The Future of Oil for Australian Transport

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1: Introduction

The June 2004 issue of *National Geographic* magazine carried, as the cover story, "The End of Cheap Oil" [1]. While *National Geographic* cannot be regarded as a wholly authoritative primary source, it does suggest that oil futures are now truly a matter of public concern and transport engineers should be at least as well informed as readers of that magazine!

In this paper we will present a wealth of evidence from sources as diverse as recent Australian government White Papers, a group of European academics with an interest in oil futures, the Chartered Institute of Transport, the International Energy Agency and others which together should be sufficient to convince any transport planner that the future of oil is definitely something that he or she should be concerned about.

This paper begins by offering an explanation in a nutshell of why people are concerned that the Age of Cheap Oil may be nearly over, despite global production of oil never having been higher (Section 2).

It then reviews estimates of demand (Section 3) and, briefly, the consequences for greenhouse gas emissions (Section 4).

After looking back on a landmark national symposium on transport energy futures in 1998 (Section 5), the current global oil supply situation is reviewed (Section 6).

Then the paper offers some opinion, which is meant to stimulate thought and debate rather than be taken as definitive, on the issues arising (Section 7) and the options open to us (Section 8).

We intend that this paper be presented in various places, and Section 9 is where local attitudes and initiatives can be described if required (it is blank here).

Section 10 offers some conclusions. Finally, Section 11 makes some recommendations based on the past work of an Engineers Australia transport taskforce which addressed sustainable energy. References and an Internet "bibliography" then follow. Graphics (24 figures) are to be found in a separate file.

2. Peak Oil

The issue can be clearly stated. For the last hundred years or so, the supply of oil has kept pace with rising demand. The world today is highly dependent on oil not just for transport but to feed itself and for many other uses. We have become used to treating oil as if it will always be available and it will always be cheap. But oil is a finite resource, and sooner or later we will inevitably pass the point at which we have used more of it than we have left.

Demand can be expected to continue to rise, not only from developed countries which are accustomed to cheap energy but also from fast-developing nations like India and China with aspirations to similar economies and lifestyles. Nobody is making more oil, however, and supply will eventually be unable to keep pace with demand. It will plateau and after a while the amount of oil produced in the world annually will start to fall.

The point at which the demand and supply curves start to diverge is known as “Peak Oil”. Before Peak Oil, there is enough oil to meet demand. After Peak Oil, we can expect rising prices, harder procurement and the need to “chase our tail” by devoting more and more energy to extracting the remaining reserves of oil-based energy (because the EPR – the Energy Profit Ratio - falls as oil fields become depleted).

Figure 1 graphically illustrates what we can expect. The world will not run out of oil (or gas): but we will eventually pass the peak of production and it will start to become a scarcer resource. There is considerable disagreement among authorities about how much oil there is, and when the point of “Peak Oil” will be reached. To some it is already past or is happening now: others assert that it is twenty or more years away. But few dispute that it will eventually be reached and passed – and that presents the world in general, and transport in particular, with an awesome challenge.

(Figure 1, and all other figures, are presented in a separate file).

3. Demand

That demand is rising worldwide, there can be little doubt.

Figure 2 shows global population projections published by the United Nations in 2001 [2]. This shows that world population is expected to grow from 6 billion to 8 billion people over the next 30 years, with most of that growth occurring in urbanised areas of developing countries. Thus, even if energy demand per capita were constant, the world would be faced with accommodating the growing energy requirements of these cities in developing countries additional to existing demand.

The International Energy Agency (IEA) is an organisation established by the OECD to, among other things, monitor and forecast energy needs. There is considerable debate over the quality of their monitoring and forecasting, but it can be said that the IEA is unlikely to take a radical position. Figure 3 is an extract from their “Global Energy Outlook 2002” [3].

Figure 3 shows the IEA expectation that global demand for energy will increase by about two thirds between 2000 and 2030, with the demand for each of the major energy sources (coal, oil, gas) also increasing roughly pro rata.

Figure 4 is a projection by the World Business Council for Sustainable Development, a think-tank supported by global automotive and energy interests, of world transport fuel use over the next fifty years [4]. It is a projection rather than a forecast, since it does not take account of any supply-side constraints. Figure 4 makes transport's dependence on oil-based fuels very clear.

What of Australia, specifically? Two Government White Papers published during 2004 paint a picture. A White Paper on Energy ("Securing Australia's Energy Future", [5]) and a White Paper on Transport Infrastructure Funding ("AusLink", [6]) between them contained several forecasts of interest.

Figure 5 (from the Energy White Paper) shows the expected growth of final energy use by sector, of which transport is one. The expectation is that energy used for transport purposes in Australia will roughly double between 2000 and 2020.

Figure 6 (from the Energy White Paper) gives an interesting picture of petroleum flows in Australia in 2004-05. The picture that emerges is a disturbing one for Australian transport, especially when Figure 6 is redrawn to scale (Figure 7). It shows that most of the crude oil that is produced nationally is exported in its crude state, and that much of the feedstock of Australian refineries is imported. This is supplemented by a considerable amount of imported refined product, and by far the most dominant user of refined product – of whatever origin - is the transport sector.

Figure 8 (also from the Energy White Paper) shows the government's forecasts of final energy use by different transport modes – road, rail, sea, air and pipeline. It can be seen that the two largest requirements for energy, and highest absolute growth in energy demand, are for the two modes most heavily dependent on oil – road transport and aviation. We return to modal issues a bit later.

Figures 9, 10 and 11 come from the AusLink White Paper, and show how the demands for transport (tonne-kilometres of non-bulk freight, passenger movements through Australia's largest airports, and urban transport by mode) are expected to increase to 2020. In all cases demand is expected to increase, and the expenditure proposals in the White Paper are intended to go towards providing the national land transport infrastructure that that demand will require.

