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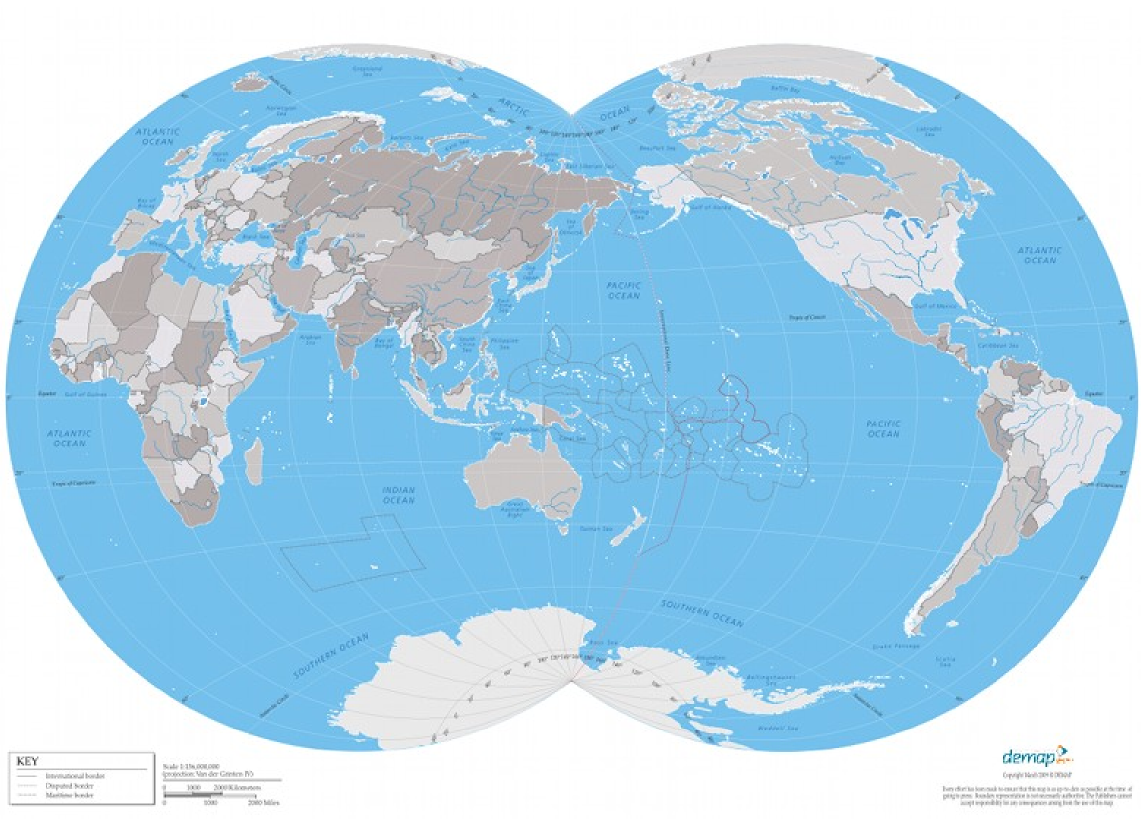
Energy security/insecurity and climate change in Australia



Hugh Saddler

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Synopsis

Hugh Saddler of Energy Strategies and the Australian National University defines energy security as a situation whereby "all users of energy services, whether they be householders, small businesses, large industries, or people or material goods moving from one place to another, should have access to supplies of energy that are sufficient, reliable, and in the correct form to meet their needs at a price that reflects the full resource, environmental and social costs of doing so." Saddler argues that "significant impacts on energy security are likely to arise from implementation of the changes that will be required to move to a low emission energy system." Saddler concludes that the high levels of energy security in the transition to a low emission electricity system will derive from a strategy that "will make use of large numbers of widely distributed energy generators, using a diversity of renewable and natural gas based generation technologies, and place very strong emphasis on increasing energy efficiency."

About the Author

Hugh Saddler is the founder and Managing Director of the Canberra consulting firm Energy Strategies. He is the author of a book on Australian energy policy, 'Energy in Australia' and over 50 scientific papers, monographs and articles on energy technology and environmental policy, and is recognised as one of Australia's leading experts in this field. He is currently a member of the Experts Group on Emissions Trading, appointed by the Australian Greenhouse Office, of the ABS Environmental Statistics Advisory Group, and of the ACT Environment Advisory Committee. His recent work includes Clean coal and other greenhouse myths, (with George Wilkenfeld and Clive Hamilton), Research Paper No. 49, The Australia Institute, August 2007.

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Hugh Saddler, Energy Strategies Pty Ltd

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1. What is energy security?

The phrase "energy security" came into widespread currency nearly thirty five years ago, in the aftermath of the First Oil Shock. In late 1973 the major oil exporting countries took control over production, export and pricing of the oil they produced from the US and European domiciled global oil companies which had controlled the industry until that time. The immediate consequence was selective supply embargoes, lifted within a few months, and a quadrupling of the global price of crude oil, which persisted.

Since then, the term "energy security" has been used in many different ways to justify and explain many different policies and actions by governments, corporations and individuals.

Nevertheless, despite their many differences, the various usages of the term "energy security" almost all have one common feature: they are concerned with the supply of energy to meet a largely unconsidered and unexamined demand. This can be clearly seen in the energy policy White Paper released by the Howard Government in June

2004 under the title Securing Australia's Energy Future. This document devoted its first five chapters to discussions of “developing Australia’s energy resources” and “meeting Australia’s energy needs”. Energy demand is not examined until the sixth chapter, dealing with energy efficiency. The White Paper also has a chapter on energy security, which it defines as “ensuring that consumers have reliable, competitively priced supplies of energy” (p. 116).

This supply dominated perception of energy security is seen at its most egregious in the attitudes of most US policy makers and, one presumes, the majority of US citizens, to the usage of petroleum fuels for road transport. These attitudes have led to levels of per capita consumption of petroleum much higher than in any comparable country and to a dependence on imported oil that is seen to be strategically debilitating for a superpower. Energy security, from this perspective, means giving policy primacy to the quest for additional sources of supply, with scant regard for the other consequences of doing so. Pursuing energy security in this way has resulted, on the part of the USA, in foreign and strategic policies that damage its own long term interest and are often disruptive to the rest of the world. It has also meant ignoring environmental damage, such as that likely to result from oil production in environmentally sensitive coastal waters or polar seas, and the environmental consequences of producing petroleum fuels from such resources as tar sands and oil shale.

It is no less a mistake for Australia to define energy security in such exclusively supply side terms, even though the unfortunate consequences of doing so are less global in scope than when the mistake is made by the USA or, for that matter, China.

Defining energy security in terms of the supply of energy resources is but one manifestation, albeit a very important one, of a more general feature of most public debate on energy policy. This is to focus almost entirely on the supply side of the energy demand and supply system – what may be called supply side bias. Some participants in the policy debate engage in lengthy discussions over what to do about the supply of petroleum, or electricity, or natural gas; others advocate one or more of a wide variety of new or different energy sources and technologies as the solution to Australia’s energy problems. All give little more than a perfunctory nod, either in opening or closing, to the demand for energy.

The reasons for supply-side bias are understandable. Intellectually, it makes a convenient conceptual framework for a large volume of technical, economic, environmental and social information. Institutionally, it reflects current organisational structures; energy supply is provided by a relatively small number of specialist businesses, some of which are very large and powerful, while demand for energy comes from every business and every consumer. Decisions affecting supply are thus highly concentrated and relatively easy to see and understand, while decisions affecting demand are highly diffuse and correspondingly difficult to see and understand.

Supply-side bias is, however, mistaken at the level of the most basic economic principle. Supply exists to meet demand, not vice versa. Policy and planning processes which ignore demand and consider only supply of any commodity or service are certain to result in economic inefficiency and waste, as the failure of Central Planning in the former Soviet Union so clearly showed. In the case of energy, supply-side biased policy and planning have demonstrably led also to thermodynamic inefficiency, excessive consumption of fossil fuels, and global environmental damage.

