STATE SUSTAINABILITY STRATEGY
OIL VULNERABILITY
SUBMISSION BY
BRIAN J FLEAY
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INTRODUCTION

This submission will focus mainly on sustainable energy options to petroleum fuels and on the central position that the non-renewable petroleum fuels play in our present lifestyle, viz. oil and natural gas. This is a vast subject and pressures of time and other commitments will prevent me from commenting on all but a limited number of topics. Key websites will be given as references.

An understanding of the central role that energy plays in all economic and social activity is central to developing all sustainability strategies. My stand point comes from the rapidly growing field of ecological economics which is built around the central role that energy and resource quality characteristics play in economic and social activity. Such an understanding is absent in neo-classical economics and is a major flaw in this discipline which is thereby unable to satisfactorily address issues of resource and environmental constraints.

I will focus on the energy performance indicator of net energy yield from primary energy sources, as well as the related performance indicators of Energy Profit Ratio (EPR) and of the embodied energy content of goods, services and labour. Net energy yield is the useful energy remaining after subtracting from the gross energy output both the direct and indirect energy consumed in extracting and converting energy from the primary source into a useable form**. Only the net energy output is available to perform useful work for humans.** EPR is the ratio of gross energy output to this direct and indirect energy input Other characteristics affect the economic utility of an energy sources as well, like ease of storage and transport and fine control characteristics.

In the case of goods, a mineral is regarded as 'high grade' if it has a high metal content. For example, the best iron ore has a metallic iron content of around 60 per cent. It is regarded as high grade because the energy needed to mine and convert the ore into iron is less than that needed for lower grade ores, and therefore the iron is cheaper in both energy and dollar terms. It has a low embodied energy content. The highest grade mineral deposits tend to be mined first so that, over time, the cost of obtaining iron tends to increase as ore grades decline.

High quality petroleum fuels and electricity since the 1930s have so far countered these trends. But for petroleum fuels, from now on, we can expect its energy quality to diminish as net energy yields from these sources decline - net energy will decline faster than gross petroleum supply as the resource is depleted. Improved technology can partly compensate for rising costs from declining mineral resource quality, but will eventually be overwhelmed by the sheer volume of ore that has to be mined and processed with increasing energy input. The energy cost of recycling iron also sets a limit to the scope for recycling iron products that are discarded after their usefulness has come to an end. It is not possible to achieve 100 per cent recycling.

Not all energy sources are equivalent in applications. Quite apart from any equivalence they may have in net energy yield, different energy sources have different qualities that render them more or less effective in economic activity. Solid coal is less useful than liquid petroleum fuels. Electricity cannot be easily stored whereas liquid petroleum fuels can, a factor that disadvantages the application of electric power in transport. Energy quality is an important factor and is wider in scope than EPR. To paraphrase the famous quotation from George Orwell's book *Animal Farm: "*All fuels are equal but some are more equal than others".

This submission will summarise conclusions in the book *Beyond Oil* (Gever et al 1991) with some reference also to *Energy and Resource Quality* (Hall et al 1986). Both books focus on the United States with some international reference and give the theoretical background to net energy yield and related concepts. Both books are available on the Boston University's Center for Environmental and Energy Studies website, **www.bu.ed/cees/wpaper.html**. Click Research and look up publications. The 1999 paper by

Cutler Cleveland on the same website, *Biophysical Economics: From Physiocracy to Ecological Economics and Industrial Ecology,* gives a good overview of ecological economics and its critique of neo-classical economics in the context of this submission.

The core of *Beyond Oil* reports on a modelling of the US economy to 2025 using a conventional economic model adapted to incorporate energy and resource constraints disregarded by the conventional model. The work was carried out at the University of New Hampshire in the early 1980s. The adaptation of the conventional model to incorporate net energy and other resource constraints made it particularly suited to long term modelling, but not for the short term.

The reference model suggested that US Gross National Product (GNP) per capita would peak between 2000 and 2005 and then decline to 1950s levels by 2025, due to the stage then expected for depletion of US oil and natural gas resources, as well as the declining grade of key minerals and the productivity limits of a petroleum dependent agriculture, compounded by soil degradation. Components of the model were first validated against historical economic data.

It is worth noting here that GNP is a poor indicator of welfare as it fails to distinguish between economic activities that contribute to welfare and those that detract from it and omits factors that are outside market transactions. Gever et al were aware of this deficiency.

Sensitivity tests of the reference case were made by varying input parameters and by modelling alternative "hard energy paths" (e.g. nuclear and coal) and "soft energy paths" (renewables, solar, energy efficiency, demand management). All these variations consistently showed GNP per capita peaking between 2000 and 2005 and then declining, suggesting this is a robust conclusion for the US. However, the outcomes and implied social structure on the downside were quite different for the "hard and "soft" paths.

The declining EPR rates and trends for US fossil fuels along with the corresponding EPRs for "soft path" alternatives and their trends and respective energy qualities were key factors in shaping the outcomes of the modelling. The earlier the transition to post-petroleum fuels begins the less traumatic the transition. Delay the transition and the modelling showed a decline of over 60 per cent in per capita GNP in less than 20 years before a partial recovery. Introduction of post-petroleum fuels requires the diversion of some current energy resources to develop these alternatives and build the appropriate infrastructure. If this task is delayed until the net energy yield of petroleum fuels has become too low and dependence on imports too high, then the diversion can only occur on a sufficient scale at the expense of the rest of the economy. In particular for solar electricity most of the energy input is in the initial installation, similarly for energy efficiency initiatives. Much energy inefficiency is built in to existing infrastructure and cannot be quickly changed. Restraining population growth helps. You cannot have your cake and eat it too.

Beyond Oil was originally published in 1986 with a second edition in 1991 which reaffirmed the conclusions reached in the 1986 edition. Nothing has happened since to fundamentally change these conclusions. And what happens in the United States affects the world, and certainly Australia.

There is to the best of my knowledge a lack of information on the net energy yields of Australian fossil fuels and their derivatives, along with their lifetime profiles and trends. Studies on the net energy yield and economic qualities of alternative energy sources is urgently needed - not enough is known. Further work is needed on the embodied energy content of Australian goods, services and labour - again not enough is known, especially on recent trends. Such information is vital to successfully develop and implement a State Sustainability Strategy embracing Oil Vulnerability and to provide some of the hard objective criteria on the difficult choices that we now face.

But before this is done there needs to be *standardised criteria* for making such net energy yield and embodied energy determinations. *In particular a standardised approach for net energy yields* is needed to ensure that the embodied energy from ALL services and labour is included in the energy input assessments. There is a tendency to under-estimate the energy input supporting many services and labour.

This submission has a national focus in a global context as most of the immediate action and information gathering needed is of national significance. There is a need to both take urgent action at a State level and to lobby the Commonwealth to play its part. in a national sustainability strategy.

WORLD OIL SUPPLY

Since 1995 a consensus has been emerging in the petroleum industry that world production of cheap oil will peak around 2010, then decline at a rate mainly governed by the physical performance characteristics of oil wells and oil fields. This consensus considers the Age of Oil will essentially be over by 2050. Cheap oil (conventional oil) in this context includes the easily accessible and extracted free flowing oil mostly obtained from giant oil fields (> 500 million barrels - one barrel equals 159.9 litres). These comprise less than one per cent of all fields and produce at very low cost and mostly with a very high EPR. Oil discovery peaked 40 years ago and few giant fields have been discovered since 1980. Oil is now being consumed at four times the rate of discovery. 80 per cent of current production comes from ageing fields more than 25 years old.