These forecasts, and others like them, carry the implicit assumption that fuel of some sort will continue to be available at roughly the same price and under roughly the same conditions as in the base year. For transport, that fuel is predominantly oil, and there must now be severe doubts about the applicability of that assumption. If there isn´t enough fuel with which to run the vehicles, the forecasts can´t eventuate.

4. Greenhouse Emissions

Transport, as can be seen from Figure 12, was estimated to be responsible for just over 14% of Australia's greenhouse gas emissions in 2002. This estimate shows that the big area for attention if the nation is to reduce its greenhouse gas emissions is the "stationary energy" sector, principally power generation. This is slightly misleading as power generation is not an end user of energy, but an intermediate step in energy conversion (mainly to electricity) for use elsewhere – in manufacturing, in domestic heating and lighting etc. Some of it, indeed, is used to power transport, particularly the metropolitan rail systems in our largest cities. And it is probable (this must be subject to confirmation) that oil refineries would also count as stationary sources.

After stationary sources, agriculture is the next largest emitter of greenhouse gases. Much of this is in the form of emanations from livestock.

Transport's 14.4% is the third largest emitter, according to BTRE. "Over the past decade, greenhouse gas emissions from transport have increased at a slightly faster rate than total greenhouse gas emissions (20% compared to 17%). Road transport is responsible for about 85% of total transport sector emissions. Over half of these emissions are due to passenger vehicles, while road freight accounts for around 30% of road transport emissions." [7]

Power generation is heavily dependent on coal, with oil also a significant fuel. The concentration of government on coal technologies is therefore understandable. However the fact that transport was responsible for "only" 14.4% of emissions does not make it unimportant, especially when these emissions are primarily oil-derived (and hence largely unaffected by the development of coal-related technologies).

5. The "Beyond Oil" Symposium 1998

In 1998 the Chartered Institute of Transport in Australia (as it was called then) held a symposium to gather together views on the oil future facing Australia from a variety of sources. What CITIA heard was profoundly disturbing, as can be gathered from the Outcomes Statement [8] which was issued at the end of the symposium (CITIA 1998). We reproduce this in full.

> *CITIA Outcomes Statement*
>
> We are at the climax of the fossil fuel age. The Chartered Institute of Transport in Australia draws attention to this fact following its 1998 national symposium "Beyond Oil: Transport and Fuel for the Future". Unlimited use of our greatest ever source of cheap energy may soon contract and the "Petroleum Age" in which we live can now be seen to be approaching an eventual end.
>
> The symposium heard that a clear consensus is emerging that cheap oil production outside the Middle East will begin permanent decline around the year 2000, to be followed by permanent world decline within 15 years.
>
> We have reached a crucial stage in the development of our local, national and international transport services. Our present path is leading us into potentially serious economic, social and environmental problems. New directions are needed for our future transport fuels and vehicles. "More of the same" in our current transport plans and ways of thinking is no longer tenable.
>
> The unlimited use of cheap oil that has characterised this century will end and we will be faced with one of the greatest transformations of human affairs. The signs are already there. Risk of chaos, disorder and conflict will arise unless we face up to this great challenge and make the difficult decisions essential to the future well being of us all. These decisions must be based on the care of people and of the environment if we are to proceed down the path of constructive change.

Congestion, pollution and diminishing oil supplies are the central drivers of this change. Communities across the world are increasingly going to be faced with the need to revise their transport systems in response to these drivers. Congestion and pollution are already major factors in some cities - the diminishing fuel supplies will increasingly become apparent as the next century progresses.

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".

The participants in the symposium workshops identified the following key issues:

- key factors affecting oil based transport are congestion, pollution and oil supply;
- the real cost of transport is going to increase and must be considered as a major factor in setting the economic agenda for the 21st century;
- the need for Government to support the introduction of viable alternative fuels, more efficient vehicles and alternative transport systems which are environmentally acceptable and fuel efficient;
- the need for greater transport industry and public awareness of the need to prepare for the decline and end of the "Petroleum Age";
- it is essential that care of people and of the environment be recognised as the principal standards for addressing these issues.

To assist the development of constructive change in response to these issues, the Chartered Institute of Transport, the professional body of transport managers in Australia, calls for the development of greater understanding and awareness of these crucial issues and for their consideration in all policy formulation and decision making relative to the future of transport and fuel in Australia.

The CITIA sees a need to communicate this message particularly within the transport industry, and seeks co-operation from the oil industry and others in its efforts to draw attention to the great challenge which confronts us all.

CITIA – or CILTA, as it is now called (the Chartered Institute of Logistics and Transport in Australia) – is a very conservative body not known for extreme views. If CITIA was sufficiently concerned to issue a statement like that six years ago, then we should now be extremely concerned.

A review of that symposium [9] can be found in Kilsby (2000). The conclusions of that review (which would not necessarily be shared by all who attended the Symposium) included the following.

*Available data is **very** rubbery*

It was a shock to realise how little agreement there was on items that should be matters of fact and beyond debate. For instance, an obvious question is - how large are the world's proven oil reserves? At the time the US Geological Survey was saying more than three trillion barrels, while an authoritative voice from within the petrochemical industry, Colin Campbell [10], said no, it's less than one trillion. This level of professional disagreement over a matter of such vital significance to our future on this planet is staggering. Definitional differences and the intrusion of political or commercial interests all present traps for the unwary.

Wide spectrum of views

Perhaps as a consequence of the lack of reliable data, there is a wide spectrum of views about the seriousness of the problem. These views are based more on the holder's perception of their own identity than on evidence. Five different positions can be caricatured, as per Table 1, and all must be respected.