For these reasons I believe the issue of energy security should be examined from the perspective of energy users. This requires firstly that demand be defined in terms, not of particular sources of energy (fuels) but of energy services. An energy service is what using energy provides. Examples of energy services include hot water, heat for cooking, and sources of light in homes, steam and heat to drive industrial processes in industry, ventilation, cooling and the means to power electronic equipment in offices, and the energy required to transport people and material goods from one place to another at acceptable speeds and levels of comfort.

This paper defines as meaning that all users of energy services, whether they be householders, small businesses, large industries, or people or material goods moving from one place to another, should have access to supplies of energy that are sufficient, reliable, and in the correct form to meet their needs at a price that reflects the full resource, environmental and social costs of doing so.

In order to understand what such a definition may mean in practice for Australia, it is first necessary to understand energy demand, that is, how much energy is used in Australia and what it is used for. It is then necessary to know how demand is currently supplied. Taken together, this means knowing what the Australian energy system is.

2. Australian energy demand and supply

Energy use statistics normally categorise energy use by either the type of fuel being used or by the sector of the economy in which use is occurring. While both are useful and necessary for some purposes, they are far from ideal for understanding the energy system as a whole. A better understanding is provided by a categorisation that takes a more engineering or thermodynamic approach, more closely related to the type of activity for which energy is used. The following description of Australian energy use is based on the official national energy supply and demand statistics, published by the Australian Bureau of Agricultural and Resource Economics (2008). The data has then been re-arranged, to allocate energy use to one of three categories: mechanical drive (motive power) for mobile equipment, heat and electricity. The process of re-arranging required some generalised assumptions to be made and involved a measure of professional judgement. Nevertheless, it is considered to give an adequately accurate representation of how energy is used in Australia. A short description of the process can be provided on request.

The definitions of the three categories are as follows.

- Mechanical drive (motive power) used in all types of mobile equipment. This is distinguished from motive power used in stationary applications because of the different requirements on potential energy supply sources.
- Thermal or heat is self-explanatory, but it takes different forms (temperatures), which is usually very important in determining the best sources of energy and options to increase the efficiency with which the energy source is used to provide the required heat..

- Electricity is a special case in that it is both a form of energy which is unique to some types of energy use, such as electronic devices, and is also a versatile energy carrier that can be used to provide mechanical drive and heat. Its major use is in electric motors that provide the motive power for an enormous diversity of non-mobile equipment with a flexibility and efficiency that other energy sources cannot match.

Figure 1 shows Australia's demand for energy by final energy consumers, in the three forms of mobile equipment, heat and electricity. The data are for 2004-05, but the proportions have not changed greatly since then. The allocation to the three categories is made by using the following assumptions about energy use by economic sector data.

- Mobile includes all transport energy, plus petroleum products used in the Agriculture, forestry and fishing, Mining and Construction sectors, where the overwhelming majority of petroleum products are used in internal combustion engines to power mobile machinery, such as tractors, dump trucks, and earth moving equipment.
- Thermal includes all other direct use of combustion fuels in final consumption. A smallish proportion of this energy is in fact used to provide motive power, being burnt in gas turbine engines, mainly at gas processing and chemical plants. It also includes solar water heating.
- Electricity includes all use of electricity, with the exception of an adjustment for the relatively small quantity used in mobile equipment (rail transport).

Figure 1: final energy consumption, 2004-05

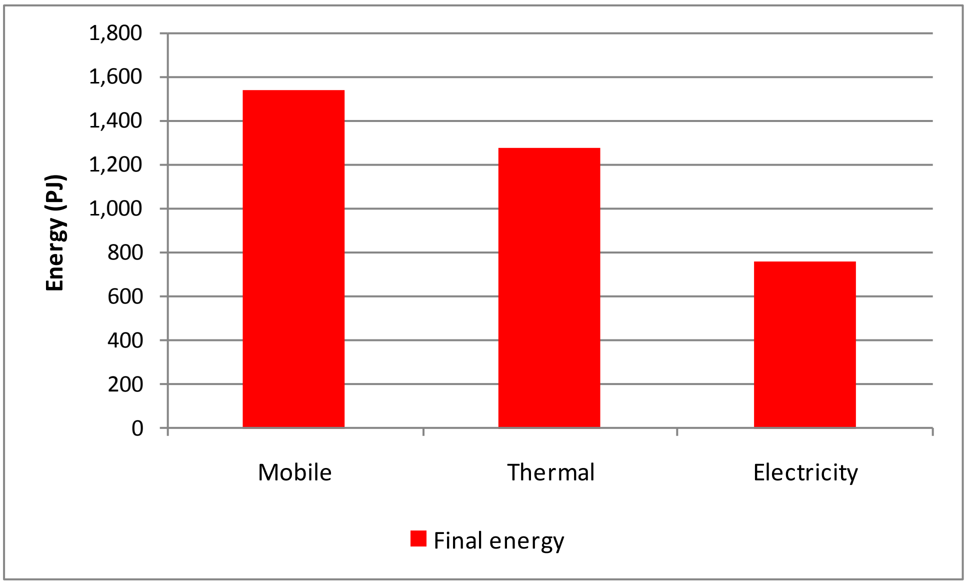
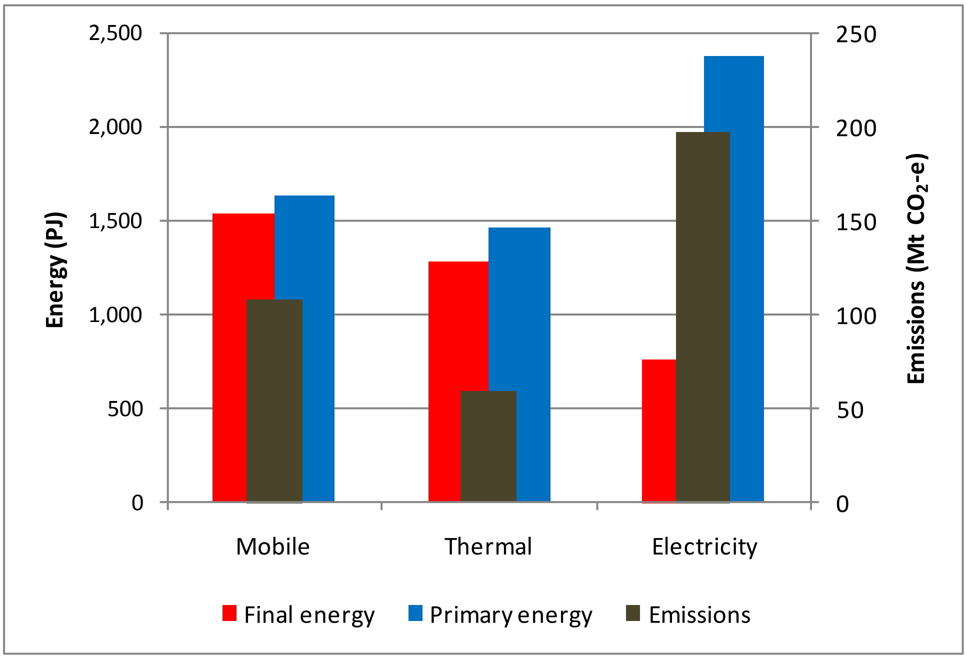


Figure 2 again shows final energy demand in these forms, and also shows the primary energy demand associated with each and the greenhouse gas emissions. Primary energy is the energy content of raw fuels, as extracted from the ground (in the case of fossil fuels) or harvested from the environment (in the case of renewable energy). The difference between primary and final energy is very large for electricity – this is an inherent consequence of the thermodynamics of electricity generation processes, combined with the quite significant own use and losses. The latter are about 7% of generated electricity for conventional coal fired electricity generation (plus another 7% in transmission and distribution losses), and will be much more for carbon capture and storage (CCS).

The difference between primary and final energy is much less for oil refining and gas processing than for electricity generation. However, these differences in processing losses of primary energy need to be offset against the different thermodynamic efficiencies of converting electrical energy to useful energy compared with the chemical energy in petroleum and natural gas to useful energy. These differences mean that measuring final energy demand for all fuels in the same energy units has the effect of understating the contribution that electricity makes to demand for useful energy. e.g. a modern electric railway locomotive is approximately 90% efficient at converting electrical energy to motive energy in the wheels on the rail, while for a diesel locomotive the ratio of energy on the rail to the energy content of diesel fuel is less than 30%.

