Agricultural Competitiveness White Paper Submission - IP285
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Agricultural Competitiveness: a submission on energy supply constraints and implications for Australian agriculture.

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This submission is based upon my recently completed Masters of Environmental Science research thesis via the School of Geography and Environmental Science at the Monash University (2014). This thesis is published and in the public domain. It is entitled PEAK OIL AND OIL VULNERABILITY: WHAT ARE THE IMPLICATIONS FOR INDUSTRIAL AGRICULTURE AND RURAL COMMUNITIES? WITH A CASE STUDY BASED IN THE SOUTHERN GULF REGION OF QUEENSLAND.

It is an exploratory research format that attempts to address the issue of the peaking of world oil supply and resultant oil vulnerability means for Australian agriculture, rural communities and with a case study focussed in the community of North West Queensland where I was working at the time This submission will draw directly from sections of my thesis where relevant (included as italicised text) and would sit best in response to question 5 below, although given the supply and flow on economic and social consequences could apply to most other sections of the other questions via external influences upon material, motive power supply, economics and markets and social implications. The publishing of this research will be further pursued via application for inclusion in academic journals.

5. Enhancing agriculture's contribution to regional communities

• What community and policy responses are needed in rural and regional communities to adapt and change to new pressures and opportunities in the agriculture sector?

However this issue outlined below will have implications for all of the following areas as outline below for consideration in the White Paper.

1. Food security in Australia and the world through the creation of a stronger and more competitive agriculture sector;
2. Means of improving market returns at the farm gate, including through better drought management;
3. Access to finance, farm debt levels and debt sustainability;
4. The competitiveness of the Australian agriculture sector and its relationship to food and fibre processing and related value chains, including achieving fair returns;
5. The contribution of agriculture to regional centres and communities, including ways to boost investment and jobs growth in the sector and associated regional areas;
6. The efficiency and competitiveness of inputs to the agriculture value chain—such as skills, training, education and human capital; research and development; and critical infrastructure;
7. The effectiveness of regulations affecting the agriculture sector, including the extent to which regulations promote or retard competition, investment and private sector-led growth;
8. Opportunities for enhancing agricultural exports and new market access; and

9. The effectiveness and economic benefits of existing incentives for investment and jobs creation in the agriculture sector.

It is my knowledge that Minister Joyce is aware of the issue of peak oil having sat on the Senate Standing Committee into Australia's future oil supply and alternative transport fuels (Commonwealth of Australia, 2007b) . The Senate enquiry provided a sound, although now dated overview of the issue, with relevant sections of good analysis in relation to the economic implications. Unfortunately its recommendations were neither strong nor directed enough to drive any active outcomes.

Other useful Australia studies around the topic include the NRMA reports into transport and supply vulnerability (Blackburn, 2013, Diesendorf et al., 2008) and Dodson and Snipe's Griffith University vulnerability analysis, although this is mainly dealing with urban vulnerability, their paper cited in the text below specifically deals with agriculture. (Dodson and Sipe, 2005, Dodson and Sipe, 2006, Dodson and Sipe, 2010, Dodson et al., 2010).

Australian supply situation:

The peaking of oil supply presents a significant macro and micro challenge for Australia's global economy. Australian indigenous supply has peaked around 2000 and is in decline.

Due to its ability to meet most of its domestic needs from local oil fields Australia was buffered from the oil shocks of the 1970's because it could draw upon its own reserves of light sweet crude which is suitable for local transport fuels and was able to supply some demand on the world market (Commonwealth of Australia, 2007b); some of which Australia traded for the heavier crude suitable for tasks such as diesel fuel, lubricating oils and heavy oils for bituminous road surfaces (approximately 128 million barrels per annum in 1968). Consumption in 2009 was around 329 million barrels per annum (Department of Resources Energy and Tourism, 2010, Geoscience Australia, 2010). However, according to ABARE statistics Australia's fields reached peak point in 2000 and have been in decline since (Akehurst, 2002, Robinson and Powrie, 2004). Production has fallen from 650,000 barrels a day to less than 430,000 barrels a day since mid-2002 (Geoscience Australia, 2010, Geoscience Australia and ABARE, 2010). BP's statistical review of world energy determined that Australia's proven reserves are sufficient to meet our needs for only the next 14 years at current production rates (Bourne, 2003). This is consistent with the lower figure of oil supply constraint (2020) identified in CSIRO's Future Dilemmas report (Foran and Poldy, 2002). The CSIRO report models Australia's oil consumption to grow from 30 million tonnes currently to more than 50 million tonnes by 2015, presuming continued growth rates at the present level and does not include the potential for new technologies or fuel use efficiencies. This presents Australia with the situation of declining supplies of high quality light sweet crude, suitable for both local supplies to the petrol engine market, while losing availability of supply to the international market to offset the cost of importing oils suitable (in a global situation of increasing price) *for the transport and agriculture sectors.*

In 2003 a study found BP's statistical review of world energy determined that Australia's proven reserves are sufficient to meet our needs for only the next 14 years at current production rates (Bourne, 2003). This is consistent with the lower figure of oil supply constraint (2020) identified in CSIRO's Future Dilemmas report (Foran and Poldy, 2002). The CSIRO report models Australia's oil consumption to grow from 30 million tonnes currently to more than 50 million tonnes by 2015, presuming continued growth rates at the present level and does not include the potential for new technologies or fuel use efficiencies[1]. Foran and Crane using OZECCO modelling techniques believe

[1] Future Dilemmas note that efficiencies tend to be taken up by increased consumption.(Foran et al 2002)

that by the mid 2020's, when oil reserves fall below 30% and the energy cost for production becomes higher than the energy delivered we will cease local production.

Foran and Crane write:

The depletion date of domestic oil stocks is around 2025 (Figure 2). This date arises from the simulation following a series of moderately optimistic assumptions on the discovery of new petroleum stocks combined with increasing consumption of petroleum in line with growth in the physical economy. The sharp decrease in the graph depicting the rate of production of oil would be moderated in the real world by market mechanisms. The requirements for domestic oil and imports show a steady increase, notably in the sharp rise in import requirement after the date of oil depletion. The rate of domestic production of oil rises markedly as stocks approach depletion levels. This effect is due to an assumption that the final 30% of an oil reservoir is more difficult to extract in a physical and energy sense and more oil is used by the extraction system. The abrupt cut-off point is caused by the physical equivalent of the energy profit ratio which passes a threshold value and causes 100% of oil to be imported (Foran, Not dated).[2]

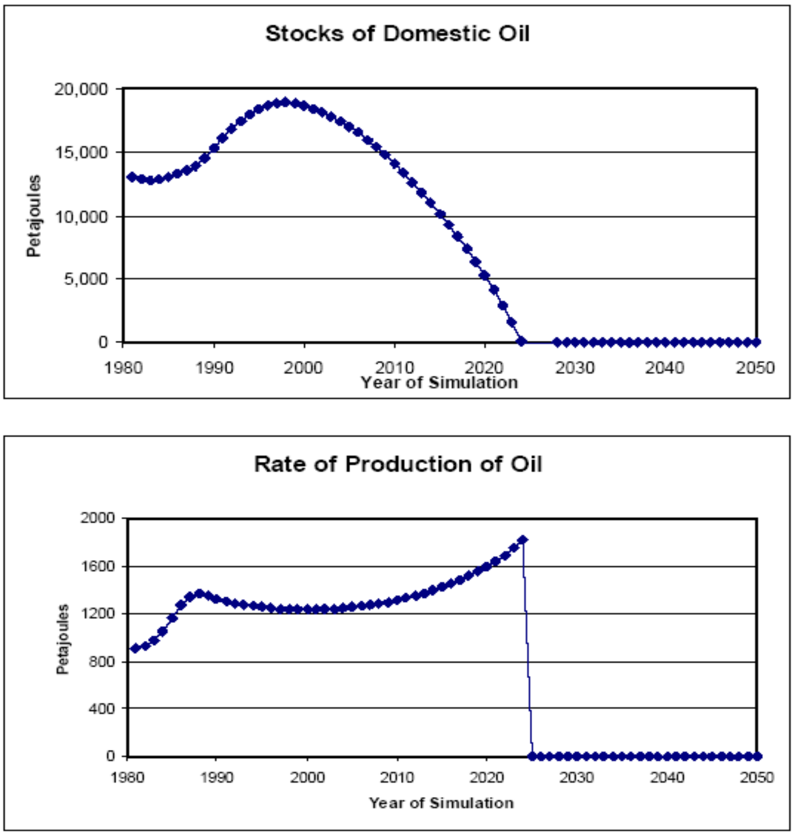


Figure 1 Australia's conventional oil production profile. Foran and Crane, not dated.