There is still a large recoverable resource of non-conventional oil - mostly heavy oil (highly viscous), fields offshore in deep water, oil from tar sands and so-called oil shale. It contributes a limited amount to current production but at high cost. Most production will occur post peak and have a long flat profile due to the enormous cost, acute environmental and other problems, especially for the solid hydrocarbons sources. After 80 years of trying there has yet to be a commercially viable oil shale project. It is doubtful whether oil from so-called oil shale can ever have a positive net energy yield.

Two retired petroleum geologists, C.J. Campbell and J.H. Laherrere, have been the leaders in this debate, supported by others. An overview of their work and the issues raised by it is given by Les Magoon (2000) from the US Geological Survey and is on their website - **http://geopubs.wr.usgs.gov/open-file/of00-320/** . This overview is mostly for conventional oil, excludes condensate from natural gas and is based on an ultimate discovery and production of 1800 billion barrels with an estimated 180 billion barrels yet to be discovered. About half the this ultimate has been produced. Non conventional oil and natural gas liquids stripped from natural gas supply just over 10 per cent of current liquid hydrocarbon production.

A more comprehensive overview of world oil discovery and production is in a paper by Laherrere, "*Forecasting future production from past discovery",* given to an OPEC seminar in Vienna, September 2001. It covers both conventional and non-conventional oil, including deep sea offshore oil since 1990. The paper is available on **www.oilcrisis.com** . He covers some regional oil provinces as well. Laherrere gives a good outline of the difficulties in interpreting the industry data base, given its inconsistent definitions, commercial confidentiality and the political motivations that influence the reliability of the data. He also gives a brief summary of the critical natural gas supply situation rapidly emerging in North America, and a preliminary overview for world natural gas. It is likely that North America natural gas will peak within five years, the first major gas province to do so. The decline rate will be steep. North America produces some 30 per cent of the world's natural gas.

A range of views from this school of thought on oils future can be found in the Hubbert Center Newsletters on **http://hubbert.mines.edu** . This lobbying newsletter has been published quarterly since late 1996 by the M. King Hubbert Center for Petroleum Studies based at the Colorado School of Mines, USA. Issue 2002/1 gives a good overview by Matthew Simmons of the role of giant oilfields. Simmons is a merchant banker from Houston Texas whose firm specialises in financial services to the US upstream petroleum industry. He is also a member of the US President's Energy Committee. Since mid-2001 he has joined the Campbell/Laherrere camp on the future of petroleum fuels.

Ivanhoe, also in issue 2002/2, describes the major problems associated with tar sands production in Alberta, Canada and the very high consumption of very cheap local natural gas associated with it. - well below rising gas prices in the North American market. Riva in the same issue describes the developing Canadian natural gas supply crisis in the North American context and its likely impact on Canadian tar sands and heavy oil economics. The EPR of oil from these tar sands is less than two (Youngquist 1997).

Hubbert Center Newsletter 98/4 has an excellent article by Youngquist on the shale oil saga. Articles in other issues describe the oil status of many other countries and regions.

The US Geological Survey in 2000 published a report that gave a more optimistic picture of 3000 Gb for world ultimate production than the 1800 Gb of the Campbell/Laherrere school. The USGS forecast new discoveries of 732 Gb between 1995 and 2025 from the many as yet poorly explored sedimentary basins. That is an average of 25 Gb per year. Campbell (2002) has challenged this projection, pointing out that annual discoveries from 1995 to 2001 averaged 10 Gb and would now require an average discovery rate of 30 Gb to 2025 to reach this target. And in the past large fields have been found early in exploration - one would expect average discoveries so far would be higher than 25 Gb per year. Nearly all these basins have had initial surveys using modern sophisticated exploration techniques. Preliminary wildcat drilling has had little success which is why companies are now scaling down their exploration activity. Campbell says the USGS estimates are based on unrealistic assumptions, neglecting the real problems that oil explorers face.

Production has been buoyed since 1990 by non conventional oil from deep water offshore, from discoveries under the Caspian Sea since the collapse of the USSR and a shift of focus back to the Persian Gulf producers who have nearly 60 per cent of the world's remaining conventional oil. But the volatile oil prices associated with the political and economic uncertainty that now surrounds Persian Gulf oil supply and the resulting risky investment environment for oil development will have a major impact on the outcome. These factors suggest 2010 as the likely timing of the global peak of oil production. The Australian Petroleum Producers and Exploration Association (APPEA) has publicly acknowledged this possibility (Jones 2002). However, there is no firm guarantee that appropriate petroleum investment will occur in the Persian Gulf countries in time on the scale required to meet expected consumption growth to 2010.

AUSTRALIAN OIL AND GAS

Given this global scenario, what are Australia's oil prospects? Both APPEA and Woodside Petroleum have called on the Australian Government to urgently develop a long-term energy policy due to an expected rapid decline in our oil-self sufficiency over the next decade (Jones 2002, Akehurst 2002). The essence of their conclusions based on the federal governments Geoscience Australia forecasts for oil and condensate production to 2010 are:

- Since 1995 Australia has been consuming oil and condensate at three times the rate of discovery.
- Australia's oil and condensate self-sufficiency will decline from its present 80-90 per cent to less than 40 per cent by 2010.
- The size of oil fields is diminishing - an increasing proportion of production is from smaller fields with shorter lives.
- Australia has low oil prospectivity. New discoveries are expected to be of small size and more technically demanding with higher risks - e.g. heavy oil and increasingly in deep water offshore.
- Consequently exploration and development costs are rising and companies are shifting their focus overseas.
- The trade deficit on hydrocarbons could change from a surplus of $1.2 billion to a deficit of $5.6 billion by 2005 and $7.6 billion by 2009/10 ($US20/barrel and $A1=$US0.55).
- Reduced federal government revenue from Resources Rent Tax of $1 billion and lower company tax revenue.
- Imports will have to come from the Middle East. These will be increasingly insecure, prone to unexpected disruption and competition from other importers of oil.
- This will occur in the context of declining world oil production outside the Middle East.
- **Australia should urgently shift to natural gas based fuels to replace oil based petroleum products, and develop other alternatives like hydrogen and ceramic fuel cells, especially for transport.**
- **Reduce oil consumption through demand management initiatives.**
- Further development of public transport infrastructure.
- The need for tax and depreciation concessions by governments to make investment in more risky hydrocarbon developments more attractive, i.e. these will be more expensive than in the past.

- ***These issues are far more important than reform of the electric power industry to introduce competition and the possibility of cheaper electricity.***

This is essentially the same message I have been promoting since the mid 1990s.

But it raises questions on the adequacy of Australia's natural gas supplies to substitute for liquid petroleum products in transport. Australian consumption of petroleum products in 2001 on an equivalent energy basis was equal to about 45 billion cubic metres of natural gas. Natural gas production was 30 billion cubic metres and nearly 80 per cent came from Western Australia's Carnarvon Basin. Two-thirds of petroleum product consumption is for land transport (including off-road for agriculture and mining) and 12 per cent is consumed by aviation. The rest is used for remote area electric power production, ship bunkers, chemical industry feedstock, lubricating oil and bitumen. Transport consumption of natural gas is negligible.

