Zealandia

Views from the Peak?

Photographs by Peter Evans

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Stratford
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Views from the Peak?

Peter Evans

Over the past couple of years I have undertaken an extensive photographic study, which documents the current oil and natural gas industry landscape of New Zealand. The discovery and wide use of oil and natural gas, which are essentially trapped remnants of ancient life forms, has transformed human society, enabling the insatiable growth of the industrialized world and has made a globalized society possible. It has become common knowledge that today for every three barrels of oil we consume, only one new barrel is discovered. Meanwhile the demand for oil and gas continues to grow (Strahan, 2007). This is an unsustainable practice in the long-term and has led many to believe that we are at the peak of oil production, and that given oil is a finite resource, global oil reserves are approaching an age of terminal decline. This raises critical issues for the future of the economy, transportation and food production worldwide.

Exploration for oil in New Zealand, particularly in the offshore exclusive economic zone is likely to occur more frequently and with greater vigor over the coming years despite highly predictable opposition. New Zealand is relatively unexplored on an International scale and given that the days of easily extracted oil are well and truly over, oil companies are set to undertake ventures in more difficult regions to quench our ever growing thirst for oil and gas. Drilling in Antarctica, offshore deep sea drilling, and negotiating notoriously difficult tar sands in Alberta, Canada are signs that it is becoming increasingly difficult to acquire the once free flowing fuels. This all makes New Zealand, both on and off shore a much more lucrative and attractive prospect.

New Zealand is a mass of land that protrudes above sea level from an otherwise submerged continent known as Tasmantis or Zealandia, hence the title of this project. Zealandia is known to contain large amounts of oil and natural gas, some of which is already being exploited in the Taranaki region. Exploration in other areas of Zealandia are currently underway, with more oil and gas expected to be discovered.

The oil industry is a hot topic in New Zealand at the moment, and presents highly political, economic and environmental issues, which will unfold over the coming years. My intent in photographing the oil and gas industry in New Zealand is certainly not to attack the industry, which would be hypocritical as I like all other New Zealanders are dependent upon the industry within the landscape. In fact on the contrary, I would like to openly thank those in the industry for giving me privileged access to in many cases restricted sites that have made this exhibition possible. I personally burnt thousands of dollars in fossil fuels, travelling around New Zealand with the purpose of photographing the industry.

Before I introduce this project – *Zealandia: Views from the Peak?* I find it appropriate to first of all outline some of the fundamental issues and thought processes that have led me to undertake a photographic study of the oil industry in New Zealand. I do not intend for the photographs that comprise this exhibition to be an illustration of the issues raised over the next several pages, however I think it is useful for the viewer to understand my inner concerns of a global nature to fully appreciate my more localised creative ambition.

In her highly regarded publication 'A World History of Photography' Naomi Rosenblum summarizes the development and integration of the medium of photography from a small pocket of specialists towards a more than accommodating wider public:

> "*The photograph was the ultimate response to a social and cultural appetite for a more accurate and real-looking representation of reality, a need that had its origins in the Renaissance…Realistic depiction in the visual arts was stimulated and assisted also by the climate of scientific enquiry that had emerged in the late 16th Century and was supported by the Middle Class during the Enlightenment and the Industrial Revolution of the late 18th Century…Industrialization and the spread of education mandated a need for greater*

amounts of comprehensive pictorial material encompassing a broader range of subjects – a necessity to which only the camera image was able to respond".

- Rosenblum (2007)

The modern photographic process was and still is an evolutionary medium that has satiated the need for the human enterprise to produce and consume imagery on an increasingly larger scale. It acts as both the recorder and a result of industrialization.

The discovery and application of coal as an energy source fueled the Industrial Revolution. After witnessing mass deforestation in Europe between 400AD and 1600AD, Europeans reluctantly turned to coal, a filthy material, out of necessity for energy in the way of heat. Coal proved to be incredibly useful. Although it was dirty, the heat provided by coking coal was so intense it enabled smelting for iron and steel production, beginning in England in the 17th Century. This development would pave way for the Industrial Revolution.

Coal was used to manufacture glass, bricks, tiles, salt (through evaporation), refining sugar and brewing beer. In the course of 100 years, coal had transformed much of the world. New forms of production, new inventions and discoveries, new patterns of work, intensified colonialism and a new geopolitical balance of power were all due to coal (Heinberg, 2005).