It is worth noting that this cutoff date is modeled upon "moderately optimistic" regional oil discoveries, however generally worldwide new discoveries are not making this target and there is little reason to assume that Australia will be any different, especially given it is not a key oil producing region. At present Australia is meeting its shortfall in local oil production via imports from

[2] The Federal Government (Australia) minister for resources, Martin Fergusson spoke of 10 years supply left, on the 7.30 report, ABC, April 2008

a range of oil producing nations, a number of which are also past peak. [3]This presents Australia with the situation of declining supplies of high quality light sweet crude, suitable for both local supplies to the petrol engine market, whilst losing availability of supply to the international market to offset the cost of importing oils suitable (in a global situation of increasing price) for the transport and agriculture sectors (Foran, 2002b). Australia's transport system uses 75% of oil consumed and given its size, dispersed rural populations and state capitals, poor soils and energy intensive agriculture shortages of liquid fuels and feed stocks for agriculture and industry will have flow on costs in terms of supply disruptions (petrol shortages and rationing), inflationary pressures and flow on economic dislocations(Hall, 2003, Dodson and Sipe, 2006, Dodson and Sipe, 2005). The Future Dilemmas report indicates that radical energy use reduction measures have been offered, but suggest that whilst a 50% reduction of energy use "…could provide the physical precursors for an energy and greenhouse lifestyle, where feasible and achievable rates of technical progress might stabilize primary energy use from fossil fuels…" but notes that this would be difficult "… for any government in a modern free market economy, concluding that "…most nations do not have the knowledge…(and)…control to attempt any profound change…(Foran and Poldy, 2002, Foran, 2002b)[4]. Alternatives such as coal to liquids replacement is a possible option but faces challenges in terms of EPR, greenhouse gas production and timing of infrastructure development, despite optimistic predictions from the industry itself.[5]Two recent government funded studies note the peaking of both world and Australian oil supplies and the implications for the Australian economy (Commonwealth of Australia, 2007a, McNamara, 2007a, McNamara, 2007b). The McNamara study notes that:

The Taskforce considered Queensland's and Australia's reserves of crude oil, as well as supplies of alternative sources of liquid fuels including natural gas, coal seam methane, coal and oil shale. It noted the very substantial environmental and infrastructure costs inherent in seeking to rely on these resources to address Australia's growing shortfall in liquid fuels. The taskforce concludes that Queensland's vulnerability to peaking of world oil supplies, and to world supply disruptions, is particularly acute given our oil supply and demand trends, as well as our regionally distributed population and industrial base (McNamara, 2007a)[6].

It further calls for a that a high level, whole of Government committee be established to develop a Queensland Oil Vulnerability Mitigation Strategy and Action Plan, which has been commissioned by the Queensland Government Cabinet to report in 2008[7], but to my knowledge was never released.

Australia's non-conventional gas production may provide a limited response to declining indigenous coil supply may provide some measure of infill, however issues of community resistance, environmental risks, greenhouse gas emissions the true amount of actual winnable reserves available and that that gas is sold onto the international market present constraints. Data and lessons coming out of the U.S. tight gas development should serve to inform over optimistic predictions around our own gas potential.

A sound and useful study (Powerful Choices) into the possible substitution of our liquid fuel supply via nation building scale project of massive scale eucalypt plantations, providing an economic

[3] http://anz.theoildrum.com/node/3657#more

[4] Ibid. Such options range from Lovin's Natural Capitalism method through to Trainer's The Simple Way.

[5] Cooperative Research Centre for Coal in Sustainable Development (CCSD), Media Release 05/03, November 22, 2005

[6] Page 4.

[7] http://www.cabinet.qld.gov.au/MMS/StatementDisplaySingle.aspx?id=56439

renaissance for rural Australia was prepared by Barney Foran and offers possibly the only active analysis of a response to our supply situation (Foran, 2009).

Peak Oil:

Defining peak oil is a key component of this (submission theme), *in that, as an economic and social driver it rates on scale of impact (from global to local), immediacy of event (timeframes for response and mitigation measures) and scope (being multi-sector) as an economy-changing event of a phase transition type. These effects, whilst not threatening numerous ecosystem functions as directly as climate change, will affect global economic, social, geo-political and environment changes and feedbacks on a decadal long scale. The fact that peak oil has not received greater policy and planning recognition, particularly regarding response and possible migration, will most likely be the subject of further academic analysis and societal dialogue into the future. However some of the lack of engagement in our society stems from (a) poor understanding of energy and the nature of oil production (also including other fossil fuel), (b) the availability of oil discovery and production data leading to restrictions in the development of analysis of depletion models and future supply forecasts, including the publication of over optimistic production levels and field decline rates, (c) limited understanding of Energy Return on Energy (EROI) invested and the linkage between net energy, oil supply as a significant energy source for the global economy and the relation to Gross Domestic Production (or economic activity). Therefore, public awareness of the research surrounding 'point maximum supply', plateau and predicted decline, including depletion (decline) rates is essential for the assessment of the nature of the event being studied in this research thesis….,*

Oil has enabled much of the economic activity of the post-war period (Aleklett, 2012, Fleay, 1995, Goodstein, 2004, Heinberg, 2003). It has provided a flexible, energy rich hydrocarbon fuel stock essential for not only the internal combustion engine but also a range of plastics, fertilisers, pharmaceuticals and the just-in-time long chain economic systems that now form the basis of our complex industrial civilisation. The integral nature of oil in sustaining industrial society and activity has resulted in it becoming an invisible although essential driver of modern culture.

The term peak oil has come to mean the point where either or both conventional oil (easy to find, produce and refine) and/or non-conventional oil (deep sea, tar sands, heavy oil, less and more costly) reaches its maximum ever rate of production and thus supply. In 2001 the petroleum geologist Colin Campbell defined peak oil as:

"The term Peak Oil refers the maximum rate of the production of oil in any area under consideration, recognising that it is a finite natural resource, subject to depletion." [8]

The concept that we could map the maximum production of oil production by assessing the accumulated data upon the production profile of the lower 48 U.S oil fields was put forward by M. King Hubbert in 1956 (Hubbert, 1956). Increasingly research has refined the Hubbertian linearisation method to include analysis of future large scale projects and giant fields to build an improved picture of future production capacity. Whilst there is now no serious debate upon the existence of the peaking of supply there is some debate upon maximum production levels and resultantly the date of maximum production. Peak production is currently being evidenced by a plateau of production, however this may be influenced to some degree by the global economic crisis and its after effects (Hook et al., 2009, Hamilton, 2009a). The peak of world oil supply is an event that will occur only once and the opportunities for collecting information beforehand are limited. The knowledge gained from this thesis could be useful in the development of adaptation models for other regions and communities.

Peak and plateau:

[8] http://www.peakoil.net/Default06.html

Prediction of the shape of the oil production peak is difficult to estimate and may only be known accurately from a historical perspective. Various methods have been used to estimate maximum rates of production in order to develop a production profile of individual fields, regions and ultimately a national production profile. As data this can be digitalised to form a graph that rises to a peak point of maximum production and then, as oil fields are finite, a rate of decline can also be defined. Both increase and decline are modified by a range of factors that are subject to individual interpretations, physical values, timeframes and availability of (reliable) data leading to varying assessments as to amounts and points of maximum production. Further this analysis can be affected by the categorisation and inclusion of differing types of energy sources, such as conventional and non-conventional oil types. Individual fields will see varying levels of depletion, due to factors including their own field dynamics, whether on or off-shore, development rates, age and quality of each field, its infrastructure, oil price and so forth. Deep water off-shore wells are often depleted sooner as production is pushed to achieve a higher return over a shorter period to off-set much higher development costs than on-shore fields (Deffeyes, 2005, Deffeyes, 2009, Fantazzini et al., 2011, Goodstein, 2004, Aleklett et al., 2010).

Further, peak production profiles differ for regions, and whilst offering some indications of future production/depletion trends, they do not follow a uniform pattern, which makes global interpretation difficult. For example, Hirsch notes, that North America and Europe are both "…reasonably contiguous and bounded…" and developed using commercial criteria they show different production peaks; with America displaying a sharp peak before plateau, whilst Europe entered an immediate plateau (Hirsch, 2008, P.889).

IEA data of conventional oil production presents a plateau moving in an average band width of 4-5% (see Figure 1.) with an apparent production cap of 75Mb/d commencing around 2004/5 (Fantazzini et al., 2011, Hirsch, 2008, Hirsch, 2011, Hook et al., 2009, Jakobsson et al., 2009, Robelius, 2007).