This subject is discussed at length in Appendix 1, *A Lot of Gas*, based on the then Bureau of Resources Sciences (now part of Geoscience Australia) 1995 median estimate of ultimate natural gas recovery (EUR) of 4000 billion cubic metres (bcm) and a May 1997 Australian Gas Association/Australian Bureau of Agricultural and Resource Economics estimate of natural gas production to 2030, based on a "wish list" of projects. The "wish list" made negligible allowance for natural gas use for transport. Subsequent developments have not materially affected the 4000 bcm estimate (about 10 per cent produced to date). Current discoveries are around 3100 bcm. The core conclusions from *A Lot of Gas* are:

- Under the "wish list" scenario Australian natural gas production could peak around 2020-25 at about 80 bcm per year. However, the timings on the "wish list" have predictably been delayed
- Varying the EUR did not significantly alter these dates and quantity.
- 80 per cent of Australian gas reserves are located offshore between Carnarvon and Darwin - some 3500 km from the eastern seaboard. Gas transport will be expensive.
- 40 per cent of undeveloped reserves are offshore in water 800-1000m deep and will be expensive to develop.
- Much of the undiscovered will also be offshore in deep water.
- Some natural gas has a high carbon dioxide content (e.g. Gorgon-Chryasor, Carnarvon Basin)
- The high development cost of offshore gas and of its long distance transport will tend to truncate a sharply defined peak in favour of a flatter plateau-like peak at less than 80 bcm per year. In these circumstances the subsequent decline rate for natural gas is usually steep.
- The gas lobby tends to publicise the upside of production and avoid discussing the downside. "The art of good marketing is never to tell a lie, but never tell ALL the truth"
- **A substantial but as yet unclear need for natural-gas based transport fuels well into this century challenges the viability of the present gas consuming and exporting agendas.**
- **There is an urgent need to assess the life cycle EPR/net energy yield of Australian natural gas projects and of gas derived fuels in these circumstances.**
- It would take a very large increase in the EUR for natural gas to significantly extend these time frames.
- **Most people, companies and agencies promoting the use of natural gas do not seem to understand these facts - or choose to ignore them.**

A gas pipeline to the eastern seaboard, either from Papua-New Guinea or Timor Sea fields, will be needed in the middle of the decade to meet growing demand as Bass Strait and Central Australian gas fields approach their decline phase. Extraction of methane from NSW and Queensland coal beds is coming on the agenda.

There is a clear scenario here of rising natural gas supply costs, both for future offshore development and for long distance gas transport. The cost of transporting natural gas over medium to long distances is 5-10 times higher than for oil on an equivalent energy basis. There will be corresponding declines in net energy yield.

The peaking of North American natural gas before 2005, mentioned above, is catching the industry and gas users there by surprise. The decline will be steep. See Laherrere (2001). As this happens attention will become sharply focussed on the future of gas supply around the world.

Natural gas based fuels for transport are not an option for North America.

The Carnarvon Basin

55 per cent of Australia's gas reserves (50 per cent probability) are in the Carnarvon Basin. Another 25 per cent are in the Browse and Bonaparte Basins (Timor Sea region). Cumulative gas production in the Carnarvon Basin reached 480 bcm in 2001 (AGSO 2000).

The Western Australian Oil & Gas Review (2001) lists the natural gas reserves for the Carnarvon Basin in the categories that follow (billion cubic metres, 50 per cent probability):

Producing fields	591
Undeveloped short-term	42
Undeveloped long term	190
Not currently viable	1145
TOTAL	2445
Produced to date	480
Reserves plus production to date	2925

The 'not currently viable' includes 800 bcm for Gorgon-Chryasor and Scarborough (Exmouth Plateau), both deep water fields and will be expensive to develop, 800-1000m depth.

Gas consuming projects on the agenda for Burrup peninsula before 2010 include:

PROJECTS	$1,000s	Tonnes/yr.	Gas 10^9 bcm/yr.
Methanex methanol plant	2,000	4,000,000	2.80
Burrup fertilsers-ammonia plant	600	760,000	0.85
GTL Resources methanol plant	610	1,000,000	2.85
Syntroleum gas-to-liquids plant	1,000	470,000	3.70
Plenty River ammonia urea plant	900	1,200,000	0.85
Japan DME dimethyl ether plant	1,000	1,700,000	~1.50
Woodside's 5th LNG train	1,600	4,200,000	5.50
TOTAL	7,700	13,300,000	18.55

Sources: WA Oil &Gas Industry 2001, West Australian 3 May 2002

The last two projects are dependent on customers signing up. China is a potential customer for Woodside's 5th LNG train.

At present Woodside's three LNG trains can convert 11 bcm of gas into 8 million tonnes of LNG. The 4th train under construction expands capacity to 12 million tonnes per annum increasing gas requirements to 16 bcm of gas. A fifth train brings capacity to 16 million tonnes per annum requiring 21 bcm of natural gas. **Another 4-5 bcm of gas per annum is needed to liquefy this gas to LNG at -140°C.**

In addition there is a growing focus in Australia on using gas turbines for electric power generation. The first five projects would consume about 180 bcm of gas by 2020 (say 15 years) and the last two about 70 bcm (say 10 years). Current production continued to 2020 would be another 500 bcm plus 65 bcm to liquefy gas to LNG, total 815 bcm. Add produced-to-date and the total comes to 1300 bcm - nearly half of reserves and by implication near peak production capacity - or already there. In addition there is new electric power generation, mining growth and the dream of minerals to metals projects - the latter big consumers of gas.

On this agenda perhaps half of Carnarvon Basin gas reserves would be depleted by 2020 BEFORE any provision is made for a major commitment to Australian transport AND of expected gas supply to the eastern seaboard, presumably offshore from the Timor Sea region.

Can new discoveries fill the breach? The Carnarvon Basin is approaching maturity and it is likely most large discoveries have been made - these usually occur first because they are large and more easily found. There may be scope for more large discoveries in the Browse and Bonaparte Basins where exploration is at a less mature stage. But industry consensus expects most new discoveries will be made in deep water further offshore than existing fields. These gas discoveries need to be very large to sustain production at levels sufficient to cater for transport fuels well beyond 2020 the eventual transition to non-hydrocarbon fuels AND sustain the present "wish list" of gas consuming projects well into the century. **Natural gas IS a non-renewable resource.**

There is a clear scenario here of supply limitations and of rising natural gas supply costs, both for future offshore development and for long distance gas transport. The cost of transporting natural gas over medium to long distances is 5-10 times higher than for oil on an equivalent energy basis. There will be downward pressure on net energy yields, particularly for natural gas based transport fuels.

The peaking of North American natural gas before 2005, discussed above, is catching US industry and gas users by surprise, the first major gas province to do so. The decline will be steep and impact severely on peak electric power capacity. See Laherrere (2001), figures 15 to 18, and *Methane Madness* in www.oilcrisis.org. As this happens attention will become sharply focussed on the future of gas supply around the world.

Natural gas based fuels for transport are not an option for North America.

TRANSPORT

Natural gas as a transport fuel is not as convenient to store and transport as existing liquid petroleum products, because it is a gas. Existing IC engines can be converted to burn natural gas, but best performance is obtained from engines specifically designed for natural gas. CNG fuel tanks for vehicles are bulky, must be pressure vessels, are heavy and more expensive by comparison to petrol and diesel tanks. Energy is required to compress the gas, even more so if the gas is used as LNG.

For these reasons interest is rising rapidly in gas-to-liquids (GTL) plants to convert gas into liquid transport fuels for the existing vehicle fleet - a plant is proposed for the Burrup Peninsula. But such processes consume energy, reducing considerably the net energy yield of the original gas. There is the energy input in building, operating and maintaining the plant. Thermodynamic theory tells us that any such energy conversion process *necessarily* leads to a substantial loss of energy - as much as 20-30 per cent from the process alone. Further lowering of net energy yield.