Coal may well have been the energy source central to the beginnings of the Industrial Revolution, but it has predominantly been the energy from oil and natural gas that has sustained industrialized societies insatiable appetite for continuous growth, characterized by a technologically advanced, image-saturated, globalized world.

All growth requires energy. Whether it is a plant, animal, human being, the economy or even society at large – all levels of growth are determined by inputs of available energy.

"*In 1859 the human race discovered a huge treasure chest in its basement. This was oil and gas, a fantastically cheap and easily available source of energy. We did, or at least some of us did what anybody does who discovers a treasure in the basement, live it up, and we have been spending this treasure with great enjoyment*".

- Boulding (1978)

To outline the origins of fossil fuels (oil, coal and natural gas) I will give a brief account acutely described by Michael Mitchell in an essay for the publication of '*Oil*' by Canadian photographer Edward Burtynsky:

"*For millions of years, tiny marine life forms lived by converting the energy of the sun into molecules of carbohydrates such as sugars. At the end of their life cycles their bodies fell by the uncountable trillions to the bottom of ancient seas where with time, both heat and pressure converted the compounds into oil. It appears that through this process the remains of plants became coal while zooplanktons became the liquid 'hydrocarbons' we call crude oil. Both preserve the energy of ancient sunlight, that's why they're called fossil fuels. Until about 500 years ago the carbon cycle was in equilibrium – every molecule of carbon dioxide emitted by decaying life and human activity was absorbed by forests and the sea. However, once people began to exploit fossil fuels the release of carbon began to exceed the uptake of the global cycle. The system is finite. Because of fossil fuel consumption, today's carbon production is roughly double the global systems capacity for capture and release. Fewer and smaller forests mean more heat retention. Hotter climes mean less snow and ice, which means less reflected solar energy, which in turn means more heat. The world has fallen out of balance. In the short term the exploitation of fossil stores of sunlight created enormous benefit. It made possible the mechanization of manufacture that we call the industrial revolution…enormous wealth resulted*".

- Mitchell (2009)

Fossil fuels; oil, coal and natural gas are a finite resource because they have taken millions of years to develop into a useful form of energy; a source of energy that we consume faster than the process takes to regenerate. According to the International Energy Agency, currently fossil fuels provide more than 80% of the world's energy! (IEA, 2012) Today we use oil for everything. The food we buy from supermarkets has travelled from all over the world thanks to transportation, it has been grown using fertilisers and pesticides, which are made from oil and natural gas. Our clothes, whether cotton, nylon or polyester are manufactured using, and some even made directly from petroleum products. Our modern medical system is oil dependent for transport and high tech equipment. Computers and microchips are made from petroleum products and use even more in the manufacturing process. All plastics are made from oil. Our roads, buildings and cities have been built thanks to the abundant, cheap supply of fossil fuels. Even alternative sources of energy including wind turbines, solar panels, and nuclear power plants demand oils energy for materials, assembly and maintenance. Mining and refining other natural resources such as silver, copper, aluminium and platinum used in electrical devices including home ware is dependant upon oil or natural gas driven machinery. Former US President George W. Bush declared in a State of the Union address in January 2006 quite bluntly that '*America is addicted to oil*' (Bush, 2006). Yet it isn't only America, it is the entire modern, industrial, technological world. It is the energy source of our civilization.

Peak Oil

Peak oil is the point in time when the maximum rate of global petroleum extraction is reached, after which the rate of production enters terminal decline.

In 1956 an expert petroleum geologist called Marion King Hubbert (October 5, 1903 – October 11, 1989) who was working for Shell Oil at the research lab in Houston, Texas, noted that for any geographical area, whether it be an individual oilfield or the entire planet as whole, the rate of petroleum production would resemble a bell shaped curve.

Production rises slowly, and then rapidly increases before slowing to a 'peak' or a 'plateau' in production (when that given geographical area produces the most it ever has and ever will produce) and then inevitably declines no matter how much effort is put in as the finite resource becomes exhausted. It is the peak in production that is known as '*Hubberts Peak*' (see Fig. 1). Those in the oil industry now almost universally accept this observation. Whilst various fields and regions may have different shaped curves of production dependent on specific discoveries and production observations unique to individual sites, it is common oil industry knowledge that all wells drilled have a beginning, a peak and an end and that they must then move on to another well.