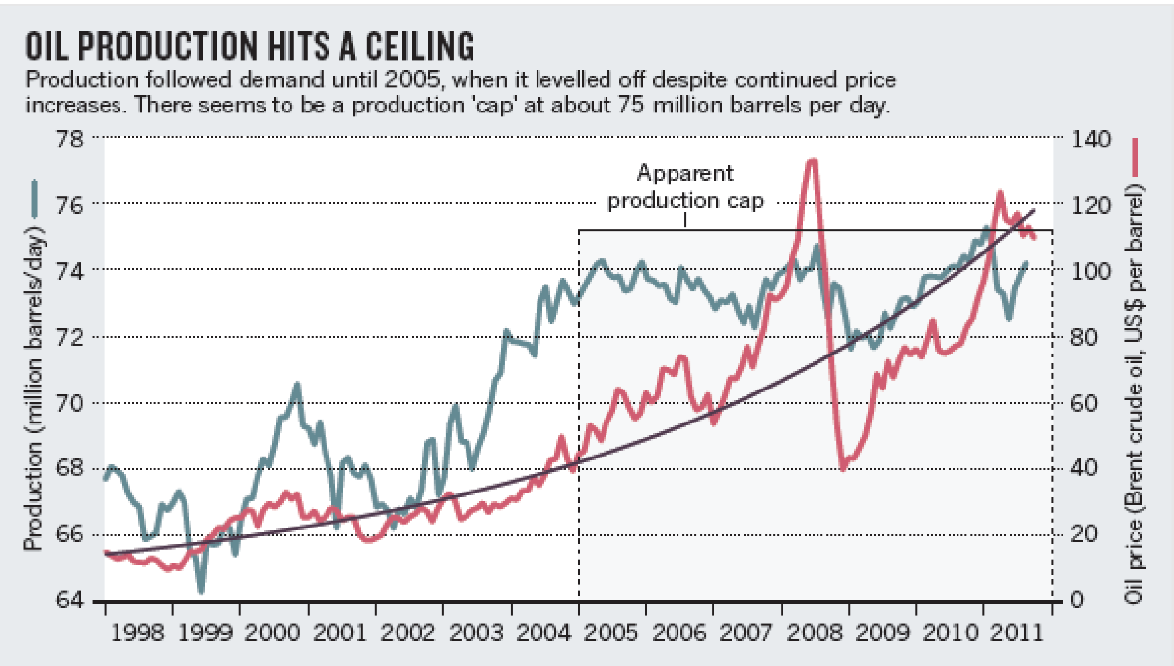


Figure 2 Oil production plateau.[9]

Murray et al presents this as a "phase transition", that is, when the price of oil has virtually no impact upon increasing production (Murray and King, 2012). Consideration of the profile of the production

[9] Murray and King, 2001, P. 434

plateau is important for planning because it gives understanding of the shape and therefore production curve we will have travelled across. Hirsch and others initially conceived peak oil as having a sharp peak similar to the profile of the U.S. production. It is now expected that the production and decline profile to be similar to that of Europe, displaying a period of undulation (in part influenced by economic considerations) followed by a relatively sharp rollover and a monotonic decline (Hirsch, 2008). Estimated periods for the length of the plateau are limited but centre around the period for roll-over within the time frame of 2012 to 2020 (Bureau of Infrastructure Transport and Regional Economics, 2009, Hirsch, 2008, Hirsch, 2011, Hook et al., 2009, Owen et al., 2010, Robelius, 2007); however as the authors note, the exact date of decline cannot be accurately predicted due to multiple variables. To date we have seen approximately 7 to 8 years of plateau, with high prices offering strong market signals for increased production in existing and yet to be developed fields. Whilst an upturn in discovery and production is possible, given the IEA estimates of the peak (2006) and decline of already discovered oil, this is also unlikely in the longer term (International Energy Agency, 2010).

However the implications of the peaking of world oil supply should not be viewed simply as a motive power supply issue. There exists a peer reviewed body of analysis that points to far more significant economic ramifications than is traditionally understood in economics and policy development.

Economic significance:

Neo-classical economics tends to focus upon models that primarily recognise only labour and capital and to view economic growth as a product of technological innovation (Hamilton, 2011, Ayres and Warr, 2002, Foran and Crane, 2006, Solow, 1956, Reynolds and Baek, 2012). Warr et al note that empirical research has not yet reached consensus on directionality in relation to the role of energy in the economy (Warr and Ayres, 2010). As a result, the role of energy is often not effectively included in the consideration of how the economy works. Models instead focus on labour and capital, with increases in economic growth being viewed as a product of labour, capital and technological innovation. A range of contemporary writers have challenged this concept, instead emphasising the role that energy plays as an enabler in the delivery of work (products and services) in the economy (Ayres, 1998, Ayres and Warr, 2002, Cleveland et al., 1998, Cleveland et al., 2000, Foran and Crane, 2006, Hall et al., 2003, Industry Taskforce on Peak Oil & Energy Security, 2010, Linderberger, 2002, Ayres, 2007). While technology does play a role in economic growth, a far more significant role in economic growth (usually measured as GDP growth) is due to increased inputs of energy rather than the interaction of capital and labour (Hall et al., 2001, Kummel, 1982, Murphy and Hall, 2010, Ayres and Warr, 2010).

If there is a direct link between energy use in the growth of GDP, and it is then accepted that energy use is a fundamental component of that equation, then any changes to energy supply will have economic impacts, either negative or positive on growth and on volume and price. Recent papers published by Hamilton reviewed the relationship between the recent high cost of oil and the economic crisis and concluded that it played a contributing factor in its occurrence (Hamilton, 2009a, Hamilton, 2009b, Hamilton, 2011). Price increase effects are more likely to be ten times greater than that of traditional economic reasoning (Murphy and Hall, 2010, Hamilton, 2000). This is consistent with a recent working paper out of the International Monetary Fund that found that:

> *… real economies have many and highly interdependent industries, and several industries, including car manufacturing, airlines, trucking, long-distance trade, and tourism, would be affected by an oil shock much earlier and much more seriously than others. The adverse effects of large-scale bankruptcies in such industries could spread to the rest of the economy, either through corporate balance sheets (intercompany credit, interdependence of industries such as construction and tourism) or through bank balance sheets (lack of credit after loan losses). (Kumhof and Muir, 2012, P.20-21).*

Hirsh also writes that: "…world oil shortages will degrade world GDP and that unity is a reasonable assumption for the relationship between percent decline in world oil supply and percent decline in world GDP, i.e., a 1% decrease in world oil supply could conceivably produce a 1% decrease in world GDP." (Hirsch, 2008, P.888)

Recent econometric modelling by Kumhof and Muir's found that:

> *…While a low income elasticity may appear like a blessing in an environment where oil output can grow without constraints, it actually makes the problem of supply constraints all the more severe. The reasoning is simple-minded, but nevertheless approximately true because very low price elasticities limit the extent of substitution away from oil. Namely, if it really only takes a one third of one percentage point increase in oil supply per annum to support additional GDP growth of one percentage point, then it must also be true that it would only take a one third of one percentage point decrease in oil supply growth to reduce GDP growth by a full percentage point. And the kinds of declines in oil supply growth that are now being discussed as realistic possibilities are far larger than one third of one percentage point. (Kumhof and Muir, 2012, P.20)*

Given that the potential annual global oil field decline rates could be around 4% and greater, this presents real challenges to the global economy. Increases in the cost of oil as price rises means an increasingly greater component of GDP will be redirected to energy supply, with a level around 5% beginning to challenge growth (Li, 2012, Industry Taskforce on Peak Oil & Energy Security, 2010). The combination of declining EROI for conventional and non-conventional oil as well as lower EROI for alternative fuels poses a real challenge for future economic growth. While the research in this area is both initial and limited in influence, the engagement of the IMF, albeit via working papers, will inform and challenge traditional economic thinking in relation to the role of energy in our economy and points directly to the economic risks of peak oil that frames this research.

Estimated date of roll-down from plateau	
Author	*Date*
(Bureau of Infrastructure Transport and Regional Economics, 2009)	*2017*
(Hirsch, 2008)	*2013-15*
(Industry Taskforce on Peak Oil & Energy Security, 2010) Skrebowski	*2015*
(Jackson, 2007)	*Beyond 2030*
(Miller, 2011)	*Before 2020*
(Owen et al., 2010)	*2015*
(Robelius, 2007) (lower estimate)	*2012*
(Sorrell et al., 2010)	*Before 2020*
(Zittel et al., 2013)	*Between 2015 and 2020, possible maximum global production reached 2012*

Table 1 List of published estimated roll-over dates

Decline potential:

Estimates of the potential date(s) for the roll-over, which is the point where supply can no longer be maintained, generally sit within a band between 2010 to 2020 (Bureau of Infrastructure Transport and Regional Economics, 2009, Hirsch, 2008, Industry Taskforce on Peak Oil & Energy Security, 2010, Miller, 2011, Owen et al., 2010, Robelius, 2007, Sorrell et al., 2010, Aleklett et al., 2010), although more distant dates have also been predicted (Jackson, 2007). (Figure 2) A recent (2013) study by the Energy Watch Group[10] sees a rollover somewhere between 2015 and 2020, with world oil production declining by 40 percent by 2030 (Zittel et al., 2013). They consider total world fossil fuel supply to be close to the maximum point of global production, possibly by 2020 in the mid to later part of this decade, with a total peak at 2012. These dates are built from varying methodologies but are consistent to this time period. Although the Global Financial Crisis has lowered demand it has also led to, at least initially, reduced field development and subsequently limited impact upon the possible roll-over date. Hirsch estimates that the GFC has only pushed back the date by months (Hirsch, 2011). High prices in the 2005-2011 period has not seen increased production either from existing or yet to be developed fields for conventional oil.