Table 1: Simplification of spectrum of views on oil futures

Point of view	Caricature	Tends to be held by...
Very pessimistic	"Mankind is doomed to go the way of the dinosaurs unless we make radical changes to our lifestyles"	Environmentalists
Pessimistic	"Oil is a finite resource and cannot be considered as subject to the "laws" of economics"	Geologists
	"There is a major transition in human affairs ahead which must be planned for"	Planners
Undecided	"Something will turn up, there's no evidence to make us change our behaviour yet"	The "silent majority"
Optimistic	"We'll come up with something, technology will save the day"	Engineers
Very optimistic	"Get the price right and the market will sort things out efficiently."	Economists
	"What's the problem? Market forces will change the commercial viability of fuel options and you'll use less oil and more of something else"	Oil & gas industry executives
	"There's plenty of oil"	"Nimtoo" politicians ("not in my term of office")

(A more recent paper [11] has characterised the debate as being between "anti-depletionists" – principally economists – and "depletionists" – principally geologists.)

Not just a transport issue

It is not just transport that is dependent on oil – it is essential for so many other functions that if it starts to become harder to get then the impacts will fundamentally affect the way we live. To mention just two other sectors, agriculture and defence would change beyond recognition.

The world's capacity to feed itself without fertiliser was allegedly passed when world population passed about 2.8 billion [12]: it is over 6 billion now. Oil is a prerequisite for the production of fertiliser. With a tightening of oil supply in future, the world may be faced with a choice between travelling and eating.

The world's armed forces are major consumers of energy. The world's largest single user of oil is allegedly the United States Navy – a little ironic when much of the USN's activities are devoted to securing or protecting national sources of oil! When there is less of it to go round, and the remainder is much more precious, how will the world's generals, admirals, air force chiefs behave?

The Energy Profit Ratio concept (EPR)

It is not just the price that will be affected once the point of "peak oil" has been produced. The "Energy Profit Ratio" (EPR) is the ratio between the amount of energy obtained from a resource and the amount of energy it takes to process that resource into a form in which the energy can be extracted. It takes energy to extract oil, and if you have to put more energy in than you get out in the form of the oil, you´d be better off on energy efficiency grounds leaving the oil where it is. The EPR characteristics of the giant oil fields in the Middle East are such that it will be a long time before this is an issue, but for more marginal fields the EPR could impose a significant constraint on extraction. Certainly oil found in shale fields requires a lot of processing (mining, crushing etc) and has a much lower EPR than conventional oil fields and it would be misleading to regard these two sorts of oil resource as equivalent to one another.

Figure 13 shows the Energy Profit Ratio domains of various fuels – plainly "conventional oil" from the large Middle Eastern fields is in a class of its own and none of the possible replacements are qualitatively similar in EPR terms.

However the EPR changes as a field is depleted. When a field is young, it is easy to extract the oil and the EPR is high. However, once the field is past its peak (more than half depleted), it becomes progressively more difficult to extract the remaining oil and the EPR is much lower. Hence it is not adequate to count the amount of unused oil believed to be left in a known field towards "Reserves"; not all of it will be worth extracting.

The depletion profile of a gas field is different from an oil field. Gas is more fluid and is easier to extract until there is little left: gas supplies from individual fields are therefore more likely to terminate relatively abruptly than oil supplies.

Different outlooks for road, rail, sea, air

The Symposium included modally-oriented workshops which considered energy futures separately for road, rail, sea and air transport.

Rail and sea transport were considered to face the least difficulties (relatively) if oil became scarcer. A railway locomotive is essentially a power plant rolling on rails, and it can be powered by whatever fuel is most economically viable at any given time. Thus railway locomotives have at various times been powered on-board by wood, coal, oil or gas, or provided with reticulated electricity generated elsewhere. Similarly, ships carry their own power plants.

At the other end of the scale, aviation was considered to face the most difficulties. There is simply no feasible alternative in sight to oil-based aviation fuel. The shielding required to protect passengers from a nuclear engine would be too heavy to contemplate. Passengers are likely to resist to sharing an aircraft with tanks of liquid hydrogen, on safety grounds (possibly mistakenly, but perceptions matter when they affect behaviour).

Road transport lies inbetween. There will be much change in the road transport sector, and many more vehicles than today – both cars and trucks – can be expected. However technological development will be highest for this mode, and tomorrow's vehicles may be very different from today's.

Figure 8 showed that the greatest growth in Australian transport energy use is expected in the most oil-dependent modes, namely road transport and air transport.

6. Supply

Now we return to the question "how much oil is there"? We have seen how any supposedly authoritative data has to be taken with a pinch of salt. In 1998 Sir Guy Greene, as Governor of Tasmania, opened the CIT Symposium referred to above and among other things said:

> "Debate about that issue [oil scarcity] sometimes gets bogged down by inconclusive discussions about the exact size of the remaining oil resources and exactly how long they will last. I suggest that it is more fruitful to proceed, as I understand this symposium will proceed, on the basis that although we don't know exactly when the reserves will run out or at least when they will become so scarce or costly that large scale reliance on them becomes untenable – it will happen. The question we ought to be concentrating upon is what we can do to prepare for and to cope with the revolution in transport that it will create. I would suggest that it doesn't greatly matter if it turns out that our forecasts about the rate at which the changes will take place are unduly pessimistic. The magnitude of the adjustments we shall have to make is so great that we need all the lead time we can get."

There are several estimates of the amount of oil still to be extracted. They all show the same roughly "bell" shape, although the date of the height of the peak varies from now to 20 years time. Figure 14 shows a typical estimate, from EnergyFiles, a US-based consultancy. It shows world oil production rising for a few years still, but once the peak is passed there is a steep decline. It also shows that once the peak is past OPEC countries will be the dominant producers, as most of the significant remaining reserves will be in their hands.