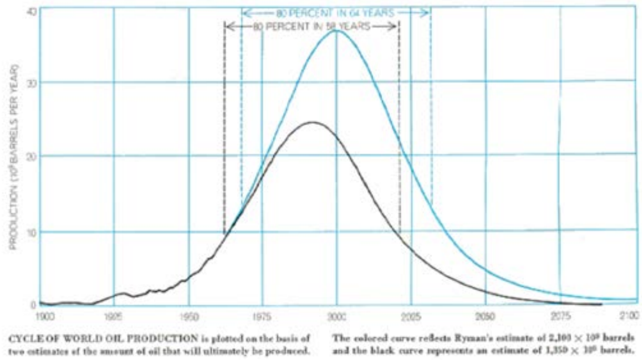


Fig. 1: *Peak Oil Production (two estimates).*

Hubbert correctly predicted that U.S oil production would peak in 1970. When 1970 rolled around he was virtually laughed out of his profession for making such a ridiculous prediction as at that time the U.S were producing the most oil they ever had, Ironically this was the year in which the US oil production peaked and has been in terminal decline ever since (see Fig. 2, *note: the red dotted line indicates 1956, the year Hubbert made this prediction*).

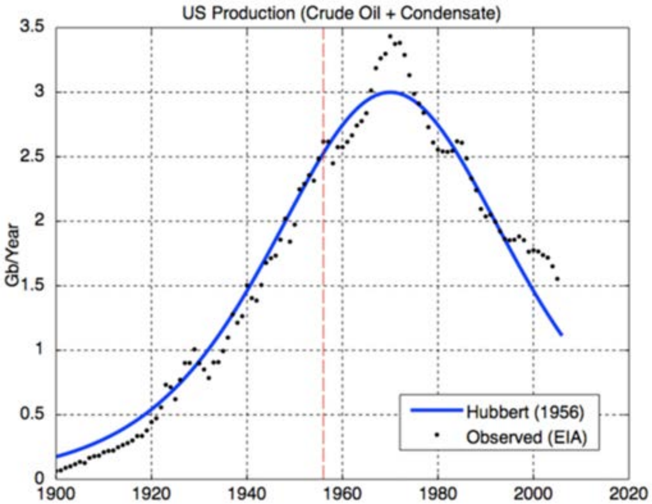


Fig. 2: *US Oil Production and M.K Hubberts prediction.*

To get this graph, Hubbert made an educated estimation based on the discoveries of oil reserves, which he noticed followed a similar, earlier bell shaped curve to production. The discovery of US oil reserves had peaked and declined by the 1930s. Hubbert took the data of past discoveries and included current proven reserves as well as the estimated future discoveries based on the trends of current and past discoveries to make his future prediction.

Hubbert used the same method to predict the peak in global oil production. Having noted that global oil discoveries peaked and have been in continuous decline since the late 1960s, In 1976 Hubbert declared that world crude oil production would peak in 1995. He did also mention that the oil crisis of the 1970s due to the OPEC oil embargo might offset the peak about 10 to 15 years to around 2005 to 2010.

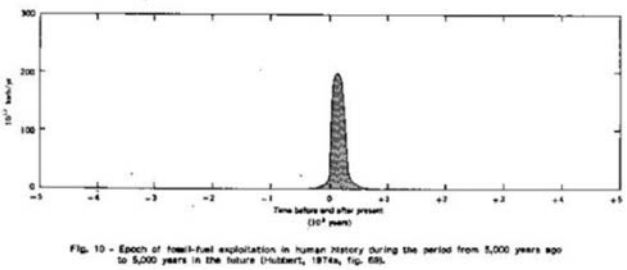


Fig. 3: *Epoch of fossil-fuel exploitation in human history (10,000 year timespan). Source: M.K Hubbert. Energy from fossil fuels, 1949.*

One of Hubberts favourite graphs was called '*fossil fuels in human history*' (see Fig. 3). In this graph, Hubbert reveals gross global fossil fuel exploitation in a time span of 5000 years ago, to the present (1976), to 5000 years into the future. In this humbling sketch Hubbert places the human species reliance on fossils fuels in a historical context:

> "*So what this shows is that this largely monumental like spike here is the episode of fossil fuels; coal, oil and natural gas and every other kind of fossil fuel in human history. It's the most disturbing thing that's ever happened to the human species, it's responsible for our technological society and in terms of human history, it's a very brief epoch*".
>
> - Hubbert (1976)