As well as this, as decline becomes apparent, producing countries, dealing with growing populations and declining reserves may withhold production in an attempt to maintain homeland political stability resulting in a steeper production decent (Hirsch, 2011, Owen et al., 2010, Brown and Foucher, 2010).

From the literature, it is reasonable to make the following assumptions, being that:

That (a) conventional oil levelled out in terms of production around 2005/6 and (b) is travelling (along with non-conventional oil production) across a saw-toothed plateau that will (c) go into decline at a rate of between 4-6% per annum, (d) likely before 2020 (International Energy Agency, 2008, International Energy Agency, 2010, International Energy Agency, 2011).

Further, that we are increasingly entering a period of fossil fuel availability with a declining EROI and higher environmental impact and greater reliance on sources from regions that are geopolitically unstable and that are environmentally difficult and sensitive to damage. These factors combined with declining reserves will have a significant drag on the global economy.

Analysis of peak oil prior to the plateau period initially focussed upon the peak production date and, like mountain climbers, they had their eyes set resolutely on the summit. Now resting at the top admiring the view they have noticed the summit has an undulating top with the far side shrouded in cloud. Some climbers believe decent down the other side is near whilst others believe the climb continues. The analysis presented in this thesis points to a drop off in production that is not too many years forward into that cloud, with above and below ground production factors, time and consumption clearing the view forward and defining the topology.

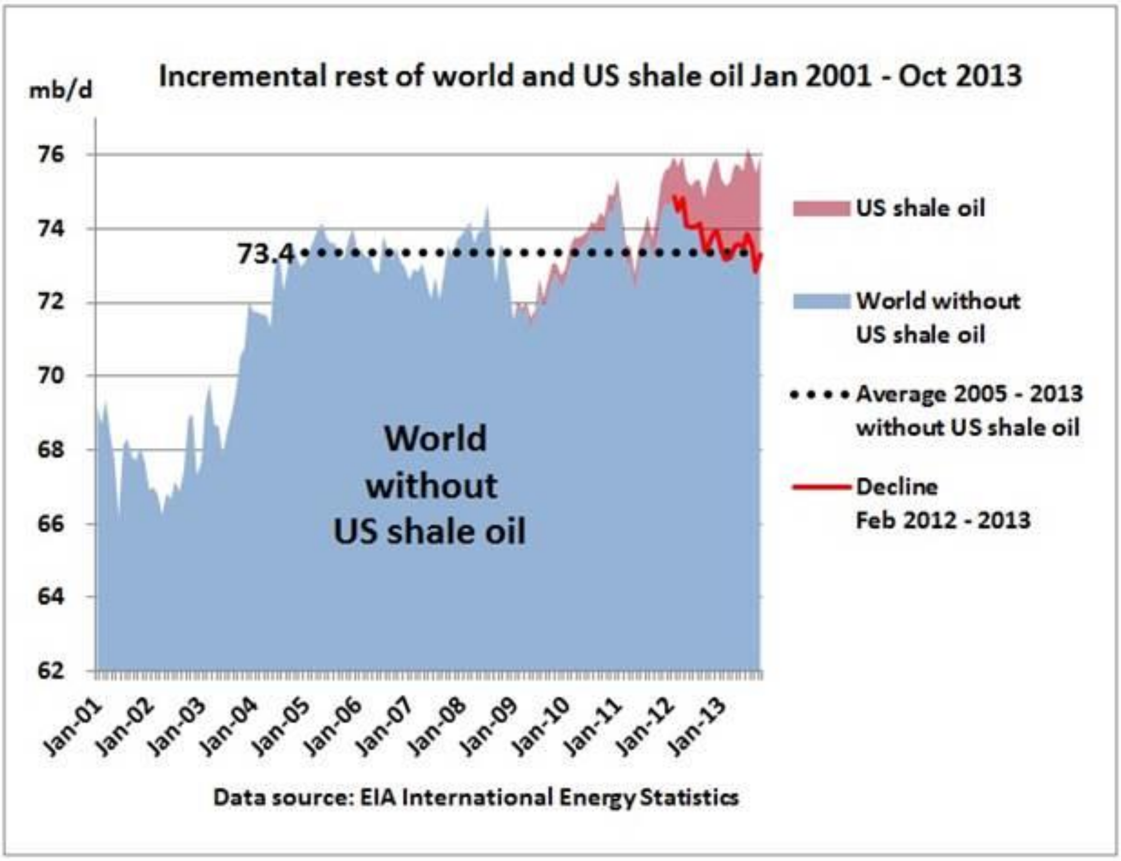
This improved, although limited, peer reviewed literature has analysed published data to clarify the production situation. Whilst much of this analysis will remain unnoticed by policy and planning development, it offers a challenge to the more optimistic view of our oil production future.

Whilst dissenting opinions exist in relation to the event of oil occurring these are generally dismissed. Oil is a finite resource, oil fields deplete as bounded by the laws of physics and oil is consumed at an increasing rate. Debate around the date of peaking of supply, including the use of the Hubbertian model for determining EUR has been limited. Both Lynch and Deming refute EUR and peak dates offered by the Hubbertian peak oil modellers, offering criticism of Hubbert's initial assumptions, questioning the accuracy of predictions, noting variations between estimates and actual production

[10] www.energywatchgroup.org

delivered, as well as questioning the application of the Hubbert model to world production figures (Deming, 2000, Lynch, 2002, Lynch, 2004)). Maugeri offers optimistic future production figures, but these presume very optimistic production levels and flawed analysis of data (Maugeri, 2012). Lynch's main concerns are that the Hubbertian model places emphasis upon geophysical constraints at the expense of traditional economic arguments regarding demand driving research and substitution. For example shortages of conventional oil will encourage the move to the development and use of alternatives, including LPG, tar sands and the more technically challenging reserves such as deep-water and polar oil reserves (Aldelman and Lynch, 1997). Whilst oil price increases have led to production increases via the opening up of previously uneconomic fields and the production of previously uneconomic resources, such as tight oil and tar sands, this has led to only led to the prolongation of the production plateau described above. Ultimately, unless the rates of development of these resources increased markedly, which is very unlikely, the depletion of the conventional oil fields will swamp the production outputs of the nonconventional resources. For example the boom of tight oil and gas fields in the United States is now being revealed to be short lived, with very high depletion rates and with a significantly reduced total production capacity leading to 6-10 year production boom (Hughes, 2011a, Hughes, 2013, Heinberg, 2013).

That boost from shale oil will start to run out around 2017 or thereabouts around the time that conventional oil starts to significantly deplete, although it is already starting. At which point we will truly be in another era.
See graph below.



This graph was pulled together from International Energy Agency data by Mat Mushalic and shows a 1.5 million barrel per day decline offset basically by US production

http://www.resilience.org/stories/2014-03-26/world-crude-production-2013-without-shale-oil-is-back-to-2005-levels

Little Australian academic or policy analysis exist that looks at direct or indirect impacts of (a) energy use in industrial agriculture or (b) the impact that price increases or supply shortages would have on agriculture and/or related food production. Recent studies, such as the Australian Food Plan, were silent around this matter (DAFF, 2012) (Department of Agriculture Fisheries and Forestry, 2012).

Australian Agriculture:

Industrial agriculture uses fossil fuels for the production, processing and transport of agricultural commodities which has enabled significantly increased volumes and diversity of food/products and allowed for the development of a wider mechanism and structure for distribution to global markets. The development of chemical fertilisers, pesticides and the development of mechanisation both before and beyond the farm gate led farmers to increase scale, crops, harvesting outputs and transport mechanisms. New and significant production industries have been developed increasing the product range and scale.

Whilst changes have occurred in the structure of rural living with the development of improved roads, better vehicles and cheap fuel as well as enhanced communications, enabling commuter, tree/sea changer lifestyles and the development of organic farming, boutique crops and farmers markets, much of rural Australia is still engaged in larger scale industrial agriculture (Barr, 2005, McKenzie, 2006). Mechanisation has made the physical act of production less demanding but has locked agriculture into a dependence on high energy, primarily fossil fuel inputs. Modern industrial agriculture requires an input of between seven and ten calories of oil for every calorie of food produced (Giampietro, 1994, Pimentel and Giampietro, 1994, Pimentel and Giampietro, 2008, Pimentel et al., 2005). While a proportion of this is post-farm gate, with four tenths consumed at the household/supermarket level, the integrated systems of industrial food production binds the farmer to the consumer via long-chain production and supply systems as well as global economic markets. The resilience of the long chain systems in modern agribusiness to oil shocks and prolonged price increases has not been fully researched and presents a significant risk to the viability of current rural production (Dodson et al., 2010, Gever et al., 1991, Pfeiffer, 2006, Pollan, 2006, Sloan et al., 2008). While greater efficiencies may be achievable, in a post peak world it will be a matter of maintaining income or at best diminishing income loss rather than efficiency leading to an expansion of agriculture. In a time of declining farm incomes, expenditure for practice or technological change may be difficult or impossible; especially as many of the gains of practice change for energy reduction have already been achieved. The accessibility and cost of energy is a key issue for the economic viability and sustainability of rural communities. Dunlop et al found that energy use in Australian agriculture has risen 30% in the last 50 years, while crop production had increased fivefold due to increased energy input, noting that: "… dependence on mechanisation implies increasing consumption of energy in absolute terms" (Dunlop et al., 2004b, P.49), which aligns with Fleay's finding that farm technology has made significant efficiency gains (Fleay, 1995).