Hydrogen is being promoted as a transport fuel, both in suitable IC engines and using fuel cells for direct conversion of hydrogen to electricity, now under development. But hydrogen is not a fuel, it is an energy carrier, it must be manufactured using other fuels and, being a gas has similar problems in storage and transport to natural gas. Similar losses of energy occur in these transformation processes as for GTLs. Typical processes are steam reforming of coal and natural gas, and electrolysis of water. In the latter case there are two transformation steps - conversion of a fuel or solar energy to electricity, then the electricity to hydrogen, each with attendant thermodynamic losses. 15 per cent of the energy content of hydrogen is needed to compress it for storage as a gas and 30-40 per cent for its liquefaction (Garrity 2002). Fuel cells high efficiency in converting hydrogen to electricity (~75 per cent) will partly offset these inefficiencies.

The large scale production of biofuels for transport (ethanol from grains, biodiesel from oil seeds) is not an option for even a significant fraction of current oil use. The net energy yield is small or negative, the area of land required is large at the expense of food production and the consequences for soil degradation unacceptable (Giampietro et al 1997).

The conversion from coal fired steam locomotives to diesel electric for rail transport in the mid 20th century was a shift from an inferior fuel system with very low energy conversion efficiency into motion, as well as poor fuel handling and storage characteristics. Its successor has had the opposite characteristics, substantially reducing the cost of rail transport and facilitating the change over. This, along with the maturing of petrol and diesel powered road transport in the same period, has contributed significantly to the long economic prosperity and increased productivity since 1950, especially up to 1975 when oil production was in its most energy productive and cheapest supply phase and population lower. Petroleum products have made commercial aviation possible.

It is almost certain that the resource depletion driven transition from oil-based transport fuels to alternatives fuels will have the opposite characteristics and be a more difficult transition than that from coal to oil.

Finding and introducing alternative fuels for aviation will be the most difficult task. Aviation is the transport mode most vulnerable to cheap oil depletion.

Cheap transport fuelled by petroleum products has created the contemporary tourist industry. What is its future in the oil depletion scenario?

Quantifying the life cycle EPRs of existing and alternative transport fuels, along with other energy and resource quality characteristics, are central to a State Sustainability Strategy. Such criteria will help define how urgent the change over task is, help define priorities, define unproductive pathways, give guidance on the rate at which change is possible, give guidance on where the greatest gains can be made quickly with the least effort, and show which economic and social areas are most at risk.

The immediate scope for reducing transport oil dependence is through demand management strategies - reducing unnecessary travel. The Dept. of Planning and Infrastructure's Travelsmart program to reduce urban car use is an example. Introducing an awareness of the necessity to reduce oil dependence into the Travelsmart agenda can make it a very powerful vehicle for change, given its focus on the personal motivation of people to change their travel habits. People will become inspired to take wider initiatives and be motivated to make the needed cultural changes. Travelsmart needs extending to the outer urban areas of Perth and to major regional towns. A shift to public transport combined with appropriate land use planning strategies can reduce oil consumption in major urban areas.

There is considerable scope to eliminate unnecessary freight traffic - the carting of "coal to Newcastle". For example, I believe Carnarvon supermarkets sell Queensland bananas when these are grown in Carnarvon. Carnarvon horticultural produce is transported to Perth wholesale markets with some returned for sale in Carnarvon! The dairy industry has been deregulated under Competition Policy and dairy farmers in Queensland, NSW and WA have been paid to exit dairy farming so that Victorian milk and milk products can be exported to these states!
Rail freight can be considerably more energy efficient than road freight over medium and long distances.

Global industrial production processes are developing into an international network where components are manufactured in many locations for assembly elsewhere. No one country has the complete industry, e.g. automobiles. Freight transport chains are lengthening and national freight transport is increasingly being built to accommodate this trend. The population of many countries and regions are increasing beyond the local food production capacity and becoming dependent on long haul food imports. It all depends on cheap oil-fuelled transport. **This is a dangerous development not sustainable in the medium term.**

I am confident that the cost of almost all powered transport is going to increase in real terms. The big questions are by how much, how quickly and what the new cost differentials between transport modes will be.

Transport is an important factor in every facet of human activity.

AGRICULTURE

The world limits to available good agricultural land were reached in the 1950s after more than two thousand years of expansion. The world's population has doubled since 1960 and the increase has been fed by a more than doubling of grain production through increased yields per hectare. New hybrid grain varieties combined with wide use of artificial fertilisers and an expansion of irrigation have made this possible (Brown 1999).

The increased productivity has been achieved by greater energy intensity, principally through use of petroleum products (Pimentel 1994). The USA, Canada, Australia and the Argentine supply 80 per cent of world food exports. Mechanisation of agriculture (tractors etc) in these countries has enormously increased labour productivity, facilitated the use of phosphorous and nitrogen fertilisers and has depopulated the countryside with people moving to the cities. In the more densely populated countries of Europe, Asia and Egypt their has been less emphasis on mechanisation and more on use of fertilisers to increase yields (Conforti & Giampetro 1997). A critical role has been played by nitrogen fertilisers manufactured from natural gas in a very energy intensive process, an eightfold increase from 1960 to 1990 with just over half the increase in Asia (Smil 1997). **These largely petroleum fuelled practices have enabled a more than doubling of world population since 1950.**

This feature of contemporary agriculture has been described by Bartlett as: "a way of using land to convert petroleum into food" (Youngquist 1999).

What of Western Australian agriculture? In the wheatbelt from north of Geraldton to Esperance the soils are so nutrient deficient that cereal growing is not possible without use of superphosphate. This fertiliser is also indispensable to growing leguminous plants like subterranean clover and lupins, both to maintain an adequate protein content in grains and to increase yields, and to maintain economically viable stock carrying capacity. These legumes trebled stock carrying capacity in the wetter western zone. Even so use of nitrogen fertilisers has been increasing since the 1980s leading to soil acidification and deteriorating soil conditions (loss of organic matter among others). Some farmers are now adding lime to counter the acidification. To avoid the adverse impacts of ploughing (soil compaction from heavy machinery, erosion risk etc.) for weed control farmers use minimum tillage practices that substitute petroleum based herbicides for ploughing.

In 1996 560,000 tonnes of superphosphate was used in WA, 250.000 tonnes of urea and lime use is expected to grow to 1,000,000 tonnes over the next decade to counter soil degradation. The supply and application of these chemicals has a significant transport component. The agricultural products have a long transport haul to markets.

The energy intensity of WA agriculture is high and increasing, mostly dependent on oil based fuels. Furthermore, dryland salinity, a consequence of clearing the land for agriculture last century, threatens the viability of existing cereals cultivation and farming practices. Farmers are recognising the necessity to radically change these crops and practices to ones that absorb or divert rainfall before it reaches ground water tables so that rising water tables do not mobilise salt in the landscape. Broad based initiatives to reduce oil dependence need weaving into this agenda - as big an issue as salinity itself.

Existing wheatbelt farm practices and crops are not viable on BOTH salinity and oil dependence grounds. What alternative energy options are there? How does this interface with alternative farm practices and crops compatible with arresting salinity and commercially viable farm communities? This is arguably the most significant sustainability issue in Western Australia. It will take decades to effect the transition.

The energy intensity of the whole food supply chain from farm to kitchen cannot be ignored as well. Food processing and storage, refrigeration, distribution networks, transport and cooking are all energy intensive. There is a significant hydrocarbon input.

