Australian Academy of Science

Developing Infrastructure for the Low-Carbon Economy

A submission to

Infrastructure Australia Discussion Paper 1: Australia's Future Infrastructure Requirements

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Please note that because of the limited time available between the call for submissions and the closing date for submissions, it has not been possible to consult fully with the Academy Fellowship. Therefore the submission must be considered as provisional, but the Academy would be pleased to respond to any issues which Infrastructure Australia would like to explore further.

Developing Infrastructure for the Low-Carbon Economy

A submission to Infrastructure Australia from the Australian Academy of Science

Introduction

Australia faces a painful and rapid transition to the low-carbon economy. This is driven in part by climate change considerations, the economics of which has been fully developed in the *Garnaut Climate Change Review Final Report* (www.garnautreview.org.au, September 2008). However, it is also driven by a practical need to reduce our dependence on liquid hydrocarbons. A recent *Energy-Quest* report (www.energyquest.com.au/EQhome.html, 2 September 2008) has highlighted Australia's growing dependence on foreign oil, which doubled our petroleum trade deficit to $10.85 billion in 2007-8.

This deficit will only grow over time, as Australia's oil reserves continue to be depleted, and production continues to fall. The likely projection for production versus demand is shown in Figure 1. If oil remains near $US100 per barrel, which seems optimistic, then by 2020 our petroleum trade deficit (see Figure 2) will have risen to over $40 billion per annum!

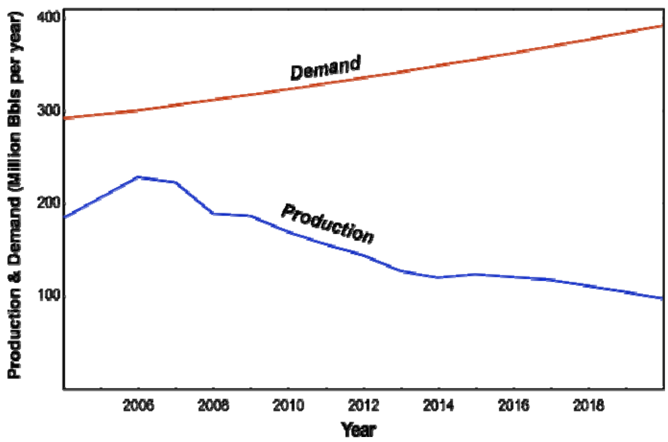

Figure 1: *Australia's production and demand for crude oil and condensates (Million barrels per year, source: http://www.ga.gov.au/image_cache/GA6111.pdf)*

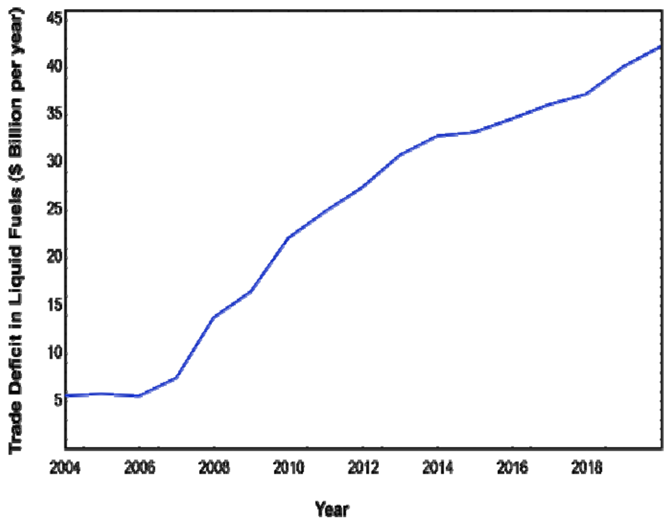

Figure 2: *Australia's projected petroleum trade deficit based upon the statistics of Figure 1. It could be $20 billion by 2010 and rise to over $40 billion by 2020.*

Therefore, we need to establish infrastructure to enable us to reduce our dependence on liquid fuels, and to develop the infrastructure we will need to make the transition to a low-carbon economy. This submission examines a number of options. In some cases a relatively small investment, along with appropriate adjustments to policy levers would go far to address this pressing issue, and to strengthen our economy at the same time.

In summary the Academy recommends serious consideration of the following infrastructure requirements and policy initiatives:

Recommendations: Transportation Systems

1.1 Provide incentives to develop natural gas-electric hybrid vehicles.

1.2 Construct a national goods transportation rail backbone having a number of "container ports" or roll-on/roll-off facilities along its length to allow efficient local distribution of goods by road.

1.3 Examine the technological options available for further reducing carbon emissions from shipping over time, see:
(http://www.dft.gov.uk/pgr/scienceresearch/technology/lctis/lctisdocpdf).