Slone et al also found that:

> *While costlier energy encourages producers to use less energy and energy-intensive inputs, antecedent improvements in energy efficiency make less certain the manner in which future increases in the price of oil may stress producers, encourage adaptation and accelerate reductions in energy use. Further, improved factor productivity has been achieved far more through progressive increases in agricultural output than through decreases in associated energy inputs. This fact highlights an agricultural oil vulnerability which exists despite greater energy efficiency: as high-yielding cultivars are especially reliant on appreciable energy inputs (as through fertilizer, chemicals, irrigation), even relatively small decreases in energy use may cause disproportionately large declines in farm output and, thus, degeneration in energy efficiency trends. This dynamic*

would both compound and be compounded by the marginal incomes of farmers. (Sloan et al., 2008, P. 7-8)

Direct costs, such as fuels, will place pressure on smaller scale farmers that may not have the credit access to tide them over until cash income from crops arrives (this may also apply to larger farming concerns, who may be able to absorb increased costs). Further, as the costs of inputs are passed on down the supply chain, consumer consumption patterns may change leading to shifts in markets and product consumption. Small farms and especially farmers with high debt levels (particularly after years of drought) will be further pressed via increased input costs. In a time of declining farm incomes, expenditure for practice or technological change may be difficult or impossible. Given that 80% of Australia's farming production is export orientated this will create further dilemmas for primary production in terms of matching supply to demand and long range forecasting for strategic planning (Cebon, 2003). Increased costs and the potential for reduction in overseas markets, especially those based around high energy cost transport such as airfreight, may face increasing charges for delivery of their product. This may be offset by a depreciating dollar, but will see increased costs for imported farm related goods (Kingwell, 2003).

Australian agriculture and its communities have changed from smaller scale production methods and related service structures to larger farms and vertically integrated food processing chains, relocation of support services to regional and capital cities, and a wind down of farm incomes and the viability of rural towns (Cocklin et al., 2001). This has been further exacerbated by droughts, trade policy and environmental damage. Farmers and families have seen an increasingly reduced direct return on goods produced as sales moved further away from their local communities, necessitating off-farm work and seeing declining population in communities, especially as young people move to cities and larger regional centres for work and education. Increased energy costs have the potential to further hurt farmers and rural communities in the short and medium term, via increased input costs and declining markets. In the longer term continued energy shortages may lead to changed farming practices and a more localized focus for markets, infrastructure and community focus. This will be difficult in the economic situation that oil vulnerability will entail.

Methods for developing on farm biofuel production, especially for broad acre farming with high liquid fuel inputs, would ensure a continued sure supply for farm production machinery, as well as having the potential to develop local industry based around bio-fuel based technology. This could include modelling of potential changes to markets, both internal and international. Further analysis of the long-chain food production system, from farm gate through to delivery and sales systems at the shop and supermarket would identify risks and allow for planning of risk mitigation. Research and analysis of risks for rural communities would assist in identifying areas of vulnerability and assist in the development of options for rural communities to build resilience and response measures.

Recommendations for research, analysis and review should include, but not be confined to the following recommended areas (a) timeframes and possible changes to oil based fuel stocks (for chemicals, fertilizers and liquid fuels), (b) the vulnerability of industrial agriculture to peak oil driven energy shifts and (c) what mitigation and adaptive measures would be possible. Research would need to look at farm energy use and how changes to farming practice might build resilience to cost pressures and/or shortages.

Rural Australia

Rural Australia has seen declining economic viability with related social difficulties, including an aging farming population and loss of youth to the cities (Cocklin et al., 2001, Dunlop et al., 2004a). This has *been further exacerbated by the closure of services such as bank branches, chemists and local health care resources leading to centralisation of many regional services, necessitating increased travel by private transport (Black, 2005, Burch et al., 1999, Maher, 1994, Smailes, 2000). The Cocklin et al (2001) study identified a range of challenges to the rural sector in Victoria (circumstances in rural Victoria can be applied in general to rural Australia) including reducing income, introduction of capital intensive labour saving technologies, declining government support and the growing influence of agribusiness and food retailers driving changes in farm practices, including increased industrialisation of farming (Cocklin et al., 2001). Economic factors have tended to result in the concentration of both upstream and downstream value adding processes, leading to a declining balance of trade for farmers for commodities, larger energy intensive farming processes and centralisation of support services, either community, government or industry service (Black, 2005, Burch et al., 1998, Burch and Rickson, 2001, Gray and Lawrence, 2001, Lockie and Higgins, 2007). These writers do not to assess the role of energy inputs and the flow-on effects of changes wrought by technological development both on and off the farm, via improved transport, pesticides and the development of downstream industrial food processing; they recognise the change but not the role of cheap energy as the background driver of that change (White 1949; Gever 1991; Tainter 2003). Flowing on from this is the failure to recognise the vulnerability of modern agriculture to increases in energy costs via its dependency of that fossil fuel framework, although this applies to most of industrial based society (Fleay, 1998, Fleming, 2005).*

Under the current industrial high energy use agricultural model, rural communities will also face the decline of related industries geared to the supply and service of agricultural needs, with a further flow on effect to related service industries for the rural community as a whole. Due to greater distances involved in regional living rural communities face greater travel times and increased costs in relation to fuel and vehicle maintenance for basic services including medical, shopping, education and work (Tisato, 2002). Many farmers depend on supplementing farm income with off-farm income (Cocklin et al., 2001). Off-farm income has doubled since the 1980's (Black, 2005) with almost half the annual income for broad acre and dairy farming being generated beyond the gate by 2001 (Hugo 2005). This is significant given that the balance of trade for the rural community has declined since 1950 with the development of the industrial agricultural system from 45% (U.K.) and 60% (U.S.) respectively; while in Australia in the 1950's it was 4 times higher than what is received today (Cocklin et al., 2001). Cheap fuel prices have encouraged travel for off-farm work as well as the development of life-style living in the rural regions surrounding regional centres. Tourism now provides income through services and asset increases for rural and coastal land, providing for the development of local businesses and off-farm work as well as niche food production and supply (Butler et al., 1998, Tonts, 2000). Since the post-war period improvements in private transport, roads and declining real fuel costs have allowed for greater mobility, but also have made possible the relocation of a range of services (also through government and economic policy), both government and commercial, leading to the closing and centralisation to regional towns (Gray and Lawrence, 2001, Argent and Rolley, 2000). Local government now services larger regions and provides services previously delivered by state and federal government (Daly, 2000).

In the longer term increased transport costs and reduced personal travel may lead to a re-regionalisation of rural communities (Pirog, 2001, Leahy, 2003). Agricultural produce freighted to and from markets will see increased costs possibly leading to a re-localisation of agricultural product with the potential for increased balance of trade incomes for farmers bypassing the vertically integrated food processing industry. Regional services will need to be relocated to communities, although in a reduced form, to ensure community basic needs are met. This will necessitate increased populations for regional towns. For example, the model of small schools servicing a local community may again be viable as personal transport and school bus costs weaken the centralised feeder model. Reducing fertiliser, pesticide and fuel costs may necessitate a move to less environmentally intrusive agricultural practices, with benefits in relation to energy and water use (Pimentel et al., 2005). The ability of rural *communities to respond to rapid change will necessitate clear and advanced strategic planning, adaptation and community capacity building models and practice.*

The mutually intertwined supply and market systems of Australian agriculture are no different. This offers significant opportunities for inflationary costs to be served up at the kitchen table. This is not to argue that agricultural production should be viewed through the lens of just energy, it is, as are other major productions systems, a complex matrix of vertically integrated production, and marketing structures, local conditions and farmer preferences and choices. Risk will be dependent upon a range of factors beyond energy, including markets, agribusiness preferences, individual farm and farmer viability (including impacts of climate change), government policy and (in)actions, consumer preferences and a range of other and often poorly understood variables. Dodson and Sipe note that farmers are price takers, vulnerabilities exist and that any assumptions about farm sector homogeneity and capacity "…to absorb institutional changes driven by a transformed energy environment must be sensitised to local institutional and geographical conditions" (Dodson et al., 2010, P.300).