Graphs

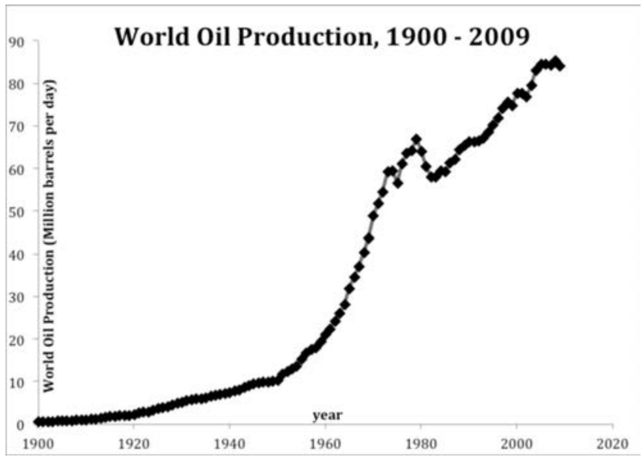


Fig. 4: *World Oil Production, 1900 – 2009. Source: Energy Information Administration (EIA).*

The graph in Fig. 4 shows world oil production from 1900 (around the time when oil was becoming general use) to today. There is no absolute knowledge of when the peak will or has occurred until hindsight, as nobody knows *exactly* how much oil there is. Dr Colin Campbell a former chief geologist and vice president at a string of oil majors including BP, Shell, Fina, Exxon and ChevronTexaco says that the peak of regular oil – the cheap and easy stuff has already come and gone in 2005. Kenneth Deffreyes a geologist who worked with Hubbert suggests the peak is occurring now. The US Geological Survey, who is traditionally known to have very optimistic views on this matter, places the peak at 2036. The UK government has said the peak in global oil production will occur around 2030. The International Energy Agency says production of conventional crude oil peaked in 2006. In 2006 Helen Clark, then Prime Minister of New Zealand said in answer to a question regarding the fuel price that:

> "*It's causing concern for every country because everyone's on the receiving end of the same phenomenon which is oil prices are very high because we're probably not too far short from peak production if we're not already there*".
>
> - Clark (2006)

Whether oil production will peak is no longer a debate, the question, if it hasn't occurred already, is when.

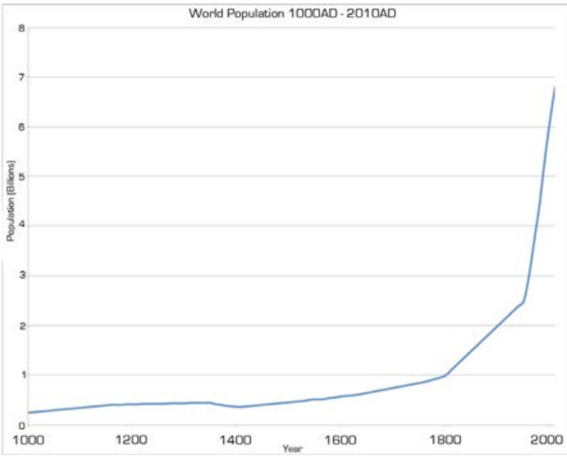


Fig. 5: *World Population 1000AD – 2010AD.*
Source: US Census Bureau International Data Base.

Fig. 5 shows human population growth by the billions since 1000AD. The world population has been growing continuously since the end of the Black Death around 1400, and today there are just over seven billion human beings living on planet Earth (October 2012).

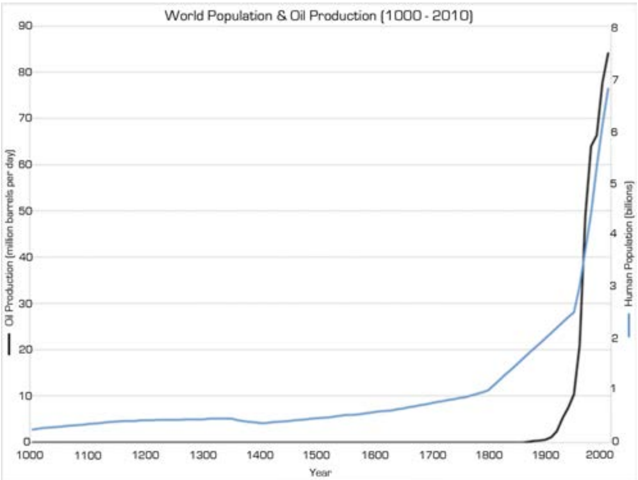


Fig. 6: *World Population and Oil Production 1000-2010. Source: See Figures 4 & 5.*

