

## **WHAT WILL OUR VEHICLES RUN ON?**

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### **ABSTRACT**

The world is facing a series of transitions as growth in the production of oil cannot keep pace with the rising demand for it. The first transition will be relatively benign, as production reaches a plateau. There are signs that we are already at this point. Future transitions will see the supply diminish as well as the price rise. The effects will have ramifications throughout society but transport will be particularly badly affected because of its high dependency on oil. This presentation will give an Australian perspective on what the next 50 years hold for energy futures for transport.

## **1. INTRODUCTION**

When we entered the current century, in 2000, the Munro Centre at the University of NSW and the Transport Panel of the Sydney Division of Engineers Australia held a seminar on “What does the next 100 years hold for transport?” My contribution was a paper entitled “Energy Futures for Transport ” [1]. Other papers dealt with the potential of Intelligent Transport Systems, the way in which community values are interpreted by our political leaders, hybrid fuel technology (such as in the Toyota Prius), a new form of ultra-light rail, and the potential of public transport generally, plus a keynote address from Derek Scrafton of the Transport Systems Centre at the University of South Australia (he retired as Director-General of Transport of that state in 1997).

Shortly before then I had had the advantage of having taken part in a workshop in Western Australia, where (along with a number of other people who were supposed to know more than an average amount about transport) the “experts” were asked to identify the ten most important trends that would affect transport over the next 100 years. We all fell over ourselves to get “the availability and price of energy” onto the board – and then following that there was an awkward silence, as we realized that compared with the energy issue nothing else came close.

I had also taken part in a 1998 Symposium “Beyond Oil”, mounted by the Tasmanian branch of the (then – it has since added Logistics to its name) Chartered Institute of Transport in Australia. The objective of this Symposium – held at a time before oil issues were of great concern – was to determine whether it was something CITIA members should be worrying about. The conclusion [2] was “yes, it was, definitely”.

Since 2000 the energy issue has become much more prominent. Climate change is on the public agenda, and is likely to feature heavily in the forthcoming federal election in Australia, which still lies in the future at the time of writing. Peak Oil is another concept which is fast becoming mainstream. The time horizon of 50 years that the current conference has adopted is more manageable than the somewhat ambitious 100 years attempted in Sydney at the turn of the millennium, but it is still a long time away. About the only things that can be foretold with safety, as far as energy is concerned, is that by then we will have found out whether the fears of peak oil and its consequences were real or not.

Increasing numbers of people are becoming aware of those fears. In late 2005 the Australian Senate referred “Australia’s future oil supply and alternative transport fuels” to its Rural and Regional Affairs Committee to look into. The resulting Senate Inquiry then called for submissions – almost 200 were received – and spent from April to August 2006 receiving evidence via a series of public hearings. Its findings are still awaited at the time of writing – the latest date to which the publication of the report has been postponed is early February 2007 (this is being written in January) but the committee issued an interim report [3] in September 2006, without recommendations.

Submissions from the National Committee on Transport (NCTR) of Engineers Australia [4] and the ASPO-Australia Working Group on Urban Planning and Transport [5] are typical of those warning that Peak Oil is imminent

Energy is responsible for at least half the industrial growth in a modern economy and represents less than one tenth of the costs of production [6]. Oil is a unique commodity, the lifeblood of modern life. It is the basis of fertilizer, plastics,

pharmaceuticals and other chemicals, but it is as a transport fuel that its use is so essential and where there are no alternative sources currently able to compete economically. In Australia “the transport, mining, chemical, electricity generation and agricultural sectors have higher than average fuel utilization and tend to experience significant first round effects.”[3]. The transport sector accounted for 75% of all oil-based energy consumed in Australia in 2003/04 [7]. The New Zealand figure was 86% in 2005 [8].

Clearly Peak Oil will be a momentous event in the history of the world, with the potential to change economic, social and environmental habits which have become taken for granted in an age of cheap oil. “An upcoming worldwide shortage has the potential to inflict disruptions and hardships on the economies of every country” [9] In this paper I concentrate on the effects on the transport sector, which will be one of the first sectors to be affected.

## **2. PEAK OIL**

A summary of Peak Oil and Australia’s position is available in a paper by Bruce Robinson and Sherry Mayo of ASPO-Australia (ASPO is the Association for the Study of Peak Oil and Gas) to an Energy Security Conference in Sydney in October 2006 [10].