Figure 2: final energy consumption, primary energy consumption , and emissions, 2004-05

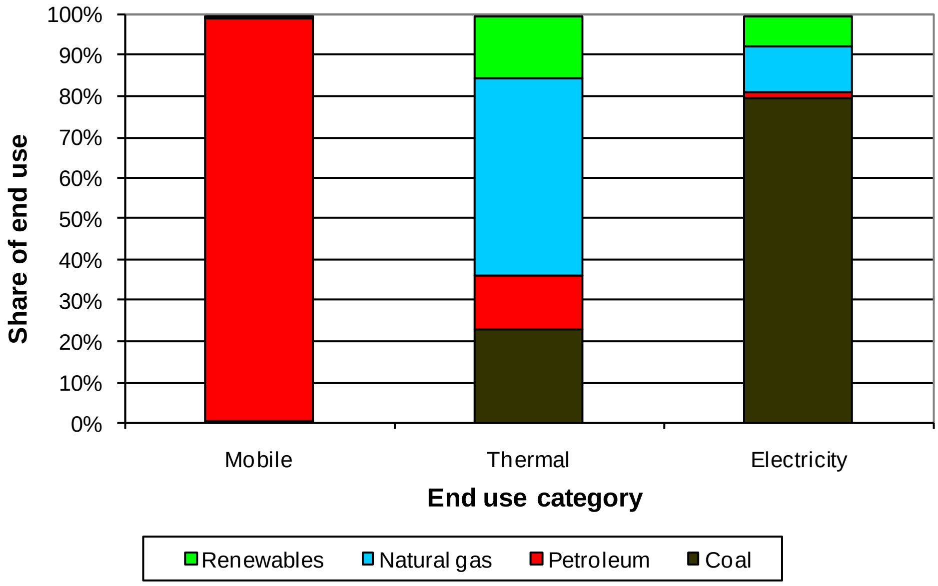


Emissions are determined by the quantity and type of primary fuel. Electricity consumption is the most emissions intensive because of its heavy use of coal as primary energy source. Thermal consumption requires the least quantity of primary fuel. Most thermal energy is provided by natural gas, plus also about 14% is fuel wood and bagasse (sugar cane residue), which, in emissions inventory terms, have zero CO_2 emissions (though low thermal efficiency). Mobile energy use is intermediate because

99% of the energy used by this category of final demand is supplied by petroleum products. These fuel relationships are shown in Figure 3.

The converse relationships between fuels and end uses is also of policy relevance, particularly in the case of petroleum. Transport uses 76% of all petroleum products (including LPG) used for energy in Australia. Other mobile equipment, as defined above, uses a further 13%, but is (or was) growing rapidly with the boom in mining. Thermal uses and electricity generation use only about 11%. Australia uses a smaller proportion of petroleum products in non-transport uses than almost any other country. This is why higher crude oil prices affect transport, agriculture, and mining, but have little direct effect on other sectors of the economy.

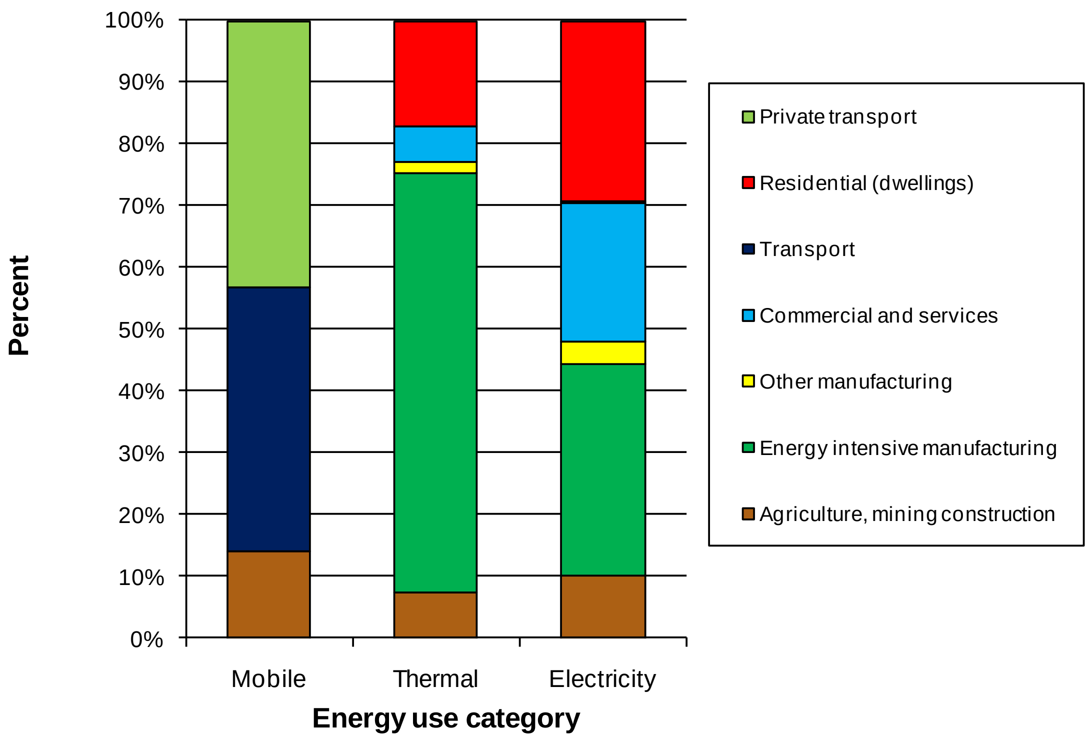
Figure 3: Final energy consumption by major primary fuel source, 2004-05



Figures 4 and 5 show key characteristics of energy use by seven major groups of energy users. The seven groups are:

- Agriculture, mining and construction
- Energy intensive manufacturing
- Other manufacturing
- Commercial and services
- Commercial transport
- Residential (dwellings)
- Private (car) transport

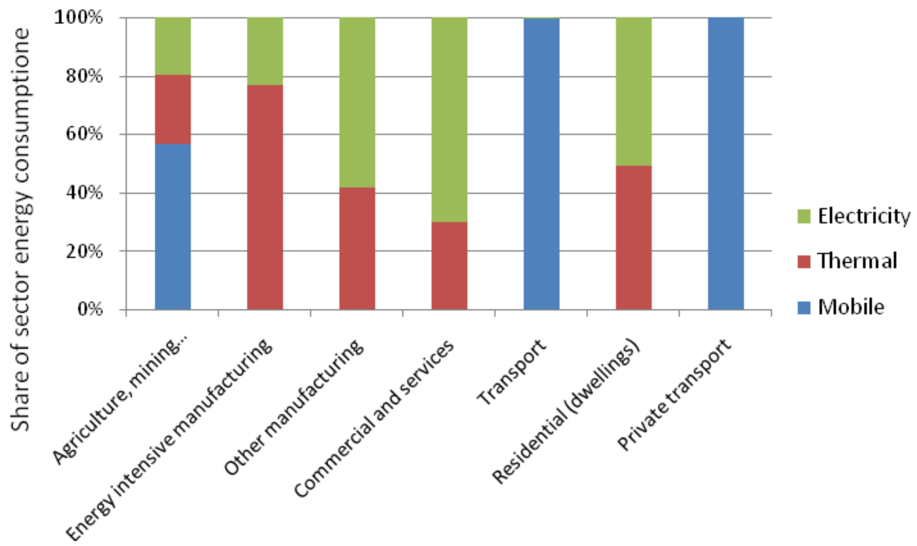
Figure 4: Sectoral shares of final energy consumption



Energy intensive manufacturing comprises what are often called the process industries, which undertake chemical and/or physical transformations of large quantities of raw materials derived from natural resources. They include production of iron and steel, alumina and aluminium, other non-ferrous metals, basic chemicals (bulk plastics and nitrogenous fertilisers), pulp and paper, cement, glass, bricks and tiles, and raw sugar.

Figure 5 shows the proportions of the three energy use categories used by each of these seven groups.