When we impose the oil production graph on top (Fig. 6), we begin to see a pattern emerge. The human population has grown with the production of oil. This is no coincidence. Cheap oil has not only been used to fuel industry, manufacture and transportation, but also our food. Physicist Dr. Albert Bartlett once called modern agriculture "*the use of land to turn petroleum into food*" (Bartlett, 1978). 75 to 95% of the increase in food production during the post WWII 'green revolution' is attributed not to miracle seeds but to the inputs derived from fossil fuels. Mechanical cultivation, fertilisers, pesticides, diesel powered irrigation, the growing, harvesting, processing, packaging, refrigeration and global distribution of vast quantities of food to feed billions of hungry people (not to mention the cooking, and disposal) is enabled by the use of fossil fuels. Oil has helped the population boom along. It took all of human history for the population to reach one billion, which it did around 1800. In little over a century there were two billion in 1930. The third billion was added in just 30 years in 1960, the fourth billionth was added only 15 years later in 1975. Another billion made 5 in 1987. There were 6 billion of us by the year 2000 and today there are just over 7 billion human beings living on planet Earth.

Let us now consider economic growth on a third graph (Fig. 7). The gross domestic product (GDP) is a basic measure of a country's overall economic output. This graph shows world GDP in millions of Geary Khamis dollars since 1820 – 2010. The Geary Khamis dollar is a hypothetical unit of currency also known as the international dollar. It is used to accurately compare GDP between nations without the confusion of currency exchange rates.

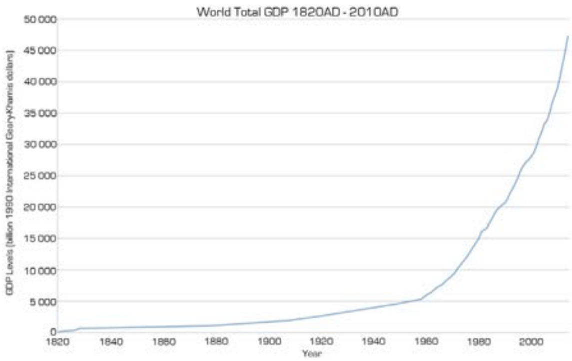


Fig. 7: *Total World GDP 1000– 2010AD. Source: Angus Maddison & US Census Bureau International Data Base.*

When we look at all three (oil production, population and economic growth) together we can again see massive similarities. Economic growth (GDP) has grown in tandem, exponentially as both oil production and population increases. Of course the energy provided by fossil fuels and the labour of ever reproducing human beings has enabled such a rapid increase in economic growth. What I find not only fascinating but also somewhat disturbing about these graphs is all of this exponential growth has only occurred over the last 200 years, since the widespread use of fossil fuels – the energy source of our civilization.

A video on YouTube titled '*Arithmetic, Population, and Energy*' easily searched and aptly tagged "*The Most Important Video You'll Ever See*" is of a modest lecture in Colorado by Professor Albert Bartlett who emphatically states, "*The greatest short-coming of the human race is our inability to understand the exponential function*". - Bartlett (2002)

Our global economy expects and demands continuous growth. Over the past 200 years this growth has been fuelled by an ever-increasing supply of energy in the form of fossil fuels. Whether global oil peaks and declines tomorrow, next year, next decade or even next century, if it hasn't occurred already, the net energy available from these fossil stores of sunlight will no longer be able to sustain a globalized economy. To date no discovery of any form of energy can replace this source from which we have built our technological world, as we know it. It is with great thanks to fossil fuels that we have experienced a growth-based economy. It is indeed all we have ever known. Yet without these energy inputs, future generations if not within our own lifetime will face a decline-based economy.