Work by Dodson et al (Dodson et al., 2010, P.301) has identified that possible changes due to oil vulnerability may bring about the following changes:

- *changes to the distribution of agricultural types within Australia's regions;*
- *changes to the intensities of agricultural land uses;*
- *shifts in the primary mode of transportation of agricultural products, such as from road to rail;*
- *restructuring of settlement patterns – concentration or dispersal – as communities adapt to higher transport costs; and*
- *abandonment of some land types or sub-regions if production and transport costs became prohibitive.*

Agricultural research and policy

My thesis research found:

… that there was minimal recognition of oil vulnerability in Australian agricultural research and policy. This was consistent with the findings of Dodson and Sipe (Dodson and Sipe, 2010) in relation to urban land use and transport policy and planning. References are scattered and infrequent. Where energy is considered it is in terms of usage, often as a carbon output, no consideration of changes to availability, cost or Energy Return on Investment are taken into account.

Key policy documents that could influence agricultural policy planning take their lead from policy directions set in the Energy White Paper, 2011. For example the National Food Plan green paper 2012 deals with future energy security via referencing the Energy White paper. The green paper states:

> *On 13 December 2011, the Australian Government released its draft Energy White Paper to provide policy direction and help address future energy challenges, and provide confidence about Australia's future energy security (see www.energywhitepaper.ret.gov.au). This in turn will ensure there are adequate energy resources available for future food production and processing (DAFF, 2012 P.71).*

Here potential energy risks for Australian food production are written away by a simple reference to the Energy White paper. Whilst the green paper recognises some difficulties in the future, both the limited analysis and energy understanding demonstrated points to superficial analysis of the situation:

> *Remaining oil reserves are more limited but could be supplemented through new discoveries and technological advances including enhanced extraction techniques or coal-to-liquids or gas-to liquids.*

and,

> *However, the cost of energy is increasing, reflecting increased demand and rising production costs. The rising costs of energy will require food businesses to reduce energy consumption and move to low energy input production and processing systems (DAFF, 2012 P.70-71.).*

Had the White Paper pointed to energy supply concerns in relation to Australian agriculture both researchers and funding bodies would have had clearer signals to develop research programs in response.

Implications of policy failure

Given that the exact flow on effects of this event, as described in this research, are both difficult to quantify in regards to scale, impact and timeframes as well as being little understood via direct research, assessments of vulnerability are difficult. Vulnerability can best be seen on broader scales as being in the realm of a failure to identify, consider, research, understand and formulate suitable, timely and active response measures that would enable society to better mitigate or manage risk and impact. At local levels it can be reduced to more measurable effects such as increased costs of fuel directly used in the operation of set business processes, services delivered or activities undertaken. However as none of these exists in isolation this form of analysis provides a limited basis for risk analysis. Individuals and organisations have in the study area made responses to past fuel price increases, but these were not formed upon the basis of a broader or longer timeframe based set of information, criteria or policy directions. In such they represent an often ad hoc and piecemeal response to immediate stimulus, although having the capacity to assist in future similar or increased pressures. For example, the purchase and use of more fuel efficient vehicles provides cost savings (after initial investment is factored), as it offsets possible future fuel cost increases, but only provides a very focussed response in terms of scale, timeframes and forward planning.

Policy presents to government, community and industry both analysis and direction for planning appropriate coordinated social, economic and environmental activities. For example, land use policy drives land use planning, hopefully sensible direction to state and local government in relation to land use schemes, infrastructure development and social planning. Timeframes and scales of activity are often long and large and have inbuilt inertia and are not readily responsive to change. Infrastructure developments may have high embodied energy inputs susceptible to changes in energy availability and cost which could lead to project failures and/or social perturbations (Tainter et al., 2003). Academic research and community input can inform policy settings, as is with the increasing peer reviewed papers around peak oil, however policy development can be supressed or hindered by a lack of, or even hostile, philosophical environment within government departments (Steele and Gleeson, 2010). Public servants and policy writers may have to wait for clear authorising environments to begin to even broach difficult topics. Until appropriate signals for research and policy development are available, Australia will be at increased risk of risk management failure in regards to this event and its ability to effectively implement timely mitigation and adaptation measures.

Conclusion:

This conclusion is drawn directly from my thesis research but given the relevance of the topic to Australian agriculture its recommendations are of value in consideration of the vulnerability and competitiveness of Australian agriculture.

It would be sensible to have in place a suite of research findings that can better inform society and planners on how best to respond to both the energetic and economic world that those response measures will need to respond to. Given the almost complete absence of research and analysis into oil vulnerability the development of a comprehensive research framework that first investigates and analyses what oil vulnerability will entail and engender would be crucial. This would involve analysis of the:

- *global oil supply and depletion situation, including Australia's own supply scenario. This would include volumes available, timeframes and possible supply constraints. This should involve a comprehensive analysis of global oil depletion trends along the lines of the withdrawn BITRE study (Bureau of Infrastructure Transport and Regional Economics, 2009). Supporting this should be an assessment both of Australia's indigenous oil supply and strategic risks, especially in a time of global depletion*
- *what this would mean for society economically, looking at the direct linkages between energy use, energy return on investment and the possible impacts for our global and local economy*
- *what adaptive measures (taking into account environmental considerations and impacts) may exist to mitigate energy supply shortfalls (significantly liquid fuels, chemicals, fertilisers, pharmaceutical and plastics) as a transition measure to a lower net energy use society.*

Beyond that it would be crucial to initiate research the impacts of what a rapid transition down the back of the oil supply (and subsequently other fossil fuels) production curve will mean for our society. This could entail in key areas analysis of:

- *energy inputs to industrial agriculture, what depletion would mean for agricultural production and how agriculture could adapt*
- *transport and communication options and alternatives. How could society keep connected, active and engaged in an energy constrained future built around a liquid fuels rich transport structure and system*
- *methods for building community resilience and social cohesion. Elements of this in a nascent form can be found in the transition movement, permaculture, elements of the counter culture movement and in some local government peak/oil vulnerability planning*

The above points are included only to set a general framework for research development. Any research should ideally flow out of a risk management analysis that identifies key areas of focus to identify significant vulnerabilities and emerging trends that would assist policy development and possible and appropriate action. Cascading from that would be analysis of energy vulnerabilities across key sectors, with emphasis on principle areas of economic activity and vulnerability. That research could then provide the basis for more targeted and specific areas of research around energetic, economic, environmental and social factors.

My research does not set out the mechanisms for research and analysis but any knowledge gained would prove very useful in terms of risk management, resilience and capacity building and potentially the development of skills, technology and industry development in advance of the event that would offer a significant competitive advantage and will be ultimately sought after by other countries. Communities will increasingly ask, as oil vulnerability begins to bite home, questions around why more has and was not done. These will be framed around the areas of due diligence and duty of care. How will we answer those questions?

AKEHURST, J. World Oil Markets and the challenges for Australia. ABARE's Outlook 2002, 2002 Canberra. Woodside Petroleum.

ALDELMAN, M. & LYNCH, M. 1997. Fixed view of resources creates undue pessimism. *Oil and Gas Journal,* 95**,** 56-60.

ALEKLETT, K. 2012. Peeking at Peak Oil. New York: Springer.

ALEKLETT, K., HOOK, M., JAKOBSSON, K., LARDELLI, M., SNOWDWN, S. & SODERBERGH, B. 2010. The Peak of the Oil Age: analysing the world oil production Reference Scenario in World Energy Outlook 2008. *Energy Policy,* 38**,** 1398-1414.

ARGENT, N. & ROLLEY, F. 2000. Lopping the Branches: Bank Branch Closure and Rural Australian Communities. *In:* PRITCHARD, B., MCMANUS P, (ed.) *Land of Discontent.* Sydney: UNSW Press.

AYRES, R. 1998. Eco-thermodynamics: economics and the second law. *Ecological Economics* 26**,** 189-209.

AYRES, R. 2007. On the Practical Limits to Substitution. *Ecological Economics,* 61**,** 115-128.

AYRES, R. & WARR, B. 2002. Accounting for growth: The role of physical work. *Advances in Energy Studies: Reconsidering the Importance of Energy.* Porto Venere: 3rd Biennial International Workshop.

AYRES, R. & WARR, B. 2010. *The Economic Growth Engine - How Energy and Work Drive Material Prosperity,* Cheltenham, Edward Elgar Publishing.

BARR, N. 2005. The Changing Social Landscape of Rural Victoria. Melbourne: Department of Primary Industries: Victorian Government.

BLACK, A. 2005. Rural communities and sustainability. *In:* COCKLIN C. DIBDEN J. (ed.) *Sustainability and Change in Rural Australia.* Sydney: University of New South Wales Press.

BLACKBURN, J. 2013. Australia's Liquid Fuel Security. Sydney: NMRA Motoring and Services.