Some work was done in Australia around 1980 on the energy intensity of the food chain from farm to kitchen. There is an urgent need for new studies to update and expand this work to more clearly identify the opportunities for reducing energy intensity and oil dependence.

The dependence of agriculture and the food chain on petroleum products along with land degradation from salinity and related issues are the most important issues on the sustainability agenda for Western Australia.

GREENHOUSE

Global warming and climate change arising from the enhanced greenhouse effect is primarily due to rising carbon dioxide levels in the atmosphere from burning of fossil fuels and has become a major international issue. It is generally regarded that coal is the worst offender among the fossil fuels due to its high carbon content, followed by oil, then natural gas. Greenhouse issues are a factor in the growing popularity of natural gas as a primary fuel. However, it is not clear whether these assessments take into account the embodied fossil fuel energy used in the extraction, transformation and delivery of carbon-based fuels to their final use, or of their derivatives such as electricity, gas-to-liquids, NGLs and hydrogen.. Some natural gas has a high carbon dioxide content, e.g. Gorgon-Chryasor in the Carnarvon Basin. Sequestering the carbon dioxide to prevent its release to atmosphere will involve an energy input releasing carbon dioxide.

It is possible that the carbon dioxide emissions generated in extracting and delivering natural gas and natural gas derived fuels to their final end use could be substantial in some instances. More attention needs to be given to this issue. Coal may not always be so inferior to natural gas in the greenhouse stakes as many people think when a holistic view is taken.

CONCLUSIONS

There is growing if reluctant acceptance in the petroleum industry and among informed people that world oil production is likely to peak and begin to decline around 2010. The supply focus will progressively shift to the Persian Gulf oil producers. During the same period Australian oil self-sufficiency is expected to decline rapidly. However, very few are aware that North American natural gas production is also peaking and will go into steep decline during the same period. These events will change the course of history.

Oil and natural gas currently supply nearly two-thirds of the world's commercial energy and are the most economically effective of these primary energy sources. 60 per cent of world oil production fuels its transport systems and hydrocarbons are now an indispensable input to agriculture, necessary to feed an uncomfortably large proportion of the world's population. Populations issues and food supply are intimately linked to the economic role of hydrocarbon fuels. Hydrocarbons are the principal feedstock for petrochemicals, e.g. plastics, synthetic fibres, paint. Natural gas is fuelling electric power production on an increasing scale and is an important source of energy for mineral processing and heat.

The world must now adapt to using less oil and look to alternative fuels where these can substitute for oil. This change-over will take decades and require diversion of hydrocarbons to develop and introduce the alternative energy sources and fuel structural change to adapt to the new sources unique characteristics.

The pace of change will be governed by the rate at which hydrocarbons can be diverted to these tasks without undermining existing economic and social well-being. Natural gas is an important transition fuel to an age 'Beyond Oil' - but it must be seen as just that - a transition fuel to the post hydrocarbon age. Natural gas is also a non-renewable resource. The earlier the transition is consciously pursued the easier the transition will be. Delay and extreme economic and social trauma is likely.

This is why the issue of Oil Dependency should be the most important facet in the State Sustainability Strategy (SSS). And why a sound Sustainability Strategy is long overdue. The SSS must advocate a national sustainability strategy with a global focus - the State is limited in what it can do by itself.

This is where the ecological economics concepts of net energy yield and energy profit ratios of energy sources, together with the embodied energy content of materials, goods and services, are critical parameters needed to guide us through the transition. Doubly so when neo classical economics is seriously deficient in this area. Main stream economists do not recognise that net energy yield and energy quality issues significantly limit the scope of energy substitutes for oil as we have known it so far.

The SSS must advocate as a priority the assessment of the life cycle net energy yield and EPR trends of both our primary and secondary energy sources, and of the embodied energy in goods, services and labour. It is unlikely that alternative energy sources can match in performance oil as we now know it. Another important reason to assess and quantify net energy yields.

This should be a national task, but the State cannot afford to wait for this to happen. Without this critical information a sound SSS on energy is not possible.

It is equally important to inform the public so that they can understand these energy issues and opportunities much better. They will be less likely to be diverted by "snake oil" merchants - and there will be many of these. The basic concepts are simple and not hard to understand.

The SSS must also give a HIGH PRIORITY to a study of the current agenda for natural gas development and high gas consuming projects, if natural gas is to play a major role well into this century as a transport fuel in the Australian transition from oil dependency. The State has a major responsibility here, having 80 per cent of the nation's natural gas. We do not have as much gas as everyone thinks. "The art of good marketing is never to tell a lie but never tell all the truth."

The industry and government agencies are coy about telling the downside of oil and gas discovery and production - often for good reasons. It is difficult to confidently assess the size of hydrocarbon resources and the scope for future discoveries, even with modern technology. You can stick your neck out and get it chopped off. But there are fewer reasons now for being so coy as we approach the limits of cheap accessible oil, and reflected in the recent stand taken by APPEA and Woodside Petroleum. A good understanding of net energy concepts helps here as significant hydrocarbon resources can be given a low priority, such as shale oil, tar sands and ocean floor gas hydrates.

This submission has focussed on these embodied energy issues and on the most critical transport and agriculture uses of petroleum products at the expense of others that are also important. It is worth mentioning here labour and labour productivity.

Modern labour productivity and high material living standards are a direct consequence of the harnessing of fossil fuel energy to labour, starting with the use of coal in steam engines and for iron smelting in the 18th century. The real productivity gains came with the development of railways and steamships. The superior economic qualities of oil as a fuel in the 20th century, and later of natural gas, boosted these productivity gains. The economic quality and usefulness of electric power, itself a product of the fossil fuel age, also enhanced these productivity improvements. It became possible, at least for the economically developed world, to have rising labour productivity and living standards for everyone.

However, world per capita energy production increased from 1850 to the late 1970s and has been static ever since. I am referring to coal, oil, natural gas, nuclear and hydro electricity. The economic quality of oil supply has declined since 1980 as the world minimised its use of its cheapest oil from the Persian Gulf countries. Population increase has also been a factor.

Now we have a choice to make. Either continue a line of high labour productivity for a few and have high unemployment with all its attendant social ills., or lower our sights on labour productivity and have lower unemployment We can no longer have our cake and eat it too. Issues of social justice and equity are now paramount. Failure to follow the second path will eventually lead to social upheaval.

We have reached the climax of the fossil fuel age.

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APPENDIX

A LOT OF GAS

- AND NOT MUCH OIL

Visions, Fantasies and Reality

By Brian J Fleay
March 2002

The art of good marketing is never to tell a lie, but never tell all the truth.

BACKGROUND

In May 1997 the Australian Gas Association published its *Gas Supply and Demand Study* projecting high local consumption and export growth to 2030 and requiring a trebling of production (AGA 1997). How realistic are these dreams? How does projected production growth match with the best estimates of ultimate Australian gas production?

The projections were based on a "wish list" of gas consuming projects predicated upon high growth in both Asian economies and gas fired electricity generation in Australia. Western Australian projects included expansion of LNG exports, petrochemical and nitrogen fertiliser plants plus four briquetted iron and steel plants, mostly by 2010. Mining developments fuelled by gas were expected to grow.

However, these projections made negligible provision for gas based fuels for transport, a role now being promoted by leading petroleum industry spokespersons as Australia's oil self-sufficiency is forecast to rapidly decline with increased dependence on Middle East imports at high cost and risk of supply disruption.