Figure 15 presents some estimates of global "proven reserves" of oil. Care should be taken when comparing estimates as there are often significant but unexplained definitional differences between them, as to what is included and what is not.

We tend to prefer the estimates emanating from ASPO (the "Association for the Study of Peak Oil") to others. ASPO is "a network of scientists, affiliated with European institutions and universities, having an interest in determining the date and impact of the peak and decline of the world's production of oil and gas". This quote appears at the start of the monthly Internet newsletter issued by ASPO [13].

ASPO estimates are based on scientific evidence (mainly geology), and seem relatively untainted by political (where claims to extensive reserves may be made by OPEC countries to influence their production quota) or commercial (where movements in a company's stated reserves may affect its share price) considerations.

Figure 16 gives ASPO's latest estimate of the profile of world oil and gas production. It asserts that the peak will be earlier than that shown by EnergyFiles (Figure 14) – one of the major reasons is a more pessimistic assessment of the ability of OPEC countries to increase production dramatically in future to keep up the growth rate in supply. A side effect of this is that the ASPO estimates do not drop off as steeply as those from Energy Files once the production peak has been passed. The past is less contentious than the future, and as can be seen from Figure 16, the advent of "peak oil" has already happened for several sources of oil, and most notably in the United States which passed its domestic peak of production in the 1970's and has been increasingly relying on cheap oil imports to maintain its mobility since then.

It is a truism that before you can use oil, you have to find it. Figure 17 shows the growing gap between discovery and production according to ASPO (which backdates any increases in reserves to the date at which the original fields were discovered). The 1950's and 1960's were the golden age for discovering oil fields: since then the rate of discovery has been tailing off, while the rate of consumption of the oil that has been discovered has been rising. At the present moment the world is using up oil at four times the rate it is finding new sources.

Figure 18 shows the lag between the cumulative discovery and the cumulative consumption of world oil. Both activities can be represented by logistic curves – starting low, rising fast during a middle period and then tailing off as physical limits are reached. The consumption curve seems to have trailed the discovery curve by about 32 years in its early stages, but the gap is now widening a little.

Figure 19 is based on ASPO's current estimates of the production of oil to 2075. According to ASPO, the earth once contained about 1.85 trillion barrels of conventional oil. On ASPO's estimates we have discovered where 92% (1.7 trillion barrels) of this is so far, and we have already used 54% (0.92 trillion barrels) of what we have discovered. Current proven resources are about 0.78 trillion barrels, according to ASPO. Gas and unconventional oil resources alter the timing of the peak rather than the general picture (see ASPO newsletters [13]).

Table 2 shows a comparison between ASPO's current estimate of world reserves of conventional oil, and Colin Campbell's as presented to a UK House of Commons All-Party Committee in 1999 [10]. These two estimates come from sources with a common outlook and should be readily comparable. They clearly show that the world's oil position has deteriorated in the five years since 1999, despite a higher than expected discovery rate which has boosted the "ultimate" total by 50 billion barrels. Known reserves have fallen and the depletion rate has risen. Action is no less urgent than it was five years ago.

Table 2: World "conventional oil" discovery and consumption – comparison of 1999 and 2004 estimates in Gb from Colin Campbell and ASPO respectively

	1999 estimate[1]	2004 estimate[2]
1. Produced	816	920
2. Reserves	821	780
3. Ultimate	1800	1850
Discovered (1+2)	1637	1700
Yet to find (3-2-1)	163	150
Yet to produce (3-1)	984	930
Annual consumption (rising)	23/yr	24.6/yr[3]
Annual discovery (falling)	~6/yr	~6/yr[4]
Annual depletion rate	2.2%	2.4%[5]

[1] Source: The Imminent Peak of World Oil Production", presentation to UK House of Commons All-Party Committee by Colin Campbell, 1999
[2] Source: ASPO Newsletter June 2004
[3] IEA data (Figure 16) implies that the annual consumption rate had increased by 30% between 1982 and 2002, equivalent to an annual increase of 1.3%. The 2004 consumption rate was estimated by applying a 1.3% annual growth to the 1999 estimate.
[4] Left unchanged from the 1999 estimate as actual discoveries 1999-2004 were higher than forecast in 1999.
[5] Calculated as net annual consumption/known resources

Comparison of Table 2 and Figure 20 shows considerable disagreement between supposedly authoritative sources about world oil reserves. The International Energy Agency estimated proven global oil reserves at 1.05 trillion barrels in 2002, sufficient (they estimated) for 38 years of consumption at 2002 rates of consumption. This is a higher estimate of reserves than ASPO, and closer examination of the IEA consumption rates shows that they have risen 30% between 1982 and 2002. The IEA's own data (Figure 3) shows the consumption rate increasing by a further 67% between 2000 and 2030, in which case we will have considerably less than 38 year's worth of oil left. And even if the supply is eked out for 38 years, what happens in year 39?

It is unlikely that the world will run out of oil, as several things will happen as the peak of oil production recedes into the past. One is of course that the price will rise. The media seem to go into a frenzy when certain psychological thresholds are passed: in particular oil used to become "expensive" (before it reached its heights approaching $55 a barrel) once it passed $US40 a barrel. Oil selling at $US39.65 a barrel was therefore not something to be concerned about! Figure 21 shows the variation in the price of a barrel of Brent Crude between 1996 and 2004. It is certainly consistent with what would be expected as a production peak is passed: initially a very low price, as plenty of oil is available at the height of the peak, followed by a steady and inexorable trend upwards. It will be interesting to observe whether the price moves downwards again in the next few months, as some authorities expect it to if only OPEC would produce more of it.