BOURNE, G. Moving Beyond Oil. 5th Energy in Western Australia Conference, 23 March 2003 Perth. 17.

BROWN, J. & FOUCHER, J. 2010. *Peak Oil versus Peak Exports* [Online]. Available: http://aspousa.org/2010/10/peak-oil-versus-peak-exports/ [Accessed 17 November 2012.

BURCH, D., GOSS, J. & LAWRENCE, G. (eds.) 1999. *Restructuring Global and Regional Agricultures: Transformations in Australasian agri-food economic and spaces,* Aldershot: Ashgate.

BURCH, D., LAWRENCE, G., RICKSON, R. & GOSS, J. 1998. *Australian Food and farming in A Globalised Economy: Recent Developments and Future Prospects,* Melbourne, Monash University.

BURCH, D. & RICKSON, R. 2001. Industrialised Agriculture: Agribusiness, input-dependency and vertical integration. *In:* LOCKIE, S., BOURKE L., (ed.) *Rurality Bites.* Annandale: Pluto Press.

BUREAU OF INFRASTRUCTURE TRANSPORT AND REGIONAL ECONOMICS 2009. Transport energy futures: long-term oil supply trends and projections. Canberra: BITRE.

BUTLER, R., HALL, C. & JENKINS, J. 1998. *Tourism and Recreation in Rural Areas,* Chichester, Joseph Wiley and Sons.

CEBON, M. 2003. The Australia-US Free Trade Agreement: An Environmental Assessment. OzProspect.

CLEVELAND, C., KAUFMANN, R. & STERN, D. 1998. The aggregation of energy and materials in economic indicators of sustainability: Thermodynamic, biophysical and economic approaches *Accounting for growth: the role of physical work.* Porto Venere, Italy: International Workshop on Advances in Energy Studies: Energy Flows in Ecology and Economy.

CLEVELAND, C., KAUFMANN, R. & STERN, D. 2000. Aggregation and the role of energy in the economy. *Ecological Economics,* 32**,** 301-317.

COCKLIN, C., DIBDEN, J., KILPATRICK, S., HIGGINS, V., SASS, J., SNELL, D., BIRRELL, B., FALK, I., PFEULLER, S. & WADELL, D. 2001. Social Capability in Rural Victoria: The Food and Agriculture and Natural Resource Management Sectors. Department of Natural Resources and Environment.

COMMONWEALTH OF AUSTRALIA 2007a. Australia's future oil supply and alternative transport fuels. *Senate Standing Committee on Rural and Regional Affairs and Transport.* Canberra: Australian Parliament.

COMMONWEALTH OF AUSTRALIA 2007b. Australia's future oil supply and alternative transport fuels. *Senate Standing Committee on Rural and Regional Affairs and Transport.* Canberra: Parliament of Australia.

DAFF 2012. National Food Plan green paper 2012. Canberra: Department of Agriculture, Fisheries and Forestry.

DALY, M. 2000. The Challenges for Local Government in the 21st Century. *In:* PRITCHARD, B., MCMANUS P. (ed.) *Land Of Discontent.* Sydney: UNSW Press.

DEFFEYES, K. 2005. *Beyond Oil: The view from Hubbert's peak,* New York, Hill and Wang.

DEFFEYES, K. 2009. *Hubbert's Peak: the impending world oil shortage.,* New Jersey, Princetown University Press.

DEMING, D. Oil: Are We Running Out? Second Wallace E. Pratt Memorial Conference, 12-15 January 2000 2000 San Diego, California.

DEPARTMENT OF AGRICULTURE FISHERIES AND FORESTRY 2012. Resilience in the Australian food supply chain. Canberra: DAFF.

DEPARTMENT OF RESOURCES ENERGY AND TOURISM 2010. Australian petroleum resources. Canberra.

DIESENDORF, M., LAMB, D., MATHEWS , J. & PEARMAN, G. 2008. A Roadmap for Alternative Fuels in Australia: Ending our Dependence. Sydney: NMRA Motoring Services.

DODSON, J. & SIPE, N. 2005. Oil Vulnerability in the Australian City. Brisbane: Griffith University.

DODSON, J. & SIPE, N. 2006. Shocking the Suburbs: Urban location, housing debt and oil vulnerability in the Australian City. Brisbane: Griffith University,.

DODSON, J. & SIPE, N. 2010. Emerging Australian planning practice and oil vulnerability responses. *Australian Planner,* 47**,** 293-301.

DODSON, J., SIPE, N., RICKSON, R. & SLONE, S. 2010. Energy Security, Agriculture and Food. *In:* LAWRENCE, G., LYONS, K. & WALLINGTON, T. (eds.) *Food Security, Nutrition and Sustainability.* London: Earthscan.

DUNLOP, M., POLDY, F. & TURNER, G. 2004a. Environmental Sustainability Issues Analysis for Victoria. Melbourne: Department of Sustainability and Environment.

DUNLOP, M., TURNER, G. & HOWDEN, S. 2004b. Future Sustainability of the Australian Grains Industry. Canberra: Grains Council of Australia and the Grains Research and Development Corporation.

FANTAZZINI, D., HOOK, M. & ANGELANTONI, A. 2011. Global oil risks in the 21st Century. *Energy Policy,* 39**,** 7865-7873.

FLEAY, B. 1995. *The Decline of the Age of Oil,* Annandale, Pluto Press.

FLEAY, B. 1998. Climaxing Oil: How will transport adapt?

FLEMING, D. 2005. *Building a Lean Economy for a fuel-poor future* [Online]. Dublin: Feasta. Available: www.feasta.org./documents/wells/content.html?panel1.htm [Accessed 15/11/2005.

FORAN, B. 2009. Powerful Choices: Transition to a Biofuel Economy in Australia. Land and Water Australia.

FORAN, B. & CRANE, D. 2006. Powerful choices: options for Australia's transition to a low carbon economy. *Advances in Energy Studies: Perspectives on Energy Futures 5th Biennial International Workshop.* Porto Venere, Italy.

FORAN, B., CRANE D. Not dated. Modelling the Transition to a Biofuel Economy in Australia. Canberra: CSIRO.

FORAN, B. & POLDY, F. 2002. Future Dilemmas Options to 2050 for Australia's population, technology, resources and environment. Report to the Department of Immigration and Multicultural and Indigenous Affairs. Working Paper Series 02/01.

FORAN, B., POLDY, F. Between a Rock and a Hard Place: Australia's Population options to 2050 and Beyond. The Desert Knowledge Symposium, 27-30 August 2002 2002b Alice Springs. 12.

GEOSCIENCE AUSTRALIA. 2010. *Australia's annual production of crude oil 1975-2025 and forecast of annual production 2009-2025* [Online]. Canberra. Available: http://www.ga.gov.au/resources/publications/oil-gas-resources-australia-2008/production-development/production-figure-2.jsp.

GEOSCIENCE AUSTRALIA & ABARE 2010. Australian Energy Resource Assessment. Canberra.

GEVER, J., KAUFMAN, R., SKOLE, D. & VOROSMARTY, C. 1991. *Beyond Oil: The threat to food and fuel in the coming decades,* Niwot, University Press of Colorado.

GIAMPIETRO, M., PIMENTEL, D. 1994. *Food, Land, Population and the U.S. Economy* [Online]. Washington: Carrying Capacity Institute. Available: http://dieoff.org/page40.htm [Accessed 21/03/2009.

GOODSTEIN, D. 2004. *Out of Gas: the end of the age of oil,* New York, Norton and company.

GRAY, I. & LAWRENCE, G. 2001. *A Future for Rural Australia: Escaping Global Misfortune,* Oakleigh, Cambridge University Press.

HALL, C., LINDENBERGER, D., KUMMEL, R., KROEGER, T. & EICHHORN, W. 2001. The Need to Reintegrate the Natural Sciences with Economics. *Bioscience,* 51**,** 663-672.

HALL, C., THARAKAN, P., HALLOCK, J., CLEVELAND, C. & JEFFERSON, M. 2003. Hydrocarbons and the evolution of human culture. *Nature,* 246**,** 318-322.

HALL, C., THARAKAN, P., HALLOCK,J., CLEVELAND, C, JEFFERSON, M. 2003. Hydrocarbons and the evolution of human culture. *Nature,* 246**,** 318-322.

HAMILTON, J. 2000. *What is an oil shock?* [Online]. National Bureau of Economic Research. Available: http://www.nber.org/papers/w7755.pdf [Accessed 21 August 2010.

HAMILTON, J. 2009a. Causes and Consequences of the Oil Shock of 2007-8. *In:* ROMER, D., WOLFERS, J. (ed.) *Brookings Papers on Economic Activity.* Washington: Brookings Institute.

HAMILTON, J. 2009b. Oil Prices and the Economic Downturn. *Joint Economic Committee of the U.S. Congress.* Washington.

HAMILTON, J. 2011. Oil Prices, Exhaustable Resources, and Economic Growth. *Handbook of Energy and Climate Change.*

HEINBERG, R. 2003. *The Party's Over,* Gabriola island, New Society.