Eastern Australian gas reserves at January 1998 were 450 billion cubic metres (bcm) with 255 bcm already produced, i.e. 705 bcm discovered (AGSO 2000). The Australian Bureau of Agricultural and Resource Economics (ABARE) expects another 255 bcm to be produced to 2009/10 (ABARE 1995). Scope for additional discoveries in these states is minimal and a pipeline from Western Australia, Darwin or Papua-New Guinea will be needed around 2005 when Bass Strait and Central Australia will be unable to meet growing consumption.

Over 80 per cent of Australia’s discovered gas reserves are located offshore from the north west coast of WA, mostly in the Carnarvon, Browse and Bonaparte Basins, the latter two between Australia and Timor. In the mid-1990’s a new exploration and development phase began in the Carnarvon Basin which is reaching a mature development stage. The other two basins are at an early stage.

Unfortunately for the gas lobby the Asian Economic Meltdown from late 1997 flattened economic growth and energy consumption. Kingstream's steel plant at Geraldton has lapsed and Woodside's LNG export expansion project has only just commenced construction. The Gorgon-Chryasor gas project seems even further away. BHP's briquetted iron plant at Port Hedland has been a technical disaster and its future is under a cloud. Gold and nickel mining has slowed and technical problems at new laterite nickel plants are affecting profitability and performance.

However, government and industry hype still conveys a vision of unlimited gas driven growth, even if subdued compared to the days before the Asian Meltdown. In Western Australia new electricity generation for growth and replacement of coal-fired plant seems to be focusing on natural gas as a fuel.

What is the real position on Australia’s oil and gas supplies?

The Canberra based Bureau of Resource Sciences (BRS), now part of the Australian Geological Survey Organisation (AGSO), estimated in December 1994 that ultimate recovery (EUR) for Australia’s natural gas would be 3,700 bcm on a conservative 95% probability estimate (P95) and 4,500 bcm on an optimistic 5% probability estimate (P5), with 4000 bcm most likely (BRS 1996). By the end of 1997 about 10 per cent (407 bcm) had been produced and 3,200 bcm discovered. There have been subsequent minor additions to reserves, mainly in the Carnarvon Basin and some in the Bonaparte Basin (AGSO 2000). AGSO’s next report is due in early 2002.

Exploration and development slowed in 1998-99 but revived with the higher oil prices from 1999 to early 2001. However, major international oil companies are winding down their exploration activity in Australia (Akerman 2002). Subsequent low oil prices are again inhibiting exploration and development. Investment in the Bonaparte Basin has high risk due to its remoteness and the unstable political environments in Indonesia and East Timor. The petroleum fields there cross national boundaries and the resource will be shared between Australia and East Timor. In recent months the Bayu/Undan gas field in the Bonaparte Basin has moved closer to development, but has been deferred due to disputes over tax regimes with East Timor. This project was planned to connect with Central Australian gas pipelines supplying the eastern seaboard. Any further delay could be critical for eastern Australian gas supply. Some 2000 km of new pipeline is required to connect with 1500 km of existing pipeline from central Australian gas fields to the eastern seaboard.

OIL, NATURAL GAS AND TRANSPORT

Oil based fuels drive the transport system and are an essential input to agriculture, construction and mining. Transport consumes 60% of the world’s oil supply, and an even higher proportion in Australia. *These industry sectors were expected to consume petrol and diesel equivalent to 28.5 bcm of gas in 2000, or 80% of Australian gas production (ABARE 1995).* Fuels based on natural gas are the only ones that can readily replace oil for land transport using existing engine technology - but only at a price.

Australia has consumed about half of its EUR of conventional cheap-to-produce crude oil and our self-sufficiency is expected to decline rapidly over the next decade. Barry Jones, Executive Director of the Australian Petroleum Producers and Exploration Association (APPEA) in a paper to an Australian Institute of Energy conference in November 2001, quoted AGSO sources, saying that there was a 50% chance that Australia's oil self-sufficiency would decline from its present 85% to 90% down to 55% in 2008-10, see FIGURE 1 (Jones 2001 and Powell 2001).

A growing proportion of production will be liquids (light oils) stripped from natural gas, to over half by 2010. Further declines can be expected post 2010. Jones said relying on imports would lead to a huge loss of government revenues from resources rent taxes, a major increase in the cost of oil imports impacting on the balance of payments and damage the Australian oil refining industry. He drew attention to forecasts that production of conventional world oil was expected to peak around 2010, commencing with the current peaking of non-Persian Gulf oil - the reason why oil prices soared last year (Campbell 1997, Campbell & Laherrere 1995). The five Persian Gulf producers have 60% of the world's remaining cheap oil and currently supply 30% of production. Les Magoon (2000) of the US Geological Survey has summarised the situation for conventional oil in *Are we Running out of Oil?*, a poster on the USGS website,. Les Magoon was the Petroleum Exploration Society of Australia's Distinguished Speaker for the year and was recently in Perth. The imminent peaking of world oil is now openly discussed in the leading petroleum industry journals.

The CEO of Woodside Petroleum John Akehurst (2002), in a paper to ABAREs annual Outlook Conference, has repeated Jones' arguments pointing out that Australian oil discoveries since 1995 have only matched half of production and JUST one-third of consumption! International oil companies have almost ceased exploration in Australia which he says has low prospectivity, and mostly small fields in marginal locations, such as deep water.

Both Jones and Akehurst called for a comprehensive national energy strategy that goes beyond a review of the eastern states electricity sector, that included tax and royalty concessions for their industry. They also called for gas based fuels to substitute for oil as well as demand management initiatives.