The key point – for this paper – is that, while there is some dispute about when the peak in global oil production will occur (estimates vary from the recent past to three decades hence), there would be few (some, but few) who would assert that in fifty years time oil will not be scarcer and more expensive than today. There will of course still be plenty of oil available – the world is in no imminent danger of running out of oil – but it will no longer be cheap oil. Hence in fifty years time our transport will have had to reduce its oil dependency if transport costs are not to be dominated by the higher price of fuel in future.

Dr Ali Samsan Bakhtiari, a former senior executive with the National Iranian Oil Company, describes the failure of the growth in global oil supply to keep up with the growth in global oil demand in terms of a series of transitions. He asserts that the first, relatively benign, transition began in 2006, with price rises while there is still plenty of oil to be had. In later transitions there will be a physical decline in the quantity of oil available, with the world’s ability to supply oil declining at an ever-growing rate. He asserts that by 2020 the world will only be able to produce about 55 million barrels a day of conventional oil, compared to 80-85 million today and forecast of about 118 MBpd needed by 2030. Dr Bakhtiari came to Australia and gave evidence to the Senate Inquiry in July 2006 [11].

What alternatives are there? With a fifty-year time horizon, it is not possible to rule out an unforeseen technical breakthrough, (after all, a similar exercise conducted in 1907 would probably have failed to predict the great war, the rise of automobility, and of aviation - although with hindsight the early signs of each were there) so failing such an unforeseeable event the main candidates are already identifiable. According to the Interim Report of the Australian Senate Inquiry [3], the main supply side options to ease the economic disruption of restricted fuel supplies and high prices are:

- finding more conventional oil supplies within Australia or in Australian territorial waters;
- sourcing a proportion of fuel requirements from biofuels such as ethanol or biodiesel;
- non-conventional petroleum, producing transport fuels by liquefying coal or natural gas, or producing it from oil shales, and
- fuel shifting, for instance using LPG, natural gas or hydrogen as a transport fuel.

These are the options as seen in Australia. It is likely that New Zealand options may differ – despite similar geographical positioning, New Zealand is not known for abundant fossil fuel resources, despite uncommercial lignite deposits, but benefits from a greater endowment of renewable energy in the form of hydro or geothermal power. Table 3.1 contrasts energy supply in the two countries in 2005.

	Australia 2005	New Zealand 2005
Oil	35%	38%
Coal	35%	13%
Gas	22%	20%
Hydro	5%	12%
Geothermal	0%	12%
Other renewable	2%	5%

Table 3.1 Australian and New Zealand energy supply mixes 2005

Sources : Australia: 2005 Interpolated from graph in [7]  
NZ 2005: [8]

Table 3.2 shows the extreme vulnerability to overseas market conditions of New Zealand, and the way in which more domestic oil production in Australia was exported than was used domestically, resulting in higher exposure to overseas markets than might be expected. Table 3.2 assumes that an Australian oil breakdown for 2003/04 can be applied to the initial 2005 breakdown of Table 3.1.

Oil	Australia 2003/04	New Zealand 2005
Imported	22%	35%
Indigenous - used	14%	3%
Indigenous - exported	16%	presumed 0%
Total used domestically	35%	38%

Table 3.2 Australian and New Zealand dependence on overseas oil 2003-2005

The way in which the future unfolds will determine very much the approach to oil taken. As the CIT outcomes statement observed [2]. *“Should self interest predominate, we could become locked in conflict, unable to adapt and with the likelihood that we will dissipate unproductively the scarce high quality petroleum fuels so essential to a safe transformation to a world “beyond oil”.*

It is not only the means to produce transport fuels but also the means to store them, to distribute them and to use them that are required. Transport ideally needs a fuel which is portable and energy-dense, which is what makes liquid oil-based fuels so suitable and why the oil storage, distribution and utilisation systems have developed along with the production (exploration, extraction, refining) systems over the last hundred years or so. However it is likely that changes to at least some of these subsystems will be needed before the next fifty years are out.

The length of time for these necessary subsystems to develop to support alternative fuels should not be under-estimated. The World Business Council for Sustainable Development [12] estimated that it would be at least 2050 before vehicles to utilise hydrogen-based technology, for instance, could be commercially available. (The WBCSD, representing “the Big End of Town” and focusing on 2030, did not subscribe to the peak oil theory and advocated further development of the Internal Combustion Engine as the most cost-effective way forward). “It looks as if supplies will meet that demand [a projected 20% increase in oil consumption by 2030]. If there is an obstacle ... it will be the politics and policies of oil-producing countries and swings in global economic growth.”