There could be more complex feedbacks, as the rising demand for oil is driven by a growing world economy which in turn is fed by an increasing supply of oil. Oil supply problems could throw the world economy into major recession and hence dampen the increase in demand. (We are assured by eminent economists and Alan Greenspan that there is no danger of world recession.) While economists might feel vindicated by this feedback mechanism, as evidence of market forces at work, it produces a scenario that most of us who would have to live through it are probably quite keen to avoid.

Figure 22 shows the short-term fluctuation in the daily oil price (light sweet crude as traded on the New York Mercantile Exchange, which is slightly more desirable for transport than Brent Crude and hence slightly more costly) since the G8 Finance Ministers and OPEC oil ministers discussed the (then) unacceptably high price of oil in May 2004 and supposedly "sorted it out". The price trajectory over the following four months (including a five week period when I was not in a position to monitor it) does not display any signs of an over-priced commodity returning to a lower and more "normal" level. Ups and downs have much more to do with world events – the lowest price was on the day that Iraqi sovereignty was restored to them, while the verdict of the International Court of Justice on the legality of Israel's security fence, bankruptcy threats to Russia's giant production company Yukos, sabotage in Iraq, rebellion in Nigeria, industrial unrest in Venezuela and Norway and even hurricanes in the Gulf of Mexico produced a succession of highs. If civil unrest were to affect Saudi Arabia a massive impact on oil prices was feared, since the Saudis with their vast reserves try to "top up" any transient shortfall of global oil production by temporarily increasing their own. After the US election in November 2004, the price started to fall quite dramatically (mainly motivated, apparently, by forecasts of a mild winter and of no shortage of heating oil)– but at the time of writing (March 2005) it has crept up again to within a couple of dollars of the previous high price. OPEC oil ministers had agreed in December 2004 to restrict the production of oil to encourage the price to rise again.

The conclusion is that the trading market reacts to short term factors and cannot be relied upon to reflect long term depletion issues until they become obvious and immediate. Given the long lead times involved in bringing alternative technologies to commercial viability, it may then be too late to expect an orderly transition to some other energy source for transportation.

The increase in the resource cost of oil has been passed on to consumers but in fact it has not made much difference to the price at the pump. A 200% rise in the resource cost of oil between 1998 and 2000 only led to a 20% increase in the cost of petrol at the pump because that cost also includes the cost of refining and distribution and, most notably, government tax. Figure 23 shows the amount of Government charges applied to petrol in various countries. It can be seen that Australian petrol excise is relatively low by world standards, though not as low as that of the United States. It should not be overlooked that if Government revenues from petrol taxes were to fall, other taxes would have to increase if public expenditure is to be maintained. Each country maintains a balance between consumer prices and public revenue that it is prepared to live with.

For many, the next election date is as far as time horizons stretch. With a much longer view, the Age of Oil will be seen as a transient blip in human history, as suggested by Figure 24. Peak oil effects are unlikely to be felt by time of the next federal election in Australia, and possibly not by the one after that. But as Figure 24 shows, historical trends are independent of electoral cycles and the nature of our world after the consumption of all the fossil fuels on earth is something that we will have more control over if we plan for it now rather than wait until the fossil fuels have nearly all gone.

We do not have any consensus on how that world will look, so making supplies last longer than they would in an unplanned scenario would at least allow that consensus more time to develop.

7. Issues

The foregoing analysis of the likely gap growing between demand and supply raises several issues of fundamental importance to the way our societies function. Here we note some of them briefly. Each one merits far more discussion than is possible here.

Prioritisation of use

Oil is essential not just for transport but also for agriculture, manufacturing, construction, power generation, mining, defence and many other activities. If the supplies of oil become constrained, choices will have to be made as to the priorities for its use. At its starkest, the choice may be between eating (agriculture) or travelling (transport). It is likely that within any sector the least important activities will be curtailed. Within transport, it is likely that commercial transport will be seen as more important than private car use. Hence it will be necessary, especially in urban areas, to develop alternative means of personal mobility such as walking, cycling and public transport. This is not just a "fad" of well-meaning planners: it will be essential for the continuation of urban societies as we know them.

Geopolitics

It is an unfortunate fact that the much of the world's accessible reserves of oil and gas are found in countries of less mature government, unstable politics, religious strife, insurgency and other internal problems. This virtually guarantees future difficulties over global access to resources, and hence the probable fulfilment of one of the CIT's fears: *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".*

Transition

This CIT fear, and Figure 24, do highlight one important feature of the Age of Oil: namely that it will not last forever, and that it will be followed by something else. We do not know what that will be. The contention that it will be the "Age of Hydrogen" has many supporters: this is reviewed briefly, with other possible technological changes, in Section 8. Whatever it is, it is likely to need changes to infrastructure, vehicles, fuel distribution systems – in other words, there is a period of transition ahead. The energy needed to implement this transition is potentially available in the world's remaining stocks of oil and gas: if this is squandered on less essential uses or in non-productive conflict, the transition will have to be managed with some other source of energy which we cannot yet identify. This transition must be planned properly and regarded as a top priority.

Coal in Australia

Australia is a resource-rich country. The national oil reserves are now relatively low, and the natural gas will not last forever. The principal energy resource is coal, which on current consumption rates will last Australia for about another 300 years. Unfortunately coal is not a viable transport fuel – its principal uses are in generating overseas dollars through exports and in generating electricity mainly for domestic and industrial consumption. Current federal government efforts (see the Energy White Paper) are focussed on coal – and in particular the development of technologies such as geosequestration (burying greenhouse gases underground) that would allow it to be used for longer and for more purposes.