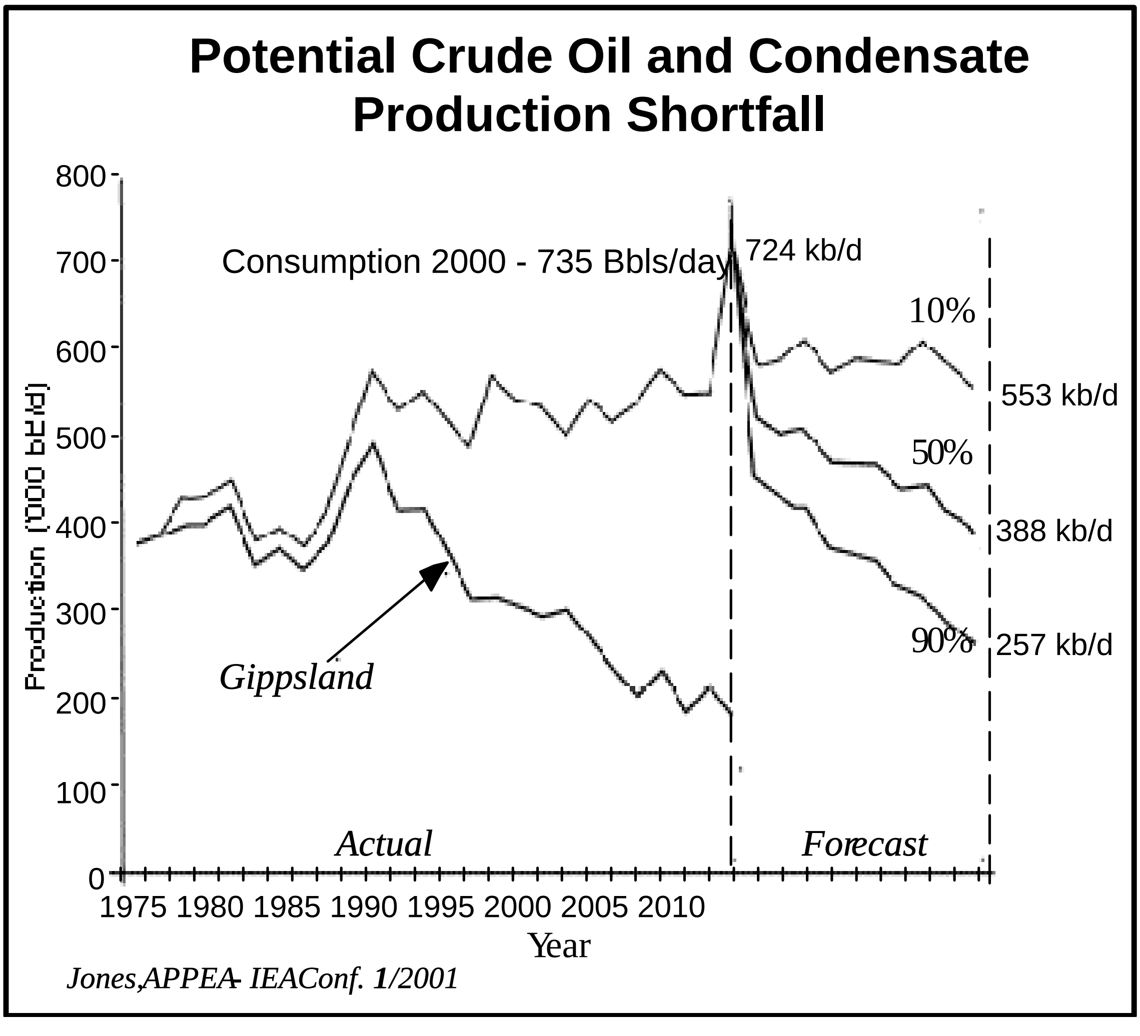

FIGURE 1

Since the mid-1980's over half the world's oil supply growth has come from Persian Gulf countries turning on wells shut down in the early 1980's, when world consumption fell while production expanded in Alaska, the North Sea and elsewhere. New oil from outside the Persian Gulf has come from expensive sources in ever smaller fields. Low oil prices since 1985 have decimated industry profit margins, has eroded the wealth of Organisation of Petroleum Exporting Countries (OPEC) and forced a downsizing of the oil exploration and development industry. By end 2000 the last of the spare Persian Gulf oil production capacity was turned on – only Saudi Arabia had limited spare capacity left (Magoon 2000). A slowing global economy in 2001 and the aftermath of the terrorist destruction of the World Trade Center in New York has reduced oil consumption and oil prices have fallen to 60% of their December 2000 level. However, this is leading to under-investment in oil development in Persian Gulf countries just when it should be expanding to meet supply from the middle of the decade.

Both Jones and Akehurst say these September 11 events in New York have enormously increased the political risk for oil supplied from the Persian Gulf and the possibility of supply disruption – almost the only region now capable of growing production for a limited period to *both* replace decline elsewhere and increase supply. The United States is particularly at risk, being by far the world's largest consumer and importer of oil.

Jean Laherrere (2001), in a paper to a seminar at OPECs September 2001 meeting, comprehensively summarises the status of oil and natural gas discovery and production trends around the world.

Barry Jones (2001) also discussed alternative fuels and options for Australian land transport and concludes that a shift to gas-based fuels is the key along with transport demand management initiatives. He said this transport fuel issue was a far more important and urgent energy issue than eastern seaboard electric power industry reform through increased competition. He said it needed urgent attention from governments (West Australian 2001). Akehurst made similar statements.

Clearly gas consumed by transport and agriculture should soon increase rapidly, adding to the pressure on supply. AGA's demand projections made negligible allowance for these sectors. Enough gas needs to be reserved to support Australian agriculture and transport through to mid-century when both sectors will have to survive without dependence on oil based fuels. By then world oil production is likely to be one quarter of present levels and world natural gas well past its peak, both with higher production costs than at present.

Can Australia's natural gas fill the breach AND support the gas driven future being promoted by the industry and government?

WHAT GOES UP MUST COME DOWN

For any non-renewable resource, like petroleum, production begins from nothing, rises to a peak, or several peaks, then declines and eventually ceases. *What goes up must come down.* But the development lobby only gives us the upside, avoiding mention of the downside like the plague. *The art of good marketing is never to tell a lie, but never tell all the truth.*

The US petroleum geologist, M.K. Hubbert, pioneered the use of the logistic equation to describe the discovery and production profiles for oil and natural gas in major petroleum provinces. In 1956 he successfully predicted the time and magnitude of the 1970 peak of US oil production in the lower 48 States. Production and discovery profiles are normally bell-shaped with the peaks occurring near the mid-point of ultimate economic production or discovery. Discovery peaks before production. The peaks for offshore development and natural gas tend to be truncated, plateau-like, due to the production constraints of offshore platforms and pipelines. It costs 5-10 times as much to transport gas than it does oil over medium to long distances.

FIGURE 2 shows AGA's consumption/export projections to 2030 (the “wish list” referred to earlier) and compares them to the 1994 BRS P95 and P5 estimates for the estimated ultimate recovery (EUR) of Australian natural gas by fitting the logistic equation to actual production up to 1998 plus AGA’s “wish list” projected to 2020, assuming the production constraints at the peak discussed above do not apply. The peak for both EUR estimates would come around 2025. Statistically the mean estimate is the most likely, or an EUR of around 4,000 bcm. Increasing the EUR by 20% (P95 to P5) does not make much difference to the timing of the peak or its magnitude!

In other words AGA's 2030 'dream' demand projection could reach a peak by 2030! But their report does not give this down side. On these projections gas production would fall to current levels in 2050. AGA did not discuss the supply position after 2030, but did include some production of methane from coalfields and imports of gas from Papua/New Guinea. These quantities do not greatly alter these dates. In particular coal field methane is difficult to extract and has a different production profile to natural gas.

The production peak usually occurs before the mid-point for giant oil and gas fields, but can come later for small fields or those offshore. These variations cancel out when the data for all fields is aggregated. Hubbert's concepts are now widely accepted. Jean Laherrere has pioneered the use of the logistic equation to describe multi-peaked production profiles where there are several phases of development, as is the case in Australia.

Of course the 1997 dream is already history with projects delayed and timings uncertain. The **production profile will certainly be multi-peaked, is unlikely to reach 80 bcm and will be flatter at the** maximum