I disagree with this conclusion, needless to say. In my view supplies will not meet demand, as documented in the references.

### **3. WHAT SUPPLY-SIDE ALTERNATIVES ARE THERE?**

In Australia there is an ongoing debate at the time of writing about how we are going to generate electricity to power our cities – using the energy in coal or the energy in uranium, both substances which Australia has in abundance. The dilemma which is being faced by our federal governments is that revenue from exports of our energy resources (natural gas as well as coal) make a significant contribution to our foreign earnings, but that policies that recognize climate change - if not peak oil - are likely to reduce this contribution. This is the main reason why our Prime Minister favours nuclear energy. However for transport, with its high dependence on oil, neither the coal nor the nuclear energy option helps very much. Clearly it will be necessary to reduce the amount of oil consumed over the coming decades, or nature will do this more painfully for us.

(I am not an expert in the NZ energy position. My impression – supported by Table 3.1 – is that the country has few commercially exploitable fossil fuel deposits, having to import almost all oil, but the energy wealth of New Zealand consists more of renewable sources - geothermal energy, hydro energy. These are difficult to harness for transport purposes but, if this obstacle can be overcome, promises to make New Zealand more independent of overseas oil markets than would otherwise be the case)

I wrote a series of articles on peak oil for CityScape, an award-winning planner’s newsletter [13], and the final one (October 2006) reviewed the alternatives to oil available in Australia. Influenced by the Senate Inquiry’s Interim report, it asked the question : would technology come up with something in time to enable us to carry on without changing our habits.

The conclusion was - it wouldn’t. All the options have disadvantages – starting with the fact that the price of transport energy will rise – as well as advantages.

Aside from the debate about more coal-fired power stations versus nuclear ones – neither of which will help transport very much – the leading alternative fuel contenders were taken to be to be hydrogen, biofuels, natural gas, and use of oil from non-conventional sources. There are other alternatives (eg LPG). .

### **3.1 HYDROGEN**

Hydrogen is sometimes seen as the energy basis for a “post-oil” age. It is the most common element in nature, but it always exists in combination with something else. It is an energy carrier, like electricity, not an energy source - energy has to be expended to produce it.

The commercial development of fuel-cell vehicles appears to be decades away. In any case there is a natural limit to the production of hydrogen - when it requires more energy to produce than the energy it provides, is it really worth producing? The Senate Committee found [3] that it “is not a useful option to consider in Australia’s current or medium term transport fuels mix”.

### **3.2 BIOFUELS**

The main biofuel options are ethanol, made from sugarcane or grain, and biodiesel, mainly made from crops such as canola and palm oil.

The addition of 10% ethanol to petrol sold in NSW has been mandated by the NSW government from 2011. Many questions remain to be assessed – whether enough land to grow ethanol-producing crops is available, the excise position, the net effects on Australia’s balance of payments if land is switched from growing crops for food to growing crops to provide transport fuel. What will those Asian countries eat who currently depend on Australian food exports? Other food-exporting countries – like the United States (and New Zealand?) – are facing the same pressures as Australia.

The aviation industry may need ethanol too – it is a possible alternative to refined jet fuel. To use ethanol, aircraft would need to be designed with larger fuel tanks, because it is less energy-dense than jet fuel.

Biodiesel lacks a distribution system in Australia.

Nevertheless the Senate Inquiry concluded that the current national (Australian) target for biofuels (350 million litres by 2010) was far too modest.

### **3.3 NATURAL GAS**

Australia is endowed with large quantities of natural gas (principally methane). The technology is sufficiently mature to modify diesel and petrol engines to run on gas, but the lack of any significant refuelling or distribution infrastructure is an obstacle to its further use. Current national policy appears to encourage the use of diesel in heavy vehicles.

### **3.4 NON-CONVENTIONAL OIL, CTL, GTL**

Here the options are more technical possibilities than commercial ones. Substantially more greenhouse gases are produced by the processing than is the case with conventional (liquid) crude oil. Most options rely on geo-sequestration (burying the gas underground), an unproven technology.

Moreover the price of these options would be impacted by the imposition of a price on carbon dioxide emissions, something global warming is likely to dictate in future.

### **3.5 SUMMARY**

Perhaps the best that can be said of the alternatives is that they offer governments the chance to be seen to be “doing something” about the peak oil issue, in the face of which they are really helpless. With federal, state and local elections all due in NSW in 2007, this is not to be sneezed at!

