *Energy Policy* 11–25 and R. Betz and M. Sato "Emissions trading: Lessons Learnt from the 1st Phase of EU ETS and Prospects for the 2nd Phase" (2006) 6 *Climate Policy* 351–359.

Some key examples of such transitions in the recent past include the oil shocks of the 1970s and World War II. The latter, in particular, has highlighted the potential for very rapid industrial, institutional and social transformations. The key to such transformations has generally been seen to involve very significant government involvement rather than market-based approaches. In light of the climate change challenge we face, crisis management approaches are the most relevant guides for our policy makers.