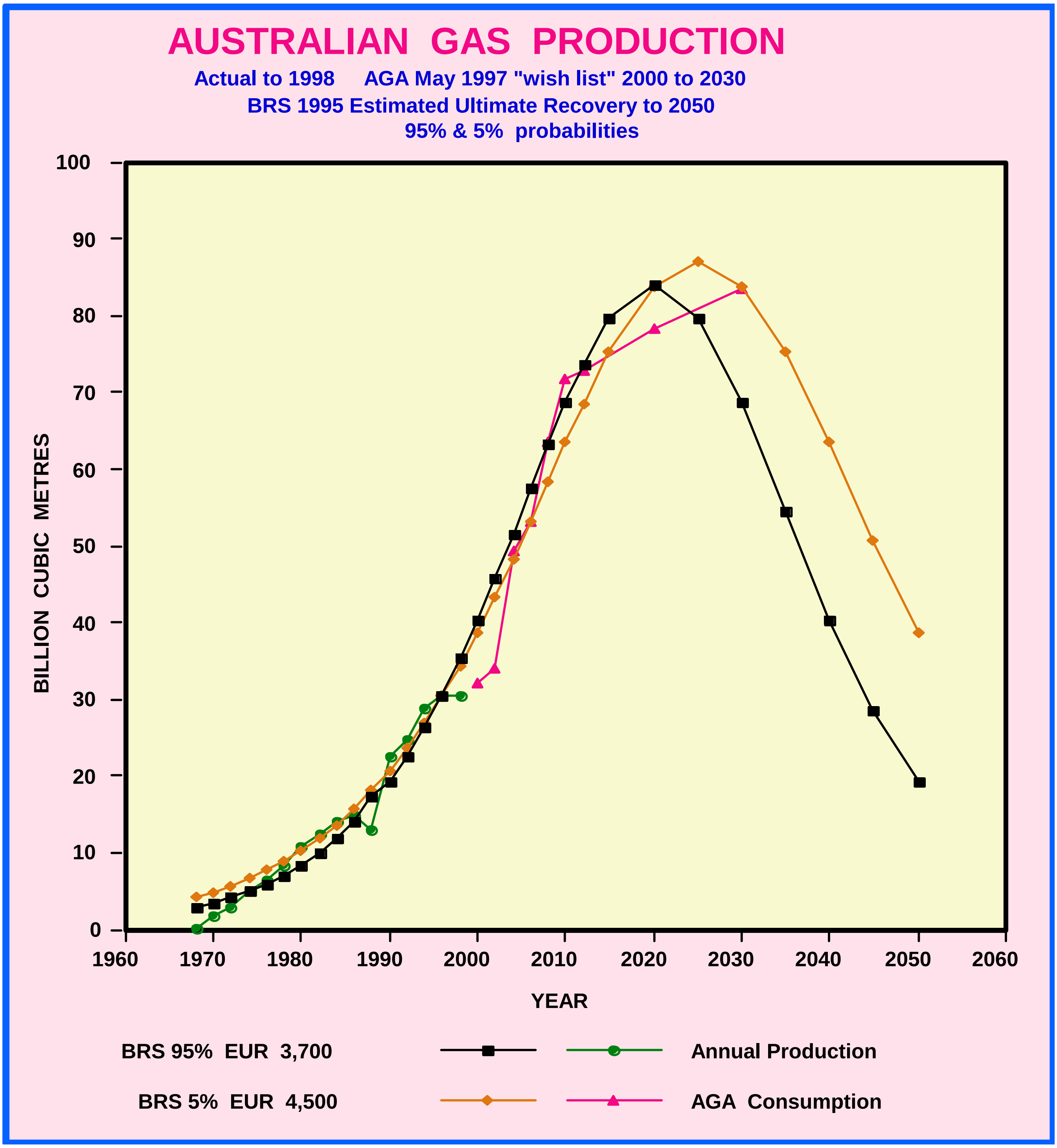

FIGURE 2

The longer large gas consuming projects are delayed the more likely the profile will assume the character of a "bumpy plateau" at somewhat less than 80 bcm/yr. Pipeline constraints will also flatten the peak. But whatever production dream is projected it can be interpreted against EUR forecasts using variants of the logistic curve, giving the downside as well as the upside. The other half of the truth.

The realism of the gas lobby's dreams must be questioned from both the demand and supply sides. What are the implications for proposed steel mills, power stations and chemical plants? Are the promoters, financiers and shareholders aware that available gas may decline so soon? Will gas become a major transport fuel? Are government agencies, economists and politicians aware? Is the public aware?

CARNARVON, BONAPARTE AND BROWSE BASINS

These basins are offshore. The Carnarvon Basin in WA is between Exmouth and Port Hedland. The Bonaparte Basin is in the Timor Sea between the Kimberley's and Timor. The Browse Basin lies to the south west of the Bonaparte Basin off the Kimberley coast. About 50% of Australia's likely EUR for gas will come from the Carnarvon Basin, 30% from the Browse and Bonaparte Basin's, the rest from Gippsland and Central Australian fields - and the latter will soon be in decline (AGSO 2000).

AGSO estimates for the EUR of Australian gas need to be qualified. Some will be very expensive. Scott Reef and Brecknock fields in the Browse Basin are 400 km north of Broome in water up to 1000m deep, 600 bcm or 15% of EUR.

Scarborough on the Exmouth Plateau in the Carnarvon Basin is 270 km north west of Onslow in water 900m deep, 230 bcm or 6% of EUR.

The Gorgon-Chryasor fields are 150 km north of Onslow, mostly in water up to 800m deep, 600 bcm or 15% of EUR (DRD 2001).

Much of the undiscovered gas is likely to be in such deep water. Bayu-Undan (100 bcm) in the Timor Sea is 500 km. from Darwin in moderately deep water. These deep water projects will be expensive to explore, develop and operate even with advances in technology, which is why the APPEA is lobbying for an exemption to wellhead taxes on production and accelerated depreciation in the tax system. Drilling costs are $5-8 million in water up to 200m deep, ten times onshore well costs, and $40-50 million in waters 1500m deep (Bulletin 1996). Floating platforms are used anchored to the ocean floor with cables. The risks are high, one such platform recently sank off Brazil shortly after commissioning.

Around 40% of Australia's remaining gas is likely to come from undeveloped fields in deep water.

Campbell (1997) says deep water economics for oil depends on very high flow rates per well and finely tuned operations that have a short life. Operations are risky and prone to massive damage if small things go wrong. These are marginal operations that are even more risky when gas is the main product.

Gorgon-Chryasor gas contains 12-15 per cent carbon dioxide. Its release to the atmosphere would significantly increase Australia's greenhouse gas emissions and it is not clear how to dispose of this and at what cost It is quite common for raw natural gas fields to have a significant carbon dioxide content.

Remaining Australian gas will be more expensive than current supply due to the higher cost of deep water gas and the long distances for transport to southern and eastern markets.

NEW FRONTIERS

AGSO has started evaluating new frontiers (AGSO 2000). Their next report in 2002 is expected to rank the prospectivity of unexplored or sparsely explored sedimentary basins in Australia (Powell 2001). Preliminary surveys have been made offshore on the Lord Howe Rise, the Norfolk Ridge, the Tasman Rise, the Kerguelen Plateau and the Townsville Trough east of the Great Barrier Reef. All these sites are in water up to 2,000m deep, are up to 800 km offshore and would be even more expensive to develop if hydrocarbon source rocks are present at all and suitable sealed giant reservoirs exist. The Lord Howe Rise is between Lord Howe Island and New Caledonia. The Norfolk Ridge is near Norfolk Island, the Tasman Rise south of Tasmania. The Kerguelen Plateau is in the Southern Ocean on the edge off Antarctica.

CONCLUSION

Statements on petroleum reserves and likely new discoveries are often political statements not to be taken at face value. Remember when production growth is projected there is always a down side. And on the downside net energy shrinks, the difference between gross energy output and the energy consumed in producing it - net energy is the useable energy produced, the parameter that matters. Production might still be profitable to the company but not so beneficial to the community. Most remaining gas in Australia will be more expensive to produce and deliver to markets. The major new use of gas for transport will rapidly challenge the current agenda for gas consuming industries and LNG export. Essential transport and agriculture - food production - must get first priority for natural gas and the available supply must be stretched out to the middle of the century. A long period of adjustment is needed to wean ourselves from our addiction to oil.

Many questions must be asked to get at the truth behind statements on oil and gas reserves and expected new discovery. What is NOT said is as important as what is said. When ALL the answers are on hand a more sober appreciation of our gas future is obtained.

Jean Laherrere is thanked for calculating from data provided the logistic equation curves in Figure 2.

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