The basic problem remains that the world is using too much oil and this is unsustainable. The only option really open to us is to reduce our use of fossil fuels – and that is something that requires time. All the alternatives outlined above should be pursued. All will make a small but worthwhile difference but none will make sufficient difference to save us from the need to use less energy.

## **4. WHAT ABOUT DEMAND-SIDE OPTIONS?**

The Senate Inquiry also reviewed demand-side options, which it considered to fall into two categories:

- Increasing the fuel efficiency of vehicles
- Reducing the demand for fossil-fuelled transport

In the latter category were options such as

- More use of rail for long distance freight
- Greater use of public transport, walking and cycling for urban person movement
- Reform of tax concessions for car use

These issues are beyond the scope of this paper. It should be noted that ASPO-Australia considers the development of alternatives to oil as a relatively low priority. In order of priority, they argue that first, the community should become engaged in the debate; second, we should start to be frugal in our consumption of energy; third, we should ensure that any energy we unavoidably consume be used as efficiently as possible; and only then should we look to alternatives to oil. (NB the author is the co-ordinator of the Sydney activities of ASPO-Australia).

## **5. MODAL REVIEW**

“Transport” can take place on land, in the air or by water. The most oil-dependent mode is aviation, especially passenger aviation, for there is no technological alternative in sight to the heavier-than-air aircraft, powered by fossil fuel. Many observers (eg [14]) consider that, on ecological grounds, the need to travel by air needs to be reduced – and peak oil adds reinforcement to that view. This is obviously of concern to an island nation a long way from anywhere else. “Modelling of a permanent doubling in the world oil price, commissioned by the Queensland Government, projected air transport activities to be 27% lower in 2016-17 than it would otherwise have been without increases in fuel price.” [3]. NB the fuel price

nationally is also affected by movement in the exchange rate, not just in the price of crude oil which is priced in US dollars.

Road transport is also heavily dependent on oil, although not to the same extent as aviation. It is likely that the future will see more road vehicles, although possibly lighter and more fuel-efficient than those that we are used to. For both passengers and freight, it is possible [15] that dividing transport by function, into independent means and services provided by third parties, could be more productive than the more traditional divisions into road and rail, or passengers and freight, or even cars and public transport (which overlooks the potential of walking and cycling to meet short-distance needs in urban areas). For heavy vehicles, operations that permit refuelling at a central depot will be at an advantage while an alternative fuel distribution system (or systems) is being established.

The other main mode for land transport is rail. A railway locomotive is basically a power plant rolling on rails. Therefore this mode, because of the greater size of the traction unit, is in theory less vulnerable to oil depletion than road transport. It can adapt to whatever fuel option is most economical at the time. In the past railways have used the energy contained in wood, coal, oil and gas.

The same comment applies, and probably more so, to water transport, where the power plant – attached to the floating payload - tends to be even larger than for railway locomotives. It is likely that marine diesel will not be so easy to come by in future, but ships do not necessarily have to be powered by marine diesel.

## **6. OIL VULNERABILITY**

All sectors of the economy need oil – if not directly (like transport), then at least indirectly to run all the necessary heavy machinery (defence, mining, construction etc). Some sectors like agriculture need oil to produce their primary product, which then has to be conveyed to the consumer by burning oil – a double whammy.

If Peak Oil is considered just at the level of an entire national economy most people, including decision-makers, will say "It is all too hard", as many have done with global warming. Most people and organisations are largely unaware of the numerous widely-varying opportunities open to them to reduce their oil vulnerability. But every location is different, so the first steps in preparing for peak oil should include a local study to see how much oil is used, what it produces for the local economy and what options might be available to reduce oil dependency. In inner areas of cities, for instance, this might include encouragement of cycling for short-distance trips, which would not be an option in regional areas.

In Australia research by two academics at Griffith University (Brisbane) [16] has showed, based on data from the 2001 Census, that the areas most vulnerable to petrol increases (and mortgage interest increases) tend to be in the outer areas of big cities, where public transport is sparse and families have extended themselves financially to acquire a mortgaged property. This suggests that the provision of alternatives to using a car should be a political priority for transport in these areas.

The so-called "Hirsch Report" to the US Department of Energy [9] introduced the concept of "mitigation wedges". Each "wedge" relates to a specific policy. From the time that it is introduced, there is a lead-in period when no effect is noticeable.

Thereafter (possibly five years later) the effect starts to be noticeable and increases over time. But no one wedge will have an effect of the magnitude that is required, so action on a number of fronts simultaneously is required, in order that the cumulative effect of the wedges can reach the required level in future.