Figure 5: Energy type shares of sectoral energy consumption



Key points are:

- Commercial transport, including air, rail, shipping and road transport of both freight and passengers, uses almost exactly the same proportion of mobile equipment energy as private car transport, with agriculture, mining and construction using somewhat less.
- The majority of heat energy is used by energy intensive manufacturing, with a significant proportion also used in dwellings (the residential sector).
- The residential and services sectors combined use over half of all electricity, with energy intensive manufacturing using much of the remainder. The majority of electricity use in this latter sector comes from a single industry, aluminium smelting, which alone uses about 18% of national electricity consumption. In the services sector, the electricity share of total sectoral energy use is considerably higher than in any other sector (see Figure 9). Since electricity, being based on coal fired generation, is the most emissions intensive of all final consumption fuels, energy use in the services sector (and aluminium smelting) is more emissions intensive than other major sectors.

3. The Australian energy system

This paper uses the term energy system to specify the combination of physical and institutional structures covering the extraction, processing, transport, delivery and use of energy throughout the economy. In terms of physical infrastructure, this definition embraces not only the entire energy supply infrastructure, for all energy sources and fuel types, but also the entire stock of energy using equipment (including buildings) throughout the economy. In institutional terms, the definition embraces all the businesses, both government and privately owned, engaged in the extraction, processing and supply of energy, the various regulatory agencies, State and national, with responsibilities affecting energy supply businesses, and all those who make decisions about the purchase and use of energy.

Amongst the most important characteristics of the energy systems of all developed countries are their size and longevity, as expressed in terms of the value of the capital stock employed by the system, and the long operating lives of most parts of that stock. That applies not only to most of the capital equipment used in supplying energy, but also to much energy using equipment, such as buildings and industrial processing equipment, as well as the supply chains and production lines of motor vehicle manufacturers, which determine the types of vehicle they are able to make for some years into the future.

The consequence is that the energy system is characterised by great temporal inertia. How we use energy today, and how that energy is supply will be a major determinant of the main features of the energy system for the next several decades, even if there are strong market and/or regulatory pressures to change. In terms of physical structure, there are three major components of the electricity system:

- Power stations or generators convert other forms of energy into electrical energy; the conversion process is usually referred to as generation.
- Transmission is the process of transporting large quantities of electrical energy over long distances through wires at high voltage. The transmission network, often termed a grid, links major power stations to areas or regions with a large demand for electricity. In eastern Australia the grid extends from Cairns in the north east to Hobart in the south and Port Lincoln in the south west.
- Distribution is the process of transporting smaller quantities of electrical energy from the transmission grid to the premises of every customer.

It is not generally appreciated that, per kWh supplied to a consumer, more capital is invested in the network than in the generator or generators producing the electricity.

The operation of both the National Electricity Market and of the network businesses are governed by the National Electricity Law and the National Electricity Rules, an extraordinarily detailed and complex, and therefore very large, document.

The great majority of electricity supplied to the National Electricity Market (about 86%) is generated by about 14 large coal fired steam turbine power stations (and a few smaller ones), located close to the mines from which they obtain their coal.

There are many other types of generation which could be used n Australia:

- coal integrated gasification combined cycle (IGCC) – not currently used in Australia
- combined cycle gas turbine (CCGT) – used commercially in Australia
- open cycle gas turbine (OCGT) – used commercially in Australia
- gas or diesel reciprocating engine – used commercially in Australia
- biomass fuelled steam or IGCC – steam is currently used commercially in Australia
- nuclear – not used commercially in Australia
- hydro – used commercially in Australia
- wind – used commercially in Australia

- geothermal – not currently used commercially in Australia
- concentrating solar thermal – not currently used commercially in Australia
- photovoltaics – used commercially in Australia
- waves – not currently used commercially in Australia.

The physical system as a whole was built to allow electricity to be supplied outward from a small number of large generators. Electricity is intended to flow in one direction, from the central power stations to consumers. Rules were written to facilitate the perpetuation of this physical structure and this mode of operation, and to make it work with maximum efficiency. The Rules were written by the organisations then responsible for designing and operating this system. Virtually no consideration was given to alternative structures and modes of operation.

Whether, this can be explained by a failure of imagination and forethought, an unwillingness to change established ways of doing things, or a deliberate intention of protecting established economic interests and blocking new competitors, as some have claimed, is not particularly important. The Rules, and the way of thinking they embody, are a severe impediment to the emergence of an alternative structure of the electricity system

The petroleum system

Stages of the petroleum supply system are:

- production of crude oil and its transport, by ship or pipeline;
- refining of crude oil to convert it into a range of petroleum products, which have the required chemical and physical properties for a wide variety of different uses;
- distribution and retailing of petroleum products.

The petroleum system differs from the electricity system in a number of very important respects:

- there are competitive markets at all stages (though the capital costs of oil refineries present major barriers to the entry of new competitors);
- it is predominantly privately owned (with the exception of the state oil companies of major oil exporting countries); and
- most importantly, it is completely globalised, this being expressed most obviously in global crude oil prices that are so widely reported.

Australia is fully integrated into the world petroleum system. The prices of crude oil and petroleum products in Australia are much the same as in all other countries, when adjusted for differences in taxes and transport costs.

Australia is a net importer of crude oil and products – 52% of total final consumption in 2006-07. As we have seen, Australia has gone further than almost any other country towards replacing petroleum in all end uses except use in mobile equipment. But our transport, agriculture, mining and construction industries are extraordinarily dependent on petroleum, and our consumption of petroleum per capita and per dollar of GDP are both very high.

As a net importer of petroleum, Australia has no choice but to pay the world price, and depends for its supply on the security of the world petroleum system. It is also a net importer of equipment, and, perhaps more importantly, technologies used in mobile equipment. The design and production of cars, trucks, agricultural machinery, earth moving equipment, and other types of mobile equipment, are all global industries. Australia is therefore largely dependent on these global industries to develop options which would allow a shift to alternative fuels, such as hydrogen, and alternative types of engine, such as electric propulsion.

The gas system

The physical stages of the gas system are:

- production of raw gas;
- processing of raw gas to either pipeline quality gas or LNG for export;
- transport by either transmission pipeline or LNG ship;
- distribution through smaller pipes to final consumers.

The gas system resembles electricity in that:

- there is an interconnected transmission network across eastern Australia, which makes competition between alternative production sources possible;
- institutional structures separate the various stages;
- there is a separate competitive retail component which operates in much the same way as electricity retailing (and the same dominant companies);
- transmission and distribution are regulated natural monopolies.

Gas processing is energy and emissions intensive – the major gas processing plants, like power stations, are large point sources of greenhouse gases, though there are far fewer of them.

But gas can be exported from Australia (lack of close neighbouring countries precludes export of electricity) and Australia is a significant exporter of gas, as LNG. The world market for LNG is currently undergoing a major transformation. Until recently, international trade in LNG was based on a series of long term bilateral contracts between producers and consumers, and there was almost no spot market. Now, however, under the influence of a boom in global demand, gas is on the way to becoming a global commodity, like crude oil.

There can be no better example of this process at work than the recent series of deals between major international petroleum and gas companies and Australian companies with ownership of coal seam methane resources in Queensland.

4. First order effects of changing climate on the Australian energy system

Over the last few years the Commonwealth government has commissioned several studies of the potential effects of changing climate on infrastructure and urban systems, including energy systems. The Department of Climate Change (2008a), summarizing the outcomes of these studies, identifies the following impacts on the energy system.

> "Increases in temperature
>
> - "Increase in peak demand for electricity in summer. However, peak demand for winter heating is likely to decrease."
> - "Extreme temperatures are likely to have impacts on the production and transmission of energy. Higher temperatures are likely to affect the transmission efficiency of powerlines. Higher water temperatures (combined with reduced water availability) will result in decreased cooling capacity for thermo-electric power generation."
>
> "Altered frequency of extreme weather events
>
> - Increased incidences of disruptions to key services, such as electricity supply and transport."

A recently released study by the Australian Academy of Technological Sciences and Engineering (2008a) identifies the following potential threats to the electricity supply system.