Recommendations: Alternative Energy

2 Where necessary, build a new electrical energy distribution system designed to transmit the energy from the alternative energy production sites to the major cities in Australia. The grid should be based on high-voltage current (HVDC) technology with efficient inter-city links to allow for energy exchange as demand varies.

3.1 Provide grants to farmers to encourage them to allow wind farms on their land, and to ensure that they receive a reasonable royalty on energy production resulting from wind-turbine installations on their land.

3.2 Support recommendations 8.2 and 8.3 in the Green Paper *Venturousaustralia: building strength in innovation* to improve the attractiveness of the R&D Tax Concession for innovative R&D based companies (www.innovation.gov.au/innovationreview).

Recommendations: Domestic Energy Efficiency

4.1 Offer a significant rebate for house owners to bring their houses up to a three star energy rating.

4.2 Introduce a new seven star energy rating for all new houses.

4.3 Introduce national standards for maximum standby power for all domestic appliances.

4.4 Introduce a national unified scheme for feed-in tariff returns which encourages participation.

1. Transport Systems

Passenger vehicles

Australia consumed 30 billion litres of fuel for transportation in the 12 months ended 31 October 2007 (62.8% petrol and 31.2% diesel). This is roughly the equivalent of 250 million barrels, or about 80% of Australia's liquid fuel consumption. Of this total, petrol-consuming passenger vehicles accounted for nearly half of the total (http://www.abs.gov.au/AUSSTATS), so it is clear that addressing the issue of energy efficiency in road transport will go a long way to reducing our petroleum trade deficit.

Governments have a clear role to play in supporting research, development & demonstration activities to bring forward lower carbon vehicles. The recent government investment in the Toyota electric hybrid car construction facility in Australia is good. However, such vehicles still rely on petrol – which is a waning reserve. With the development of improved battery technologies, plug-in (grid-charging) hybrids have been suggested as providing an especially useful alternative for city transportation. However, the impact on CO_2 emissions from this technology is not favourable while our electricity is sourced from coal rather than from clean alternatives.

Bio-diesel and bio-ethanol are not practical alternative fuels for mass-transport by road. The full carbon accountancy shows that the saving on CO_2 emissions is at best small, and in some cases negative. This would be the case for Australia where our dryness means that only relatively low-grade cellulose-rich feed-stock would be available for bio-fuel production. These fuels would also require a large area of farmland to be converted for their production, and have the potential to distort food production.

In Australia's case, there is the option of using liquified methane gas in place of petrol. The extensive deposits of natural gas on the north-west shelf will last well beyond the depletion of our oil reserves (http://www.ga.gov.au/image_cache/GA8550.pdf). Indeed, natural gas-electric hybrids could provide the solution to our road transport needs until late in the century. We therefore recommend the implementation of incentives to develop natural gas-electric hybrid vehicles.

If we compare the energy requirements of different modes of transport, then rail proves to be by far the most efficient land-based form – barring bicycles (http://cta.ornl.gov/data/index.shtml). The fundamental problem in Australia is the colonial legacy which left a sparse and inadequate rail network with each state adopting a different gauge of track. Since then there has been very little investment in the rail infrastructure, by contrast with countries such as France or Japan. As a consequence, most of Australia's commerce is carried inefficiently by road.

Rail

An alternative model would be to construct a national rail grid backbone, based on a common gauge of track, capable of carrying large loads, linked to cities, ports, farming centres and mining centres. Such a network would need a number of "container ports" or roll-on/roll-off facilities along its length to allow efficient local distribution of goods by road.

Trains and rail infrastructure are long-lived assets. The technology needs to be right from the outset or have sufficient flexibility built-in to adapt to technology developments. In the Australian case it would seem logical to combine a new electric grid infrastructure, as proposed below, with the backbone rail grid, and to make the trains electric-powered rather than diesel-powered – ideally with the electricity sourced from alternative energy.

Passengers could also be carried by this system. This would be attractive from the viewpoint of reducing air transport and its associated CO_2 and NO_x emissions. However, the needs of passengers pose stringent requirements on the performance of the system since, to be competitive, the passengers have to be transported between the major urban centres at speeds of 200 – 250 km/h.

Shipping

Shipping is also a very fuel efficient method of moving bulk freight. It remains comfortably the lowest carbon method currently available for long distance movement of freight on a per tonne basis. Fuel makes up a relatively high proportion of international shipping costs and marine diesel engines are already efficient. Internationally, there has thus far been only a limited policy or commercial focus on technological options for reducing the carbon footprint of shipping. However, while highly efficient, shipping is a not an insignificant source of carbon emissions at a global level – estimated to account for around 1.8 – 3.5% of worldwide carbon emissions – and the movement of goods by ship continues to grow.