Pricing signals

As far as the resource price of oil goes, *"Price fluctuation appears to have more to do with the degree of consensus between the national custodians of global oil reserves over appropriate short-term production levels than with long-term market forces"* [9]. The end user price is however heavily influenced by government pricing policies, as Figure 20 showed. Pricing signals can be employed to encourage users to move away from dependence on fuels that will be in shortest supply. The Peak Oil phenomenon will probably make itself felt in diesel before petrol, as Australia has little heavy oil of its own. However at present our federal government seems set on encouraging diesel use by subsidising rural freight moved by diesel-fuelled vehicles and urban public transport use of diesel buses. This has led to the State Transit Authority in Sydney changing an order for 150 gas-powered buses into one for diesel-powered buses, on the grounds that it was an unavoidable commercial decision. "Because of price, and policy changes, we have had to start rethinking our approach to gas" said the STA chief executive in June 2004. [14]

Investment Assessments

Current procedures for assessing major infrastructure projects and other significant public investments tend to focus first on the financial aspects of a proposal and then on the economic (time savings to users etcetera). In a world where energy is less freely available, a whole-of-life energy assessment of a project will be as important as a financial or economic assessment. What is the energy cost of building, operating, maintaining and eventually disposing of a proposed asset, and what are the energy "benefits" that result (presumably the "payloads" that can be moved)? The energy requirements would have to be regarded holistically, eg allowing for the "embodied energy" in a constructed feature and part of the energy needed to create, run and ultimately scrap any privately-owned vehicles that might use it. We do not yet have the analytical tools to do this.

8. Options

From the above it is reasonably clear that "Do Nothing" would be a strategic option abdicating responsibility for a foreseeable problem, and therefore it will not be considered further. The strategic options would seem to be:

business as usual – the planner´s approach - applying a variety of conventional measures to try and mitigate the impact of a reduced supply of cheap oil. This is not to say that the outcomes would be similar to today´s, rather that the measures adopted would be fairly familiar. We review the sort of future that would result.

technological change – the engineer´s approach – the ability of an advance or advances in technology to mitigate the impact. The leading contenders are reviewed. We believe these could be the use of alternative fuels (and energy carriers like hydrogen or electricity), and/or the potential of Intelligent Transport Systems to change the nature of travel as we know it.

market forces – the economist´s approach – reliance on the "invisible hand" of the market, with government intervention via pricing policies if required, to render some alternative to oil more commercially viable than oil as it becomes harder to acquire or more expensive or both.

behavioural change – the demand for oil is the result of millions of small decisions and a few larger ones – individuals and governments, businesses small and large. If it were more widely understood what the consequences of continuing to regard fossil fuels as the transport fuel of choice were, then the possibility of changes in behaviour becomes an option. Were transport users to behave as if fuel were neither unlimited nor free, different outcomes could emerge.

There is of course another possibility, namely that something completely unforeseen will emerge to change the landscape. After all, a future scan in 1900 would have probably failed to predict the rise of aviation, the advent of computers, the collapse of European empires, and probably not even the First World War which was then not too far off. Since this possibility is dependent, by its nature, on something currently unforeseeable it cannot be reviewed, but it should remind us that the options which have been reviewed here are not necessarily a completely comprehensive set of choices. They are not mutually exclusive either.

Business As Usual

A Taskforce of Engineers Australia investigated transport energy needs and reported in 1999 [15]. We revisit its recommendations at the end of this paper.

In 2002 the Warren Centre for Advanced Engineering at Sydney University issued their report on a three-year inquiry into "Sustainable Transport in Sustainable Cities" [16]. The city of Sydney was treated as a case study. This chose to interpret "sustainable transport" as meaning transport offering greater urban accessibility at lower environmental impact. Although the future availability and price of oil was considered by this study, it was not a central feature and the recommended measures were all relatively conventional (though far beyond what the NSW Government has been prepared to apply in Sydney so far). This study has been widely acclaimed and was awarded a National Excellence Award by Engineers Australia in 2003. The general categories of complementary measures recommended were:

- engaging the community;
- monitoring and reporting on transport performance;
- optimising the performance of what we have;
- modifying the shape of the city;
- introducing better planning, pricing, funding, new technology and infrastructure; and
- lowering barriers to change.

This is probably as good an indicator as any of what "business as usual" will lead to in future, although it also impinges to some extent on the other approaches considered below. The National Committee on Transport of Engineers Australia put forward ten recommendations in its review of the environmental and health impacts of transport [17], which could also be considered as a foretaste of things to come:

- reduced vehicle size for much person transport in urban areas
- use of pricing as a transport policy measure
- greater consideration of commercial transport needs
- clearer articulation of the expected outcomes of public transport investment
- breaking the nexus between car ownership and car use
- developing greater individual responsibility for social outcomes
- more public control of road use
- encouragement of regional self-containment to reduce inter-regional transport demand
- development of energy assessment methods for evaluation of infrastructure proposals
- identification and adoption of "world's best practice"

Others (eg Laird et al [18]) have argued for other measures, notably investment in adequate rail infrastructure. While all these recommendations may seem radical in a world of plentiful energy, most will probably come to be seen as inevitable "business as usual" steps in future.

Technology Development

The federal government claims to have created an environment in which the use of alternative transport fuels can grow, but it expects petrol and diesel to continue to dominate the scene (by implication, indefinitely). Developments of fuels and engines based on biomass, gas, ethanol, methanol, vegetable-based fuels etc may be of marginal assistance but are unlikely to produce an option of sufficient scale and efficiency to replace oil.

For sustainability, renewable energy is the best sort of energy. There is a Mandatory Renewable Energy Target (MRET) in force in Australia, which stipulates the proportion of national energy to be generated from renewable sources (wind, sun, tide etc). The MRET is currently set at 2% in Australia. Engineers Australia, which has been arguing for a raise to 10%, criticised the recent Energy White Paper for not proposing to raise it, noting that in some overseas countries it is set as high as 20% by 2020. [19]

Hydrogen, as a fuel to replace oil, has many advocates. They claim it could satisfy many of the world's requirements, which are for an energy source which is transportable, storable, usable for transportation, economical to produce, renewable, pollution free and independent of primary sources.