> "The electricity production and distribution sector was identified as having a very high degree of vulnerability to climate change. This is particularly seen to be critical in the southern areas of Australia which are currently put under pressure from a combination of climatic factors which may occur simultaneously. For example:
>
> - drought affects the generation capacity by limiting hydroelectric power generation and the supply of cooling water for thermal plants;
> - high temperatures increase the demand while also reducing efficiency of generation and distribution; and
> - bushfires may interfere with distribution and interrupt communication." (p. 23)

The report goes on to say that

> "Other elements of the energy sector are less critical, but strategic planning for energy infrastructure is required by taking an integrated holistic approach for the provision and management of all elements of the system." (p. 24)

It is important to appreciate that these studies assume, explicitly or implicitly, a future energy system much like today's energy system, only bigger. A good description of what such a system will look like is provided by the "Reference case" developed by the Energy Futures Forum convened by the CSIRO (2006). In broad terms, this has the following changes occurring between now and 2040.

- Electricity demand doubles.
- The proportion of electricity generated from coal falls from the current level of about 80% to 67%.
- The proportion from natural gas rises from about 12% to 21%.
- The proportion from non-hydro renewables rises from about 1% to 2.5%.

- Road transport demand doubles.
- Petroleum products continue to supply virtually all the energy needed for transport.
- World crude oil prices "slowly decline from its present historically high levels in 2006 back towards its lower historical trend". It appears that this means declining from around US$80/bbl, equivalent to about A$100/bbl, at the time of the study to between US$40 and US$50/bbl.
- Australia's greenhouse gas emissions from energy to increase by about two thirds.

Compared with the changes to this system that will be required if Australia is to reduce its greenhouse gas emissions, described in the next section, the suggested effects of changing climate on the system are relatively minor.

Warmer average temperatures will certainly decrease the amount of energy required for space heating and increase the amount required for space cooling. Whether peak demands in either winter or summer also change will depend, however, on the temperatures reached on the coldest or hottest days each year. This is rather more difficult for climate models to predict. That quibble aside, the major effect of changes in peaks is on the economics of electricity supply. Because technologies for large scale, cost effective storage of electricity at the point of use do not exist, an electricity supply system must be built with sufficient capacity to meet peak demands. As demand becomes more "peaky", there is a growing need for investments in capacity that may be used for only a few hours each year. Until now, the cost of such under utilised capital assets has been largely met by overall increases in the price of electricity. With the wider installation of interval meters, it will become possible for electricity retailers to introduce time of use pricing, which should help, along with various technical innovations, to suppress peak demand. Irrespective of such developments, however, the issue is essentially one of electricity economics that are well understood and relatively straightforward to address, albeit with some increase in the cost of electricity supply.

Similarly, the effects of higher temperatures on the performance of electricity transmission and distribution systems are ones that can be addressed by building additional capacity. Lack of water for hydro-electric plants, for example, can be offset by using more gas fired generation, which can provide the same sort of quick response capability as hydro. This is in fact how the current shortfall from the Snowy and Tasmanian systems is being covered. Increased call on gas fired generation also covered the shortfall in coal fired generation caused by lack of cooling water at Queensland power stations in May and June 2007. Again, such additional gas fired capacity will not be needed at most times on most days of the year, and so will be under-utilised and costly. The same considerations apply to decreases in the cooling capacity of thermal power stations during very hot weather. This will reduce the efficiency and hence the effective capacity of affected power stations, meaning that additional, under-utilised generating capacity will be needed to meet the demand for electricity at such times.

The other effect identified – increased frequency of extreme events – will not have such straightforward economic implications on the electricity system. The highly centralised structure of the system makes for physical vulnerability, because of the dependence on a small number of strategic facilities. This was experienced by Victorian electricity consumers two summers ago, when a relatively small bushfire in the north east of the State put a key transmission line out of action, causing large numbers of consumers in Melbourne, and elsewhere, to lose supply. Increased frequency of high winds, floods and bushfires will bring with it a greater risk of similar supply disruptions. More capital investment to "strengthen" the supply infrastructure may be able to reduce but is unlikely to eliminate the increased risk of disruption.

It is very important to appreciate that all of the effects described here have one feature in common. – their impact on a highly centralized electricity supply system. An electricity system which was able to meet changing conditions, such as very high temperatures, by changing demand as well as supply, i.e. that was demand responsive, and that was less dependent on large, remotely located power stations and more dependent on distributed local generation, would be much less affected.

5. Changing to a low emission energy system

If Australia is to make significant reductions in its greenhouse gas emissions, it will have to drastically reduce its dependence on the combustion of fossil fuels to meet its energy requirements. Emissions from fuel combustion currently account for 63% of Australia's total emissions. Electricity used in Australia is amongst the most emissions intensive of any country because of the high proportion of coal in the total electricity generation mix. Consequently, the changes needed to reduce emissions, i.e. mitigation policies and programs, are likely to have a much greater impact on Australia's energy system than will climate change itself.

An excessive amount of discussion about low emission energy systems is devoted to arguments between advocates of different technologies, who are all too often inclined to see their pet technology as the solution to everything. In fact, there is a wealth of feasible technology choices. The more challenging issues are working out how to transition from our present energy system to a low emission system, and estimating what it will cost.

At the most general level, there is little or no argument that the two most important changes will be:

- to achieve great increases in energy efficiency, by both improving the efficiency of new equipment and appliances and upgrading existing buildings and facilities,
- to change the major source of electricity from conventional coal fired generation to low and zero emission generation options.

What will be the energy security implications of such changes?

Greater efficiency of energy use will mean that smaller quantities of energy will be required to meet a given level of energy services. This will mean that less energy has to be collected or extracted, processed and transported and therefore, all else being equal, the risks of disruption by the types of events described in the previous section will be less. An additional benefit will be that the many environmental impacts of the energy system, other than climate change, will also be reduced. Achieving large, economy-wide increases in energy efficiency will face difficulties and challenges, which may affect the speed and extent of improvements in energy efficiency achieved, but are not likely to affect energy security.

This may not be the case with the changes in energy supply.

Security relating to electricity

When it comes to options for changing the sources of electricity generation, Australia has an array of choices greater than almost any other country. Wind, concentrating solar thermal, photovoltaics, waves and, almost certainly, hot rock geothermal heat could all be used to supply large quantities of electricity. There is no technical reason why, within a few decades, Australia could not be sourcing half or more of its electricity from renewable sources. In addition, there are large resources of natural gas which can be used to provide low emission electricity. This is likely to make an important contribution to smoothing out the variability of some of the renewable resources, such as wind and solar radiation, either through co-firing at solar thermal plants, or through back-up OCGT plants, or both. Other natural gas technology options that are likely to be particularly important in the early decades of the transition to a low emission energy system include stand alone CCGT power stations and greater use of combined heat and power (CHP) plants (cogeneration – electricity plus heat, or trigeneration – electricity plus heat plus “coolth”) at industrial and commercial sites with sufficient demand for energy in all these forms. CHP is a very low emission technology because it greatly increases the thermodynamic efficiency of the conversion of the chemical energy in gas to useful energy in the form of heat and electricity.

A common feature of all these technologies is that they are smaller in scale than the existing very large, centralised coal fired power stations (and also smaller than any hypothetical nuclear power station). Electricity generation will be much more widely distributed and located much closer to where electricity is being used. With some technologies, such as photovoltaics and CHP, generation will be co-located with electricity use. The electricity system as a whole will therefore be more distributed and less centralised. The transmission grid will play less of an energy transport role and more of a demand and supply balancing role.

Apart from greatly reduced emissions, a distributed electricity system based on these technologies will provide many other benefits, including:

- increased security of supply for individual consumers, because of greatly reduced dependence on the integrity of the supply network over a wide area;
- alternatively, or in addition, reduced network operation and maintenance costs for achieving acceptable supply security, especially in more extended rural parts of networks;
- avoided capital costs of transmission and distribution capacity;
- increased security and reduced vulnerability to major disruption events, including climate related events, for the electricity supply system as a whole, because of the greatly increased number and diversity of generation sources.

Advocates of CCS and/or nuclear power implicitly reject this view of the future of the electricity supply system. These two technologies are based on an assumed continuation of the current centralised system (and in fact would involve more intense centralisation). If either or both of these were adopted as the future of electricity supply in Australia, the risks to energy security identified in the previous section would be undiminished, and would be augmented by further risks arising from heavy dependence on highly complex and unproven (in the case of nuclear, more precisely, immature) technologies. If commitment to these large scale supply options comes at the expense of a reduced commitment to energy efficiency, energy security will be further eroded.