Three mitigation scenarios were tested. The thing that differentiated them was the number of years before peak oil that action was begun. The first assumed that no action would be taken until the peak of oil production was reached. The second and third assumed that action would be taken in anticipation of peak oil occurring ten years and twenty years before the event.

The conclusion was that the sooner action was taken the better, with only the 20-year scenario being relatively free of hardship (a global deficit in fuel supply). Peak oil is perhaps now no more than five years into the future, so the Hirsch report has already been overtaken by events, and in any case the options associated with each of the wedges are technological ones which may be appropriate for the United States but the mix elsewhere may be different. None of the approaches advocated below depend on the emergence of new technology.

Nevertheless the clear message of the Hirsch report is that whatever you do, it should be done as soon as possible. It presents the dilemma as a classic risk management problem, but as Western Australia's Planning Minister observed in 2004: "It is also certain that the cost of preparing too early is nowhere near the cost of not being ready on time."

## 7. WHAT TO DO?

The following options were presented to the Australian Senate Inquiry by ASPO-Australia [17]. If action on all fronts were taken simultaneously, the end result could be a halving of Australia's fuel consumption without needing to rely on technology to "come up with something" to allow us to continue our energy-profligate way of life. While the recommendations to a New Zealand government, following study, might be slightly different, similarities between the lifestyles of the two countries suggest that the recommendations too would be similar.

*Community engagement:* empowering people to understand the Peak Oil concept and to help decide the best options for us all before we face a future oil shortage.

*Individualised marketing:* a proven, rapid and low-cost strategy, offering individual households the information needed to consider options of reducing automobile travel. A 13% reduction in car-km has been achieved in large programs in Australia. It can also be used for minimisation of demand for water and electricity and perhaps can be adapted to alert people to Peak Oil probabilities and risks.

*Fuel tax escalator:* Increasing fuel taxes smoothly and incrementally to UK levels (following Margaret Thatcher's 1988 example) would provide a clear signal that we must value fuel much more than we do now. "Unthinkable" measures such as this are essential given the magnitude of the near-term risks posed by Peak Oil. Fuel tax increases would provide funds for schools, hospitals, and for sustainable transport infrastructure. The impacts could, for instance, be ameliorated by abolishing fixed vehicle-ownership charges (licence and third party charges) and by lowering income taxes.

*Smartcard flexible tradeable fuel allocation and pricing mechanism:* Providing a basic safety-net ration for modest usage, and extra fuel at an increasing taxation rate for those who want to use more than average. Unused allocations can be traded to reward those with ingenious ways of reducing fuel usage.

Robinson & Mayo elaborated on individualised marketing and tradable gasoline rights in a recent paper to a conference in Japan [18]. Sydney is the only major Australian city so far not to have undertaken large-scale individualized marketing, even though the share of passenger kilometers attributable to public transport is already, at 16%, twice as high as the next best, Melbourne, and up to four times as high as the smaller cities of Brisbane, Adelaide, Perth and Canberra [19].

## 8. CONCLUSIONS

Peak Oil will increase the price and reduce the availability of oil for transport.

Opinions differ about when this would occur, with 2010-2012 the most frequently predicted date.

When this occurs, the disruption to our first-world way of life will be enormous.

There are no technological developments currently “in the pipeline” to avoid this.

Aviation is the most vulnerable mode, followed by road transport. Rail transport and sea transport are the least vulnerable.

There are likely to be more road vehicles in future than today, although these will probably be lighter and more fuel-efficient than we are used to.

If we wait until it is evident that the peak of global oil production has arrived, it will be too late to mitigate the effects.

Embarking now in a program of community engagement, tradeable fuel allocations, a fuel tax escalator and individualised marketing would reduce the risk faced – at least in Australia.

## REFERENCES

1. Kilsby D (2000), Energy Futures for Transport, written for UNSW transport seminar, accessible at <http://www.kilsby.com.au/archive/p0900.pdf>
2. Chartered Institute of Transport in Australia (1998), *Beyond Oil*, Proceedings of National Symposium, CITIA 1998. Outcome statement accessible at <http://www.kilsby.com.au/dk-only/brainfood/context/oil.htm#cit>
3. Rural and Regional Affairs and Transport Senate Committee (2006), Australia's Future Oil Supply and Alternative Transport Fuels – Interim Report, Department of the Senate, Parliament House, Canberra, accessible at [http://www.aph.gov.au/senate/committee/rrat\\_ctte/oil\\_supply/int\\_report/index.htm](http://www.aph.gov.au/senate/committee/rrat_ctte/oil_supply/int_report/index.htm)

(The Final Report (2007) has now become available – just leave the “int\_” out of the above URL.)