HEINBERG, R. 2013. *SnakeOil: How fracking's false promise of prosperity imperiles Our future.,* Santa Rosa, Post carbon Institute.

HIRSCH, R. 2008. Mitigation of maximum world oil production: Shortage scenarios. *Energy Policy,* 36**,** 881-889.

HIRSCH, R. 2011. *Weak World GDP Growth & "Peak Oil"* [Online]. Association for the Study of Peak Oil and Gas-USA. Available: http://www.aspousa.org/index.php/2011/10/weak-world-gdp-growth-peak-oil/ [Accessed 4/14/2012.

HOOK, M., HIRSCH, R. & ALEKLETT, K. 2009. Giant oil Field decline rates and their influence on world oil production. *Energy policy,* 37**,** 2262 - 2272.

HUBBERT, M. K. 1956. Nuclear Energy and the Fossil Fuels. *Spring Meeting of the Southern District, Division of Production, American Petroleum Institute.* Plaza Hotel, San Antonio, Texas: Shell Development Company.

HUGHES, J. D. 2011a. Will Natural Gas fuel America in the 21st Century? : Post Carbon Institute.

HUGHES, J. D. 2013. Drill, Baby, Drill: Can Unconventional Fuels usher in a New Era of Energy Abundance? Santa Rosa: Post carbon Institute.

HUGO , G. 2005. The State of Rural Populations. *In:* COCKLIN, C. & DIBDEN, J. (eds.) *Sustainability and Change in Rural Australia.* Sydney: UNSW Press.

INDUSTRY TASKFORCE ON PEAK OIL & ENERGY SECURITY 2010. The Oil Crunch: A wake-up call for the UK economy. London: Ove Arup & Partners Ltd,.

INTERNATIONAL ENERGY AGENCY 2008. World Energy Outlook 2008. Paris.

INTERNATIONAL ENERGY AGENCY 2010. World Energy Outlook, 2010, Executive Sumary. *In:* INTERNATIONAL ENERGY AGENCY (ed.).

INTERNATIONAL ENERGY AGENCY 2011. World Energy Outlook 2011. Paris: International Energy Agency.

JACKSON, P. M. 2007. Peak oil theory could distort energy policy and debate. *Journal of Petroleum Technology*.

JAKOBSSON, K., SODERBERGH, B., HOOK, M. & ALEKLETT, K. 2009. How reasonable are oil production scenarios from public agencies? *Energy Policy,* 37**,** 4809-4818.

KINGWELL, R. 2003. *Oil and Agriculture: Now and in the Future* [Online]. Available: http://www.aspo-australia.org.au/References/Kingwell-Oil-in-Agriculture-2003.pdf [Accessed 11 May 2011.

KUMHOF, M. & MUIR, D. 2012. Oil and the World Economy: Some Possible Futures. *IMF Working Paper.* Washington, D.C.: International Monetary Fund.

KUMMEL, R. 1982. The impact of energy on industrial growth. *Energy,* 7**,** 189-203.

LEAHY, T. 2003. *Food, Society and the Environment* [Online]. Available: http://www.octapod.org/gifteconomy/content/foodnew.html [Accessed 12 July 2010.

LI, L. 2012. *Has the Global Economy Become Less Vulnerable to Oil Price Shocks?* [Online]. The Oil Drum. Available: http://www.theoildrum.com/node/9008 [Accessed 2 February 2012.

LINDERBERGER, D. 2002. Energy-Dependent Production Functions and the Optimisation Model "PRISE"of Price-induced Sectoral Evolution. *International Journal of Applied thermodynamics,* 5**,** 101-107.

LOCKIE, S. & HIGGINS, V. 2007. Roll-out neoliberalism and hybrid practices of regulation in Australian agri-environmental governance. *Jourrnal of Rural Studies,* 23**,** 1-11.

LYNCH, M. 2002. Forecasting oil supply: theory and practice. *The Quarterly Review of Economics and Finance,* 43**,** 372-389.

LYNCH, M. 2004. The New Pessimism about Petroleum Resources: Debunking the Hubbert Model (and Hubbert Modellers). *Minerals and Energy*.

MAHER, C., STIMSON, R. 1994. Regional Population Growth in Australia. *In:* BUREAU OF IMMIGRATION AND POPULATION RESEARCH (ed.). Canberra: Australian Government.

MAUGERI, L. 2012. Oil: The next revolution. Cambridge, MA: Harvard Kennedy School.

MCKENZIE, F. 2006. Rural complexity, regional diversity. Some observations from Victoria's Regional Matters Atlas 2005. *Australasian Journal of Regional Studies,* 12**,** 343-357.

MCNAMARA, A. 2007a. Queensland's Vulnerability to Rising Oil Prices. Brisbane: Department of Natural Resources and Mines, Queensland Government.

MCNAMARA, A. 2007b. Queensland's Vulnerability to Rising Oil Prices. *In:* DEPARTMENT OF NATURAL RESOURCES AND MINES (ed.). Brisbane: Queensland Government.

MILLER, R. 2011. Future Oil Supply: The changing stance of International Energy Agency. *Energy Policy,* 39**,** 1569-1574.

MURPHY, D. & HALL, C. 2010. Year in review-EROI or Energy return on (Energy) invested. *Annals of the New York Academy of Sciences,* 1185**,** 102-118.

MURRAY, J. & KING, D. 2012. Oil's tipping point has passed. *Nature,* 481**,** 433-5.

OWEN, N., INDERWILDI, O. & KING, D. 2010. The status of conventional world oil reserves-Hype or cause for concern? *Energy Policy*.

PFEIFFER, D. 2006. *Eating Fossil Fuels,* Gabriola Island, New Society Publishers.

PIMENTEL, D. & GIAMPIETRO, M. 1994. Food, Land, Population and the U.S. Economy. *Carrying Capacity Network.* Washington.

PIMENTEL, D. & GIAMPIETRO, M. 2008. Reducing energy inputs in the US food System. *Human Ecology,* 36**,** 459-471.

PIMENTEL, D., HEPPERLY, P., HANSON, J., DOUDS, D. & SEIDEL, R. 2005. Environmental, energetic, and economic comparisons of organic and conventional farming systems. *BioScience,* 55**,** 573(10).

PIROG, R., VAN PELT, T., ENSHAYAN. K., COOK. E, 2001. Food Fuel and Freeways. Leopold Centre for Sustainable Agriculture, Iowa State University.

POLLAN, M. 2006. *The Omnivore's Dilemma: a Natural History of Four Meals,* New York, Penguin Press.

REYNOLDS, D. & BAEK, J. 2012. Much ado about Hotelling: Beware the ides of Hubbert. *Energy Economics,* 34**,** 162-170.

ROBELIUS, F. 2007. *Giant Oil Fields - The Highway to Oil: Giant Oil Fields and their Importance for Future Oil Production.* Doctoral thesis, Uppsala University.

ROBINSON, B. & POWRIE, S. Oil depletion: the crucial factor in transport planning. 27th Australian Transport Research Forum, 29 September - 1 October 2004 2004.

SLOAN, S., SIPE, N. & DODSON, J. 2008. Assessing the Impact of Rising Petroleum Prices on Agricultural Production in Rural and Regional Australia. Brisbane: Griffith University.

SMAILES, P. 2000. The Diverging Geographies of Social and Business Interaction Patterns: a Case Study of Rural South Australia. *Australian Geographical Studies,* 38**,** 158-8.

SOLOW, R. 1956. A contribution to the theory of economic growth. *Quarterly Journal of Economics,* 70**,** 65-94.

SORRELL, S., SPEIRS, J., BENTLEY, R., BRANDT, A. & MILLER, R. 2010. Global oil depletion: a review of the evidence. *Energy Policy,* 38**,** 5290-5295.

STEELE, W. & GLEESON, B. 2010. Mind the governance gap: oil vulnerability and urban resilience in Australian cities. *Australian Planner,* 47**,** 302-310.

TAINTER, J., ALLEN, T., LITTLE, A. & HOEKSTRA, T. 2003. Resource Transitions and Energy Gain: Contexts of Organisation. *Conservation Ecology,* 7.

TISATO, P. 2002. How much further do regional South Australians Travel? *In:* TRANSPORTSA (ed.). Adelaide: TransportSA.

TONTS, M. 2000. The Restructuring of Australia's Rural Communities. *In:* PRITCHARD, B., MCMANUS P. (ed.) *Land of Discontent.* Sydney: UNSW Press.

WARR, B. & AYRES, R. 2010. Evidence of the causality between the quantity and quality of energy consumption and economic growth. *Energy,* 35**,** 1688-1693.

ZITTEL, W., ZERHUSEN, J., ZERTA, M. & ARNOLD, N. 2013. Fossil and Nuclear Fuels - the Supply Outlook. Berlin: Energy Watch Group.