The principal policy instrument by which the Commonwealth proposes to achieve the transition to a low emission energy system is the Carbon Pollution Reduction Scheme (CPRS). In its Green Paper (Department of Climate Change, 2008) the government acknowledges that there are energy security concerns relating to the introduction (a position strongly argued by businesses with interests in existing large coal fired generators). The main concerns are summarised in the following terms.

> "Increased risk for investors in the industry would increase the cost of energy, as new investments would require a return sufficient to cover a higher risk premium than previously, purely because of greater uncertainty about regulatory settings. In extreme cases, particular investments could be delayed or abandoned, potentially affecting energy security." (p.370)

A much more extreme version of this argument has been advanced by some industry representatives in media interviews, though not in formal written submissions. They have suggested that some generators, particularly Victorian brown coal generators, would be unable to recover the additional cost of emission permits in the market, would thereby become unprofitable, and would respond by shutting down, with severe implications for energy security. The Green Paper makes no reference to this argument, implying that it has not been considered in the proposed design of the CPRS.

What the Green Paper proposes, to address the risk to energy security arising from the more modest claim of increased investment risk in generation, is to provide direct financial assistance to generators with existing coal fired power stations through a proposed Electricity Sector Adjustment Scheme. By contrast, the Garnaut report (Garnaut, 2008) does not consider that the owners of generators should receive compensation. This position rests on a consideration of social equity. The report does not discuss the energy security arguments.

Security relating to other forms of energy use

Policy debate has given much less consideration to other forms of energy use. These present a greater policy challenge for the longer term, because the technical options are more limited on the supply side and in some cases also on the demand side.

For heat, the major source of energy is currently natural gas. Energy efficiency, including much increased use of CHP, offers great potential for reducing demand for low temperature heat, used for space heating and to produce industrial process steam.

There is probably less potential for energy efficiency, because appreciable improvements have already been made, in reducing the requirement of heat energy for high temperature (kiln and furnace) applications, such as the production of cement, glass, ceramics and steel. These industrial processes require very large quantities of concentrated heat energy, which fossil fuels are uniquely suited to supplying. In theory, renewable energy sources such as biomass or concentrated solar heat could be used for some of these processes, but they could not do so on the scale of modern production. The overall energy efficiency of these processes is intrinsically greater at large scale, so even if it were possible to revert to small scale production using renewable fuels, it would be at the expense of energy efficiency and much higher unit production costs. If society is going to have a continued requirement for these materials, the best source of the required energy will be natural gas.

Petroleum is currently almost the sole source of energy used by transport and other types of mobile equipment. The incentive to reduce consumption of petroleum is twofold, stemming not only from greenhouse gas emissions but also from the consequences of the very much higher prices which seem likely to prevail when global petroleum supply becomes permanently unable to meet potential demand, i.e. the time after so-called “peak oil”. Over the next few decades, electricity is a potential replacement energy source for small road transport vehicles, both directly by means of electric vehicles (for cars and light commercials), and indirectly through modal shift to rail transport.

For larger road vehicles and, especially for mining, agricultural and construction equipment, and also for shipping, electricity is not a technically feasible option. It appears to be not widely appreciated in Australia how dependent the mining and agricultural industries in particular are on diesel fuel.

Biofuels, specifically biodiesel, may be capable of supplying some of this requirement, provided that the environmental and social impacts of some may arise with biofuels production are avoided (see below). The reliable, year on year supply of raw materials for biofuel production may also be adversely affected by climate change that increases the frequency of droughts. Careful thought needs to be given to whether limited biofuel resources can most effectively contribute to long term, low emission national energy security.

Liquefied natural gas is perhaps a more universally applicable option, and it is already being used by some operators of heavy road freight vehicle fleets. The continuing long term availability of natural gas could be extremely important for mining in particular. In conclusion, therefore, the long term security of energy used to provide both heat and motive power to crucial sectors of the economy seems likely to depend on the availability of natural gas. Given that supply of electricity will also depend on increasing use of natural gas, at least over the next several decades, the availability of natural gas will have a crucial bearing on Australia’s energy security.

6. Australia in the world energy system

As will be clear from the preceding discussion, Australia is particularly well endowed with both fossil fuel and renewable energy resources. The sole exception is crude oil, of which Australia has relatively modest resources and production (0.6% of world production in 2007). Its natural resource endowment has enabled Australia to become a large net exporter of both coal and natural gas (in the form of LNG), and an exporter or uranium. It is, however, a net importer of crude oil and petroleum products. It is also heavily dependent on imports of technology and equipment used for electricity generation and transmission and the production of energy from renewable sources.

Petroleum

As with most other countries, Australia's first engagement with the world energy system was through imports of petroleum products and, later, crude oil. For over one hundred years, from the early 1860s to the mid 1960s, imports were the source of all Australia's consumption of petroleum products. Major discoveries in the late 1960s enabled Australia to achieve domestic production of crude oil equivalent to roughly two thirds of total consumption for the next three decades. Since 2000, however, new discoveries and production have not kept pace with the decline in output from older fields, so that domestic production now equates to just over half of consumption.

Australia is in fact more closely integrated to the world market for petroleum than these net proportions would suggest. A substantial proportion of domestic production is exported, for two main reasons:

- well over half of Australia's total production is from oil fields off the north west coast, which are as close or closer to the oil refineries of south east Asia than to Australian refineries;
- condensates and very light crudes account for a high proportion of total indigenous production and Australian refineries, like all other refineries, need a balance of light and heavier crudes, and so cannot absorb all Australian production.

Consequently, imported crude oil accounts for more than three quarters of the crude oil processed at Australian refineries. Most trade, both exports and imports, is with east and south east Asia. In the past three years Vietnam has been the largest single supplier of crude oil to Australia, with Indonesia and the UAE also important sources.

The table below summarises Australian petroleum trade with Indonesia. The importance of crude oil imports can be seen. A small proportion of Australian crude oil exports are also sent to Indonesia. Trade in petroleum products is negligible.

Table 1: Australian trade of crude oil and petroleum products with Indonesia, 2007-08 (ML)

	Crude oil	Petroleum products
Imports from Indonesia	3,216	11
Share of Australian total	12.3%	0.1%
Exports to Indonesia	425	6
Share of Australian total	2.7%	0.1%

Imports of crude oil are supplemented by significant net imports of petroleum products, currently equal to about 20% of total consumption, mainly from refineries in Singapore. Since 2003, when the Exxon-Mobil refinery in Adelaide was mothballed, Australia has been a structural net importer of petroleum products, meaning that indigenous refinery capacity is less than indigenous demand for petroleum products. Australian oil refineries are relatively small by world standards and have higher operating costs than many of the larger and more modern refineries in east and south east Asia, particularly Singapore.

It has therefore been argued that the additional costs of acquiring permits under the proposed CPRS may reduce profitability to the point where their owners decide to close them. The owners are the international oil majors Royal Dutch Shell (two refineries), BP (two refineries), Exxon Mobil (one refinery) and Chevron, which owns half of Caltex, the balance being a public company with multiple shareholders (two refineries). Refinery closures should have no significant effect on the cost of petroleum products to Australian consumers, since the wholesale price of petroleum products in Australia has for many years been referenced to the Singapore ex-refinery price. However, it would have implications for security of supply. Opinions differ on the significance of such a change to increased dependence on product imports. Its significance would also depend on the circumstances under which such a change occurred and on conditions in the world oil market at the time.

The physical and chemical properties of petroleum make it a uniquely versatile fuel, that is easier and cheaper to transport and to use than either solid or gaseous fuels. For these reasons, it has been an important commodity in international trade since the later decades of the 19^{th} century. It is now a completely global industry, into which Australia is fully integrated in terms of both physical supply and price. Hence Australia will be fully exposed to the consequences of “peak oil”.

The prospects of much higher world oil prices and the reduced indigenous supply of crude oil have stimulated a rash of supply side proposals that involve government support for alternative domestic fuel production technologies. Australia is certainly well endowed with the raw materials from which synthetic replacements for conventional petroleum products could be produced. A project to produce diesel from brown coal in the Latrobe Valley is being strongly supported by the Government of Victoria and the current Commonwealth Minister for Resources, Energy and Tourism has, in the past, been a vocal advocate of producing diesel from natural gas in WA (so-called gas-to-liquids plants). Advocates of making liquid fuels from the abundant resources of oil shale in Queensland are still to be found in that State, and perhaps elsewhere.