4. National Committee on Transport (2005), “Energy Futures for Australian Transport”, *Transport Engineering in Australia*, Vol 10 No 2 2005, submission to Senate Inquiry, accessible at [http://www.aph.gov.au/senate/committee/rrat\\_ctte/oil\\_supply/submissions/sub04.pdf](http://www.aph.gov.au/senate/committee/rrat_ctte/oil_supply/submissions/sub04.pdf)
5. ASPO-Australia Working Group on Urban Planning and Transport (2006). Submission to Senate Inquiry, accessible at [http://www.aph.gov.au/senate/committee/rrat\\_ctte/oil\\_supply/submissions/sub133.pdf](http://www.aph.gov.au/senate/committee/rrat_ctte/oil_supply/submissions/sub133.pdf)
6. Foran & Poldy (2002), Future Dilemmas, CSIRO Research Report. Accessible at <http://www.cse.csiro.au/research/futuredilemmas>
7. Department of Prime Minister & Cabinet (2004), “Securing Australia’s Energy Future”, accessible at [http://www.dpmc.gov.au/publications/energy\\_future/](http://www.dpmc.gov.au/publications/energy_future/)
8. Ministry of Economic Development (2006), Draft New Zealand Energy Strategy to 2050, discussion paper, accessible at <http://www.med.govt.nz/upload/43136/draft-energy-strategy.pdf>
9. Hirsch, Bezdek and Wendling (2005) The Peaking of World Oil Production – Impacts, Mitigation and Risk Management, Report (“the Hirsh Report”) to the US Department of Energy, accessible at [http://www.netl.doe.gov/publications/others/pdf/Oil\\_Peaking\\_NETL.pdf](http://www.netl.doe.gov/publications/others/pdf/Oil_Peaking_NETL.pdf)
10. Robinson, B and Mayo, S (2006) The Peak Oil Debate: Will Global Oil Production Start its Final Decline Soon, or Not? Paper written for Energy Security Conference, Sydney, accessible at <http://www.aspo-australia.org.au/References/Bruce/Energy-Security-Conf-Oct-2006-paper.pdf>
11. Hansard (2006) Transcript of Dr Bakhtiari’s evidence to Australian Senate Inquiry 11 July 2006, accessible at <http://www.aph.gov.au/hansard/senate/commttee/S9515.pdf> (note mis-spelt “commttee”)
12. World Business Council for Sustainable Development (2004). Mobility 2030. Accessible at <http://www.wbcsd.ch/DocRoot/fl3lIMAvneJpUcnLgSeN/mobility-full.pdf>
13. All the Cityscape newsletters are accessible at <http://www.cityscape-news.com/>
14. May M (2005) Aviation meets ecology – reshaping policy and practice for air transport and tourism, *Transport Engineering in Australia*, Vol 10 No 2
15. Bowers D, Kilsby D & Sahhar S (2006) Promoting Australia’s future growth through efficient, integrated transport infrastructure, 29<sup>th</sup> Australasian Transport Research Forum, Gold Coast – accessible at <http://www.kilsby.com.au/archive/p0906.pdf>
16. Dodson J & Sipe N (2006) Shocking the Suburbs: Urban Location, Household Debt and Oil Vulnerability in the Australian City. Griffith University Urban Research Program research paper 8, accessible at [http://www.griffith.edu.au/centre/urp/urp\\_publications/research\\_papers/URP\\_RP8\\_MortgageVulnerability\\_Final.pdf](http://www.griffith.edu.au/centre/urp/urp_publications/research_papers/URP_RP8_MortgageVulnerability_Final.pdf)

17. ASPO-Australia (2006). Main submission to Senate Inquiry, accessible at [http://www.aph.gov.au/senate/committee/rrat\\_ctte/oil\\_supply/submissions/sub135.pdf](http://www.aph.gov.au/senate/committee/rrat_ctte/oil_supply/submissions/sub135.pdf)
18. Robinson, B & Mayo, S (2006), Australia and Peak Oil: Probable Impacts and Possible Options. Accessible at <http://www.aspo-australia.org.au/References/Bruce/Japan/Kyoto-paper-Robinson-Mayo-2006-v8f.pdf>
19. From data for 1980-1990 in Newman, P & Kenworthy J (1998), Sustainability and Cities, Island Press, Washington DC .