Recommendation 1.1

Provide incentives to develop natural gas-electric hybrid vehicles.

Recommendation 1.2

Construct a national goods transportation rail backbone having a number of "container ports" or roll-on/roll-off facilities along its length to allow efficient local distribution of goods by road.

Recommendation 1.3

Examine the technological options available for further reducing carbon emissions from shipping over time, see: (http://www.dft.gov.uk/pgr/scienceresearch/technology/lctis/lctisdocpdf).

2. The National Grid: Bringing the Power to the People

When alternative energy sources such as geothermal, or solar, are considered for Australia, the best regions for generation of energy are frequently not near the population centres. For example, the best areas for geothermal energy generation are around the Cooper Basin, near the intersection of the boundaries of New South Wales, Queensland and the Northern Territory. In the case of solar energy, solar irradiance is maximised in the interior and in the northern part of the continent (see: http://www.bom.gov.au/sat/solrad.shtml.)

However, the existing system of alternating current (AC) power lines is high loss, and may not be efficient for long-distance power transmission. Instead, any new power transmission system could be based upon high-voltage direct-current (HVDC) power transmission. Studies by the Oak Ridge National Laboratory in the USA suggest that long-distance HVDC lines lose far less energy than AC lines over an equivalent span. The US experience shows HVDC lines are also cheaper to build and require less land than the equivalent AC lines. These HVDC lines could form a "backbone" for long-distance power transmission in the same way as the proposed rail system would provide a backbone for long-distance goods transmission. The lines would terminate at a number of converter stations where power would be switched to AC for transmission using the existing power grid to consumers.

Recommendation 2

Consider a new electrical energy distribution system designed to transmit the energy from the alternative energy production sites to the major cities in Australia. The grid should be based on high-voltage current (HVDC) technology with efficient inter-city links to allow for energy exchange as demand varies.

3. Alternative Energy Sources

It is often stated that alternative energy sources will require a great deal of research and development effort. This is incorrect, since there already are a number of tried and tested technologies which can be immediately deployed. However, many of these cannot currently compete with coal-generated electricity, unless it is fully costed for its CO_2 emissions. In a world of carbon trading this is set to change and, with a carbon tax and with minor policy adjustments in favour of alternative energy, these technologies can be expected to rapidly surpass their already stellar 25% annual growth rate. Currently, the following technologies are available "off the shelf" and can be considered ready for exploitation. In addition there are other on-the-horizon technologies that have considerable potential:

Wind Farms: These are mature technologies, that require less than 2 years to recoup their investment and can generate power at a cost of 5-14 cents per kWH. For more about these, see below.

Solar Thermal Electric: This technology uses solar concentrators to focus sunlight to produce high temperature steam for electricity generation. In the US, over 450 MW of electricity is produced by this method. The cost there is currently around 25 cents per kWH, but could be reduced to half of this through the advantages of scale. To put solar generation systems into perspective, the sun's energy falling on Australia in one day is equal to half the total annual energy required by the whole world.

Solar Photovoltaic: The current costs are around 20 cents per kWH, but with the new technologies currently under development we can confidently expect generation costs to be reduced significantly (http://www.originenergy.com.au). Solar voltaics are ideally suited to domestic grid-connect power systems. For more about these, see below.

All of these technologies would benefit from government taxation changes as proposed in the Cutler review of Australia's national innovation system, *Venturousaustralia*. In particular, recommendations 8.2 and 8.3 designed to alter the R&D Tax Concession from a tax deduction to a tax credit. This would help tilt the market to assist the SMEs who are the major players in this area.

In the near term, we can expect the following technologies to come on-line for exploitation:

Geothermal: These rely on producing superheated steam in radioactively heated "hot-rock" granite deposits to generate electricity. This process works best when the substrate (~5 km deep) rock has been heated to over 250C. Fortunately, Australia has several such deposits, notably in the Cooper and Galilee Basins located close to the boundary of New South Wales, Queensland and the Northern Territory (http://www.geodynamics.com.au/IRM/content/hfr_hfraustralia.html). A cubic kilometer of hot granite at 250C has the stored energy equivalent of 20 million barrels of oil. This technology is in development in Australia by *Geodynamics Ltd*.

Of all the alternative technologies, only wind energy provides a reasonable match for the population density of Australia, see Figure 3. This suggests that new wind farms should be encouraged in order to provide a viable alternative source of electrical energy for our urban centres.