All these technologies suffer from the considerable drawback of requiring very large amounts of energy, mainly in the form of heat. Since the economics depend on sourcing this energy from the fossil carbonaceous material being processed (rather than, say, solar heat), producing these synthetic liquid fuels is far more greenhouse emissions intensive than producing conventional petroleum products. It is therefore very difficult to see how projects based on these technologies could proceed in a world that is seeking to reduce greenhouse gas emissions.

Emissions are possibly less of an obstacle to biofuels, including ethanol, which can substitute for petrol (gasoline), and biodiesel, though this is a matter of some dispute. These fuels may also have other environmental problems. The use of palm oil as a feedstock for biodiesel production, particularly in Europe has been strongly criticised because of the environmental impact (including enhanced greenhouse gas emissions) of palm oil production in Malaysia and Indonesia. (Australian Academy of Technological

Sciences and Engineering, 2008b). The one Australian biodiesel production facility that used palm oil is currently shut down (*ibid*.).

Much of the support for these technologies stems from the widely held, but erroneous, belief that they would help to protect Australian liquid fuel users from higher world oil prices. In a world in which conventional crude oil production was unable to keep pace with growth in potential demand, incremental supply from synthetic oil plants in Australia would be no more than a tiny addition to total world supply. This means that, unless Australia renounced its longstanding bipartisan political commitment to liberalised international trade and in particular maintenance of free international trade in commodities, including petroleum, by re-establishing the controls on crude oil exports that were removed in the late 1980s, increased indigenous output from whatever source would have no effect on petroleum prices in the domestic economy. There would be benefit to the balance of payments through reduced imports, and some increase in the physical security of supply of petroleum products, but this would only be important if the global oil market were severely disrupted..

Coal

Australia is the world's largest exporter of coal, supplying 37% of internationally traded coal in 2006 (ABARE, 2008b). For metallurgical coal, which commands a higher price than thermal coal, Australia supplied 55% of trade. During the last two or three years in particular, high prices received and increasing volume have meant that coal export revenues have been a major contributor to both Australia's balance of payments and tax revenue (through royalties and company tax) as well as to mining company profits. Indonesia is the second largest exporter, with exports in 2007 about half those of Australia. In recent years both its production and its exports have been growing somewhat faster than Australia's, in both relative and absolute terms.

It is important, however, to see Australia's coal exports in a full global perspective. Australia produced in total, including production for domestic consumption, only 7% of world coal (by energy content) in 2007 (BP, 2008). Internationally traded coal is only 10% of world consumption, so Australia's exports are equivalent to less than 4% of global consumption.

Confusion about the implications of an emissions pricing regime, such as emissions trading, on the Australian coal industry is widespread. Coal mining is not a particularly energy intensive process. On average, coal mining requires about 1% of the energy content of the coal produced, and the consequent emissions intensity is about 0.3 t CO_2-e per $thousand of production value, at average 2002-03 export coal prices (Saddler et al., 2006). Higher energy prices that would result from either a carbon tax or a permit price for emissions would therefore have only a minor impact on costs, and would certainly be much smaller than year to year variations in the prices exporters receive for their coal.

However, some, but not all coal measures contain significant quantities of methane which is released when the coal is mined, thereby adding to emissions if no action is taken to mitigate these releases. Most emissions come from a minority of mines which are classified as gassy underground mines. Although these account for less than 20% of production they would contribute, in the absence of mitigation, well over half of total emissions. Many of these mines have already implemented mitigation measures with publicly provided financial subsidies, available through two programs established by the previous Commonwealth government: the Greenhouse Gas Abatement Program and the Australian Coal Mine Methane Reduction Program. Experience with funded projects was that the marginal cost of abatement was in most cases quite low (less than $20 per tonne CO_2-e abated). Overall, therefore, coal mining, as an industry, should not suffer particularly large increases in operating costs as a result of the introduction of the CPRS and does not have a strong case for special transitional assistance.

The impact of higher operating costs is of course quite distinct from the impact of changes in demand, resulting from economy-wide introduction of a price on emissions. This impact could be large. Here, though, it is important to distinguish between production for domestic consumption and production for exports. Domestic demand for coal is now less than 20% of total production (in energy terms). Moreover, it is the low cost, low margin part of the industry, with most production coming from dedicated mines with limited opportunities for export (none at all in the case of Victorian brown coal), because of either low quality or lack of appropriate transport infrastructure or both.

The other 80% of the industry, depending on exports, is also vulnerable to changes in demand induced by changes in policy, but in this case on the part of the importing countries, not Australia. The industry is particularly exposed to changes in policy by Japan, which in 2007 was the destination for 44% of all coal exports. What is more, Japan took 53% of exports of thermal coal, which is used mainly to generate electricity and is thus most likely to be directly affected by emissions abatement polices. Australia’s exports of coking coal, mainly used to make steel, are more diversified, with Japan taking only 36% of the total. Other important export destinations are South Korea and Taiwan, both mainly thermal coal, and India, mainly coking coal. Trade with Indonesia is negligible.

The overall conclusion is that domestic energy and emissions reduction policies may have a severe impact on the 20% of the coal mining industry serving domestic demand, but should have little impact on the remaining 80% of the industry supplying export markets. This part of the industry is, however, vulnerable to the effects of policies implemented by countries to which Australia exports, particularly Japan.

A final comment about carbon capture and sequestration is also relevant. In 2007, metallurgical coal accounted for 54% of Australia’s coal exports. Virtually all the research and development work on CCS, however, is directed at capturing CO_2 at power stations, i.e. capturing CO_2 produced from using thermal, not metallurgical coal. There has been virtually no consideration, at least in Australia, given to the possibility of capturing CO_2 at steelworks. This distinction may account for the apparent lack of enthusiasm, on the part of the major coal exporting companies, for providing financial support for CCS. It should also be borne in mind when considering the wisdom of large public expenditures on this technology. From a purely national perspective, these could be difficult to justify, unless there is a strong expectation that exports of thermal coal will increase very considerably.

Natural gas

Australia exports natural gas, in the form of LNG. Exports from Australia are about 45% of production (including in both cases gas produced by Timor Leste but processed in and exported from Australia). In 2007 Australian exports supplied 2.6% of internationally traded gas, from production equal to about 1.4% of the world total. Australia is the world's tenth largest net exporter of natural gas, behind Russia, Canada, Norway, Algeria, the Netherlands, Qatar, Indonesia, Malaysia and Nigeria. Australia supplies a significantly larger share (12%) of imports by Asian countries – Japan, South Korea, Taiwan, Chine, India, Thailand, and Singapore. There are no exports to Indonesia.

As a fossil fuel export, LNG differs from coal in several important respects. Firstly, the energy requirement for production is much higher, at 10% or more of the energy content of the LNG produced. Production of LNG is also associated with additional emissions of CO_2, which must be stripped from raw gas prior to liquefaction. The quantity of such CO_2 varies widely between gas fields and in some cases can produce more emissions than the energy used for processing. Secondly, from the perspective of the user, gas has many advantages over coal. It emits far fewer acute air pollutants – particulates, sulfur dioxide, heavy metals; it typically emits less than 60% as much CO_2 as coal, per unit of heat energy released; and it can be used in CCGTs to generate electricity with a thermal efficiency up to 30% higher than the best coal fired power station. The latter two factors, taken together, mean that new natural gas fired generation can emit less than half as much CO_2 per unit of electricity sent out as new coal fired generation. For these reasons, in a greenhouse constrained world, natural gas will be the fuel of choice for new fossil fuel electricity generation. That is certainly the case in Japan, which is the destination for over 80% of Australia's LNG exports (China takes most of the remainder).

These circumstances raise some complex energy and greenhouse policy issues and relationships.