Unfortunately hydrogen is not an energy source, it is an energy carrier (like electricity), and although it exists in abundance in nature combined with other elements (eg in seawater, coal, oil, natural gas) energy is required to extract it. The source of this energy could be anything – geothermal or other renewables, fossil fuels, nuclear. This independence from primary sources means that a universal hydrogen economy could be developed with individual countries adopting whatever pathways to it suit their particular circumstances.

The indications are that more energy is needed to extract the hydrogen in the first place than can be gained from using it in fuel cells in the second. Hydrogen is therefore expensive in terms of energy to produce, and if that energy is not from renewable sources it may be too useful to dilute in this way. Hydrogen is also expensive in financial terms to store and to distribute. Much technological development lies ahead before a hydrogen economy can be considered a feasible proposition for Australia.

Most of the R&D funding for technological development in hydrogen and alternative fuels comes not from national governments but from the energy or automotive industries, whose objectives are to sell us more energy (not necessarily oil-based) or more cars (not necessarily oil-powered). Both are therefore likely to promote supply-side options: reducing demand for their product is not in their interest, although it is highly relevant from a public policy viewpoint..

Major advances are being made in the fuel efficiency of new engines and/or vehicles. This is a mixed blessing. On the one hand less fuel is required to move a given mass a given distance; on the other, consumers currently have the freedom to respond by buying larger vehicles or by driving more or both, and in either case more fuel-efficient cars are probably more technologically sophisticated and hence more expensive cars.

Table 3 shows BTRE estimates [7] of the change in new and average car fuel intensities, in the size of the car fleet and the amount of car travel, and in the fuel consumed by cars and commercial vehicles between 1971 and 2001. Their data shows that while the fuel intensity of new cars dropped considerably over that time, the fuel intensity of the average car in the fleet did not; the size of the car fleet, the volume of travel and the fuel consumed all increased by around 130%; and the rise in fuel consumed by the commercial vehicle fleet was much higher.

Table 3: Energy characteristics of Australian vehicle fleets 1971 and 2001
Source: BTRE [7]

	units	1971	2001 (estimate)	% change
Fuel intensity – new car	l/100 km	12.60	9.63	-24%
Fuel intensity – average car in fleet	l/100 km	12.28	12.08	-2%
Passenger car numbers	thousands	3,997	9,454	+136%
Passenger car vehicle kilometres	billions	63.8	146.5	+130%
Energy consumed – cars	petajoules	268	605	+126%
Energy consumed – light commercials	petajoules	39.6	179.3	+353%
Energy consumed – rigid trucks	petajoules	45.8	78.5	+71%
Energy consumed – articulated trucks	petajoules	29.6	101.3	+242%

Nuclear power has not featured on an Australian agenda so far, because of intractable waste disposal issues. Nuclear power stations also have high cost and limited life, though electricity can be produced cheaply once this investment is made. If we do not plan for anything else, greater use of nuclear power to generate electricity to produce hydrogen may well be the default option for transportation energy. The United States is already following this direction. If a nation was truly desperate for alternative energy sources, nuclear waste disposal issues might be deferred for later generations to sort out (as seems to have been the practice to date for a limited number of nuclear installations).

Intelligent Transport Systems, or the applications of information and communication technology to the transport sector, have the potential to improve the efficiency with which our road infrastructure is used. They are a key part of the "Low Energy Transport" component of the "Energy Transformed" flagship project of CSIRO, who believe that they lend themselves to widespread implementation by 2010. This could therefore delay the need for transport to adapt by a few years, but will not avoid it. Some ITS applications have the potential for much wider use than currently envisaged. Two examples are the "Intelligent Access Program" intended to monitor the compliance of non-standard road vehicles with their network access restrictions, and electronic tolling of road use. Some significant equity issues are raised by ITS possibilities.

Market forces and economic instruments

A rising price of oil will undoubtedly improve the commercial viability of alternative sources of energy and boost technological development. What these alternative sources might be is currently not established but it would be remarkable indeed if they became available in sufficient quantities and with sufficient efficiency to replace oil, in sufficient time.

The cost of fossil-fuelled travel is generally perceived to be little more than the cost of the fuel, which is cheap. This is because many of the costs of motoring are access-related rather than usage-related (driver and vehicle licence fees, annual insurance etc). Public transport costs, on the other hand, are based on the user paying a fare for each and every journey. This has been shown [20] to lead to peak public transport travel being perceived in Sydney as three times worse than peak car travel on average, even though the actual costs (including time) are about the same. Public transport costs less but takes longer. This distortion will not change until the costs of car use are more directly related to usage as well. It would be even better if the emphasis in public transport use were to become more access-related.

The perceived cost of fuel is heavily influenced by Government taxation, as we have seen in Figure 23. The proposals in the Energy White Paper are aimed at making petrol and diesel use cheaper: "*From 1 July 2006 the excise paid on fuels used in heavy vehicles will be converted to a road user charge. Existing urban and regional boundaries will be removed from that date. And the excise relief provided through the road user charge will apply to all fuels, including petrol – benefiting the owners of as many as 54,000 heavy vehicles*."[5]. This will undoubtedly be popular with voters but is a strange action to be taking when facing an oil-constrained future.

Behavioural Change

The approaching end of the age of cheap oil is little understood by the general public, and there is a public education role which is being neglected by federal government. State authorities have discovered that voluntary behaviour change programs are a cost-effective tool for encouraging use of their public transport systems [21], and such programs could be expanded to encourage broader changes in travel behaviour.