Recommendation 3.1

Provide grants to farmers to encourage them to allow wind farms on their land, and to ensure that they receive a reasonable royalty on energy production (say, 1%) resulting from wind-turbine installations on their land.

Recommendation 3.2

Support recommendations 8.2 and 8.3 in the Green Paper Venturousaustralia: building strength in innovation to improve the attractiveness of the R&D Tax Concession for innovative R&D based companies (www.innovation.gov.au/innovationreview).

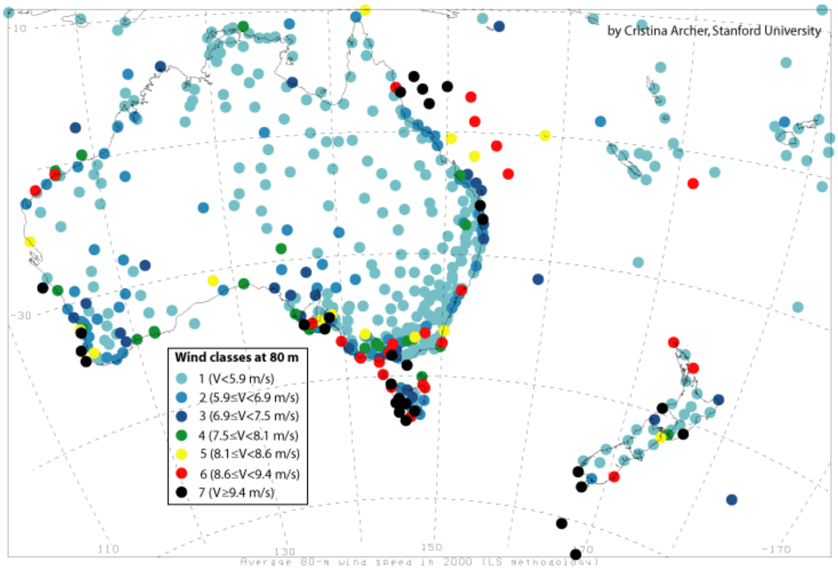

Figure 3: The potential for wind power generation. *Data taken from http://www.stanford.edu/group/efmh/winds/global_winds.html. Wind velocities above about 3 m/s are most suitable for power generation. Note that high wind regions offer a good match to population centres.*

4. Domestic Energy Reductions

According to the ABS, domestic electrical power consumption by households in Australia in 2001-2 was 53 TWh. Today, it is close to 67 TWh. This corresponds to an energy consumption per household of roughly 70 kWh per household per day, and total emissions of over 30 million tons of CO_2 per annum. Most of this energy is used for space heating, water heating, domestic electronics and lighting. In addition, wood and other forms of space heating account for even more CO_2 emissions. See: http://www.environment.gov.au/soe/2006/publications/technical/stocks/pubs/stocks.pdf

Clearly, any reductions that can be made in household energy usage and energy savings are desirable, in particular because such reductions save between $40 to $100 per ton of CO_2 (Creyts et al. http://mckinsey.com/clientservice/ccsi/pdf/US_ghg_final_report.pdf).

Practical near-term infrastructure initiatives that will help achieve this goal include household insulation, standby power and domestic electrical power generation, as discussed below.

Household Insulation: Currently there are about 8 million households in Australia. Since housing stock replacement rates are only 1.9% per annum, it will take nearly 50 years before there is a “modern” building stock with high insulation standards.

Most of our old building stock has an effective zero star energy efficiency rating. For example, the ABS has found that about 40% of Australian homes currently have no ceiling insulation. Increasing this to three stars through the provision of ceiling and wall insulation, and by the provision of double glazing could cut domestic energy consumption by 16,000 kWh per household per year. Studies commissioned by *ICANZ* (http://www.icanz.org.au/) show that retrofitting insulation into currently un-insulated Australian homes would deliver immediate and lasting benefits:

- Savings to householders of $2.9 billion on household energy bills over the period 2008 – 2020 (or savings per retrofitted household of between $89 and $336 per annum);

- Abatement of 2.4 million tonnes of greenhouse gases per annum;

- Savings of $250 million on new energy infrastructure;

- Reduction in electricity prices through delayed infrastructure spending; and

- Increase in GDP of $894 million over the period 2008 – 2030.

The current Australian Government policy is to provide $500 rebates to landlords to install insulation. However, the cost of ceiling and wall insulation is of order of $2,000 per household, and a single double-glazed window costs about $1500. Since the cost to bring a zero star energy rated house up to a three star energy rating is of about $10,000, the incentives clearly need to be set higher.

Recommendation 4.1

Offer a substantial rebate for house owners to bring their houses up to a three star energy rating.