- To the extent that coal and natural gas fired generators are competitors for new generation capacity in Japan, Australian LNG exporters will be competing with Australian coal exporters.
- If exported LNG is being used instead of coal in the importing countries (not in addition to coal), then increased exports of LNG will be contributing to reducing global greenhouse gas emissions, a point made frequently by Woodside Petroleum and other companies with a large stake in Australian LNG.
- However, increasing LNG exports will also increase Australia's own emissions. Total emissions from LNG production are currently around 1% of Australia's total emissions. Under certain very plausible assumptions about growth in LNG production, if national emissions are cut by 20% by 2020, LNG production could account for 7% of the total.
- Growing world demand for natural gas will be associated with rising prices, a process that was well underway until interrupted by the financial crisis. Extension of the Australian gas transmission pipeline network, combined with more export projects, means that the prices for gas in domestic markets will more towards export

parity, i.e. will be set by the world price for gas. This could make gas appreciably more expensive than it is now.

- Natural gas will be just as important for the transition to a low emission energy system in Australia as in any of the countries to which LNG is being exported. As explained in the previous section, it could be vital, not only for electricity generation and other stationary uses of energy, but also for mobile equipment used in agriculture and mining, for which there are few technically feasible alternatives to petroleum. Australia's gas resources, though large, are not inexhaustible. Will commitments over the next ten years to new large LNG export projects turn out to be at the cost of gas availability for domestic markets twenty years later? This could be the most important issue for Australia's long term energy security, in the face not only of climate change, but also of peak oil.

Uranium

Australia is, in world terms, a large producer of uranium oxide, In 2005 it produced 22% of world output, behind Canada (29%); Niger and Namibia are the only other major producers. (ABARE, 2008b). Note, however, that these statistics exclude production in Russia, China and former Soviet states. Production of uranium oxide is not notably more energy intensive, in terms of energy consumption per tonne of product, than production of other metallic mineral concentrates, and consequently production accounts for only a very small proportion of total Australian energy use. The uranium industry will therefore be little affected by higher energy prices resulting from a carbon emissions price. Hence continued or increased uranium production and exports has no direct implications for domestic energy policy, in the narrow sense.

For obvious reasons, however, decisions as to which countries Australian uranium can be exported, and under what conditions, have wider strategic and national security implications. That would apply *a fortiori*, should a future Australian government decide, over likely strong political opposition, to integrate Australia further into the global nuclear fuel cycle by establishing either enrichment, or high level waste disposal or both. Such decisions would have no direct bearing on Australia's energy security, though they could, in the worst case, provoke global instability and conflict, with effects on both Australia's access to petroleum and the access of its exports of coal and LNG to markets overseas.

Were Australia to choose to make use of nuclear electricity generation an element of its response to climate change, while depending on the existing international suppliers of enrichment and fuel fabrication services, the implications of such dependence for energy security would have to be carefully considered.

Energy technology and equipment

Virtually all the technologies and all the equipment used in energy supply systems are supplied from the global market place. This is the case for both fossil fuel and renewable energy systems. The number of competing suppliers, and their location, varies depending on the type of equipment. For large, complex items, such as CCGT units, or, to take an even more extreme case, nuclear reactors, there is only a handful of suppliers. For other items, such as wind turbines, the choice is rather wider. In all cases, however, there is a global price that is largely determined by the balance between supply and demand. For example, in recent years there have been waiting lists and/or high prices for wind turbines and PV panels, because global supply capacity has had difficulty keeping up with the rapid growth of demand.

As with synthetic fuels, discussed above, the existence of indigenous supply capacity for these equipment items would not greatly affect the cost of the equipment to users, which in this case are energy supply project developers. In this narrow sense, therefore, making a bigger range of such items as wind turbines or PV panels in Australia would not significantly enhance Australia's energy security. However, energy security also depends crucially on an adequate supply of skilled trades and professional workers who understand and are familiar the most up to date technologies. Building and maintaining such a workforce is likely to be more successful if a wider range of career opportunities and experiences is available in Australia. This will in turn be easier if there is a diverse range of design, manufacturing and installation activities covering all energy technologies that are important to Australia.

7. Summary of principal conclusions

The direct effects of climate change on energy security are likely to fall mainly on the electricity supply system. The effects that have been identified are relatively minor in nature, being for the most part an intensification of security risks to which the industry is already exposed and with it is familiar. There should be little difficulty in constraining security risks to acceptable levels, at the expense of somewhat higher capital and operating costs for electricity supply.

More significant impacts on energy security are likely to arise from implementation of the changes that will be required to move to a low emission energy system. There are essentially two alternative paths to a low emission electricity system. One will be based on the widespread adoption of CCS and/or nuclear power as a major source of electricity generation. In terms of the structure of the electricity system, this would represent a continuation of the current system. It would be exposed to the same enhanced direct impacts of climate change as the present electricity system, plus the additional risks arising from heavy dependence on highly complex and unproven or immature technologies. The alternative path will make use of large numbers of widely distributed energy generators, using a diversity of renewable and natural gas based generation technologies, and place very strong emphasis on increasing energy efficiency. This option will increase the level of energy security provided by the electricity system.

It has been suggested that the process of transition to a low emission electricity system, relying principally on an emissions trading scheme (the CPRS), will reduce energy security, irrespective of which path is chosen. This concern has been used to justify proposals to provide financial compensation to the current owners of coal fired power stations as one component of the design of the CPRS. However, this view does not find universal support amongst policy analysts.

Implementation of the CPRS may lead to the closure of one or more Australian oil refineries, thereby increasing dependence on imports of refined petroleum products. The impact of such a change on Australian energy security will depend on the circumstances under which the change occurs and on conditions in the world oil market at the time.

Unless it is assumed that the global oil market will collapse in the face of the challenges presented by climate change and peak oil, the pursuit of petroleum autarky through production of synthetic liquid fuels from natural gas, coal or oil shale will not significantly increase Australian energy security. It would, however, cause a large increase in greenhouse gas emissions.

Greatly increased use of natural gas for electricity generation and as a substitute for petroleum in many types of transport and other mobile equipment, together with its continuing use in energy intensive thermal process industries, will be an essential medium to long term feature of Australia's transition to a low emission, post-petroleum energy system. Continuing availability of natural gas will therefore be essential for Australia's long term energy security.

Given that many other countries will also be seeking to make greater use of natural gas, providing the opportunity for Australia to greatly increase its exports of LNG, there is a potential conflict between ensuring Australia's long term energy security and maximising export revenue in the shorter term. Increasing LNG exports will also increase Australia's own emissions by an amount that could be large, relative to reduced total national emissions.

Successful transition to a lower emission energy system will depend crucially on an adequate supply of skilled trades and professional workers who understand and are familiar the most up to date technologies. Building and maintaining such a workforce is likely to be more successful if a wider range of career opportunities and experiences is available in Australia. This will in turn be easier if there is a diverse range of design, manufacturing and installation activities covering all energy technologies that are important to Australia, even if the existence of design and/or manufacturing capacity in Australia does not, in itself, enhance the physical security of supply of the relevant equipment, given the existence of a global market for such equipment.

8. References

Australian Academy of Technological Sciences and Engineering, 2008a. *Assessment of impacts of climate change on Australia's physical infrastructure*. Parkville.

Australian Academy of Technological Sciences and Engineering, 2008b. *Biofuels for transport: A roadmap for development in Australia*. Parkville.

Australian Bureau of Agricultural and Resource Economics, 2008a. http://www.abareconomics.com/publications_html/data/data/data.html#engHIST.

Australian Bureau of Agricultural and Resource Economics, 2008b. *Australian commodity statistics 2007*. http://www.abareconomics.com/publications_html/data/data/data.html#engHIST.

Australian Government, 2004. *Securing Australia's Energy Future*, Canberra.

BP, 2008. *Statistical review of world energy 2008*. London. http://www.bp.com/productlanding.do?categoryId=6929&contentId=7044622.

CSIRO, 2006. *The heat is on: the future of energy in Australia*. Canberra.

Department of Climate Change, 2008a. http://www.climatechange.gov.au/impacts/settlements.html, accessed 28/10/08

Department of Climate Change, 2008b. *Carbon Pollution Reduction Scheme Green Paper*. Canberra.

Garnaut, 2008. *The Garnaut climate change review*, Canbridge Univesity Press, Melbourne..

Saddler, H., F. Muller and C. Cuevas, 2006. *Competitiveness and carbon pricing: Border adjustments for greenhouse policies*. Australia Institute, Canberra.

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