It has been estimated [22] that a conversion of half the car trips under 3 km in length to walking or cycling would save less than 4% of urban fuel use, because these trips are at the shortest end of the length spectrum. However with integrated land use and transport planning which allowed half the travel needs now requiring car trips of over 3 km to be satisfied in less than 3 km, and then with some mode change as well, there is the potential for urban fuel consumption to be reduced by 47%. These calculations only indicated the scale of the potential savings: clearly it would take many years of consistent and persistent action to achieve them.

Significantly, improving public awareness was one of the key directions emerging from the Warren Centre's work [16]. Previous work on behavioural change – in the health sector as well as the transport sector – suggests that all such programs have to pass through five stages: pre-contemplation (where the impact of an issue is not generally appreciated yet), contemplation (where options for change can be considered), preparation (where an option has been chosen and has to be planned for), action (when the plan has to be implemented) and maintenance (where the action selected must be supported after the change to avoid backsliding). Western Australia is notably ahead of other Australia states in seeking to change transport behaviour in the interests of sustainability, but elsewhere the pre-contemplation stage is the most common.

9. The position in (insert location)

(If this material is being presented in specific places, it is designed to have a description of how these issues are being addressed locally inserted here).

10. Conclusions

The future availability and price of oil could be the single biggest issue facing our transport systems and, indeed, our entire way of life. On the evidence reviewed in this paper, this certainly seems to be something that cannot be ruled out. The “precautionary principle” of ecologically sustainable development strongly suggests that waiting before absolute scientific certainty before taking any action would be an unecological course. Bland re-assurances that there is no problem would be more convincing if they were also accompanied by corroborating evidence or research.

This is not yet recognised as an issue of national importance by Australia’s government. We have seen that the supply and demand forecasts which are the current basis for forward planning, from the transport infrastructure and energy White Papers, do not seem to consider oil issues as a factor. On May 9 2004, a spokesman for Deputy Prime Minister and Transport Minister John Anderson said

> …to link current spiralling prices with oil reserves was ridiculous, given the instability of the oil-rich Middle East.
>
> "The Greens like the idea of catastrophe, it didn't happen in the 1970s (when they first predicted one) and it won't happen now," he said.
>
> The spokesman said the government would announce a new land transport plan on June 7 called AusLink, which would be updated every five years, based on projections 20-years ahead to deal with approaching issues including oil prices.
>
> … The spokesman said the Australian Government, along with the United State government, was already taking the issue of depleting oil stocks very seriously and examining alternatives including ethanol and hydrogen.

The first AusLink White Paper, when it appeared, did not mention oil depletion at all. Presumably, then, oil prices are not expected to be an issue within the next 20 years. The basis for this rather significant assumption is not indicated.

(But on 13 August 2004, when the price per barrel of oil hit $US45.75, the Deputy Prime Minister conceded “It may very well be that the era of cheap oil production has ended.”)

All the approaches reviewed in this paper – unusual use of “business as usual” policy measures, technological developments, the play of economic forces, behavioural change programs – will all be needed and will be more effective if they are applied as part of a conscious national strategy.

11. Recommendations

The recommendations made by the NCTR, already referred to [17], for a better environment and a healthier community would, if followed, be a useful starting point and would ease the passage into an oil-constrained future.

The 1999 recommendations of the Sustainable Energy Transport Taskforce of Engineers Australia [15] were more specific and quite compatible with those of the NCTR in 2004. These have not been fully adopted yet and remain appropriate actions:

1. Taxation and fiscal policy instruments should encourage sustainable transport.

2a. There is a strong case for increased investment in transport infrastructure that offers the opportunity to develop a transport system that is integrated, more sustainable and less greenhouse gas intensive.

2b. The market is the appropriate mechanism to allocate resources between individual transport modes, but where market forces fail to deliver environmental and social objectives governments should intervene.

3. More holistic approaches that integrate environmental considerations into transport policy, planning and investment decisions are needed. They should go beyond current Commonwealth and State and Territory environmental impact evaluations in order to examine wider impacts on health, sustainability and greenhouse gas emissions.

4a. There is a need for industry, innovation and research and development policies and commitments to support the development of cleaner transport fuels and technologies.

4b. Additionally, there is a need for research into transport pricing, economics and demand-management technologies.

(Some 22 sub-recommendations were also made).

These recommendations are already more than six years old and time, like oil, is not a commodity that can be extended indefinitely.

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World

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International Energy Agency	http://www.iea.org
Oil & Gas Journal	http://ogj.pennnet.com/home.cfm
Association for the Study of Peak Oil (ASPO)	http://www.peakoil.net
US Energy Information Administration	http://eia.doe.gov/emeu/consumption/index.html
World Business Council for Sustainable Development – "Mobility 2030" & "Mobility 2010" reports	http://www.wbcsd.ch

Australia

"Securing Australia's Energy Future" White Paper	http://www.pmc.gov.au/energy_future/index.htm
"AusLink" White Paper (and prior Green Paper)	http://www.dotars.gov.au/auslink
Australian Institute of Energy	http://www.aie.org.au
Australian Institute of Petroleum (AIP)	http://www.aip.com.au
Australian Petroleum Production and Exploration Association (APPEA)	http://www.appea.com.au

Engineers Australia

"Responding to the Challenges" Report of the Sustainable Energy Transport Taskforce	http://www.ieaust.org.au/library/publications/SustainableTransport.pdf
"Transport, the Environment and Health in Australia" – National Committee on Transport (NCTR)	Discussion Paper in http://www.nctr.org.au

position paper

Response to the National Committee on Fuel and Energy's draft Energy RD&D policy paper from NCTR (2004)	Discussion Paper in http://www.nctr.org.au
Submission to DOTARS on AusLink Green Paper 2002	http://www.ieaust.org.au/policy/res/downloads/govtsubmissions/03004.doc

Other

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