For new buildings most state regulations currently call for five star energy rating. However, if we are to meet the *Garnault Report* standards for CO_2 emission reductions this needs to be tightened. While total costs for upgrading house energy efficiencies are high, they are offset by reducing the looming future petroleum trade deficit.

Recommendation 4.2

Introduce a new seven star energy rating for all new houses.

The total space heating or cooling requirements for a Canberra house from a change to a seven star rating system are shown in Figure 4 (www.nathers.gov.au/about/pubs/starbands.pdf). Energy consumption would be reduced by 44% by an improvement from a five to a seven star energy rating. This implies building houses of a solar passive basic design, with double glazing throughout, and ceiling, wall and slab edge insulation. Typically, the additional insulation required would add $10,000 to the cost of a new house, and double glazing would add a further $20,000. Such costs are recouped many times over during the lifetime of the house.

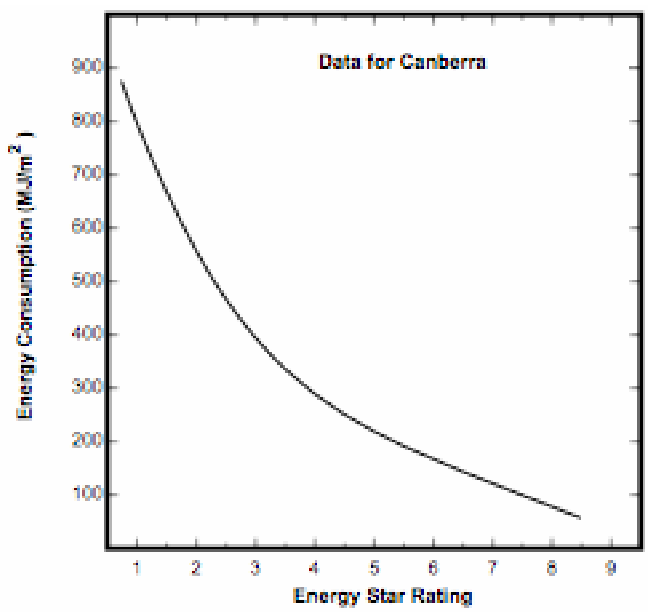

Figure 4. Domestic heating energy savings *An un-insulated house in Canberra will consume over 957 of megajoules of energy for every square metre (MJ/m2). A five star ratings reduces this to 216 MJ/m^2. A seven star rating reduces heating or cooling needs by a factor of over 8 compared with an un-insulated house.*

Standby Power Reduction: Standby functions (e.g. remote control activation of a television set) and off-mode losses (occurring when a product cannot be switched off completely when providing no service/function) are a common feature of electrical and electronic household and office equipment (consumer electronics, information and communication technology equipment, personal care products, etc.). A study conducted by the Australian Greenhouse Office concluded that up to 80% of the electricity used by VCRs was consumed in standby mode. In Europe, it is estimated that electricity consumption in standby/off-mode will be about 50 TWh per year in 2020 (an amount comparable to the total electricity consumption of a country such as Greece or Portugal, see: http://www.delaus.ec.europa.eu/news&events/EU/Environment/Memo488.htm.

Recent field studies show that in Australia, standby power accounts for 11.6% of total domestic power consumption. This is rising fast and doubling every five years. A recent study by Creyts et al. in the USA (http://mckinsey.com/clientservice/ccsi/pdf/US_ghg_final_report.pdf) has shown that reducing energy wastage in electronics and lighting provides savings to the economy equivalent to a "negative carbon tax" of $110 per (US) ton of CO_2.

Recommendation 4.3

Introduce national standards for maximum standby power requirements on all domestic appliances.

Domestic Power Generation: In Germany, the famous "million homes" initiative put a generous national incentive regime into place to encourage the take-up of domestic grid-connected photovoltaic schemes. This gave householders an initial feed-in tariff which helped to defray the installation costs of these systems. The scheme effectively acted as a direct stimulus to industry, such that today Germany is now the world leader in photovoltaics and several other forms of renewable technologies.

Australia started late along the path of feed-in tariffs, and currently has an inconsistent and incomplete national system. Those states which have implemented feed-in tariffs operate under a variety of regimes, ranging from 60 cents per kilowatt-hour in the ACT to as little as 20 cents per kilowatt-hour in Tasmania. Neither New South Wales nor West Australia has introduced such a scheme, despite the fact that these states have excellent natural conditions for solar electricity generation (Perth has 3,150 hours of sunshine per year, compared with just over 2,000 in Melbourne).

Recommendation 4.4

Introduce a national unified scheme for feed-in tariff returns which encourages participation.