Our monetary system is a man-made concept that places an arbitrary value upon all aspects of the natural world. Marion King Hubbert precisely outlined the current predicament thus:

"*The worlds present industrial civilization is handicapped by the co-existence of two universal, overlapping, and incompatible intellectual systems:*

1. *the accumulated knowledge of the last four centuries of the properties and inter-relationships of matter and energy: and*
2. *the associated monetary culture which has evolved from folkways of pre-historic origin.*

The first of these two systems has been responsible for the spectacular rise, principally during the last two centuries, of the present industrial system and is essential for its continuance. The second, an inheritance from the pre-scientific past, operates by rules of its own having little in common with those of the matter-energy system upon which it is superimposed. Despite their inherent incompatibilities, these two systems during the last two centuries have had one fundamental characteristic in common, namely exponential growth, which has made a reasonably stable existence possible. But, for various reasons, it is impossible for the matter-energy system to sustain exponential growth for more than a few tens of doublings, and this phase is by now almost over. The monetary system has no such constraints, and, accordingly to one of its most fundamental rules, it must continue to grow by compound interest."

- Hubbert (1981)

Without oil and natural gas our modern industrialized society would never have been possible, this much is clear. Almost every aspect of my comfortable lifestyle is dependent upon the industry from when I brush my teeth in the morning until switching off the light at night, and almost every other facet of my middle class privilege in between. Indeed I like several billion others on Earth may not even be alive were it not for the widespread, versatile, energy dense properties of fossil fuels. It is this apparent conflict between what is beneficial for us on one level yet problematic for us and the wider environment on another that I am interested in. The modern photographic process is entirely oil dependent. I am therefore very conscious of the relationship between myself, the photographic process and the oil industry, and the cultural sphere that encompasses the entirety of this project. The purpose of this exhibition is to present a body of work that documents the current oil and natural gas landscape in New Zealand in a fine art context for contemporary contemplation and historical reference.

I have an admiration for early New Zealand photographers such as Alfred Burton who documented a landscape in the midst of great change. As British colonialism gathered frantic pace in its imperial dominance of much of the globe, in challenging times these early photographers documented the rise of industrial influence. Over a century later the world is a significantly different place to the one those early pioneers photographed. The trees have been felled and replaced with complex industrial structures and suburban subdivisions. The landscape is awash with roads loomed over by giant billboards force-feeding us artificial desires for material goods we don't need. Consumerism is rife, it is a product of industrialized society and cheap petroleum products have fuelled it all. This landscape is also worthy of documentation, perhaps as a conclusion to the work that photographers like Burton began.

Whilst experts bicker about the specifics of looming dates of the peak in world oil production, globally, government policies are considerably ignorant to the foreseeable issues that will arise, at least in terms of making the information general public knowledge. Largely because they don't want to be bearers of bad news, this would ultimately negate any chance of re-election. But also because they are propped up by financial backers who are determined to protect profits and are negligent to the paradigm shift that is needed to move away from an economic ideology that ignores the fundamental basic insight that unlimited, continuous growth in a world of finite resources is physically impossible.

References

Bartlett, A. *Arithmetic, Population and Energy*. [video online] University of Colorado, Information Technology Services. 2002. <http://www.youtube.com/watch?v=umFnrvcS6AQ> [Accessed: September 20th, 2012].

Bartlett, A. (1978) "*Forgotten Fundamentals of the Energy Crisis*". American Journal of Physics, 46 p.876-888.

Boulding, Kenneth E. *Ecodynamics: A New Theory of Societal Evolution*. Beverly Hills: Sage Publications, 1978.

Burtynsky, E., and Michael M. Burtynsky: *Oil*. Göttingen: Steidl, 2009. p.171.

Bush, W. G. (2006). *President Bush's State of the Union Address*. Delivered to US Congress, Washington, D.C, 21st January 2006. Transcript by < http://www.washingtonpost.com/wp-dyn/content/article/2006/01/31/AR2006013101468.html> [Accessed: September 25th 2012]

Clark, H. (2006). *New Zealand Prime Minister on Peak Oil*. Interviewed by press [in person] Parliamentary Press Gallery, Wellington, 18th April 2006.

Heinberg, R. *The Party's Over: Oil, War and the Fate of Industrial Societies*. 2005. (2nd ed). Gabriola, BC: New Society Publishers, 2003. p.56.

Hubbert, M.K. "*Energy From Fossil Fuels*". Science, New Series. Vol. 109, 1949. p.103-109.

Hubbert, M.K. *Health Facilities and the Energy Crisis: A Conversation with M. King Hubbert*. [video online]. Chicago: American Hospital Association. 1976. <http://collectiveliberation.com/2011/02/04/vintage-oil-crisis-film/> [Accessed: September 20th 2012].

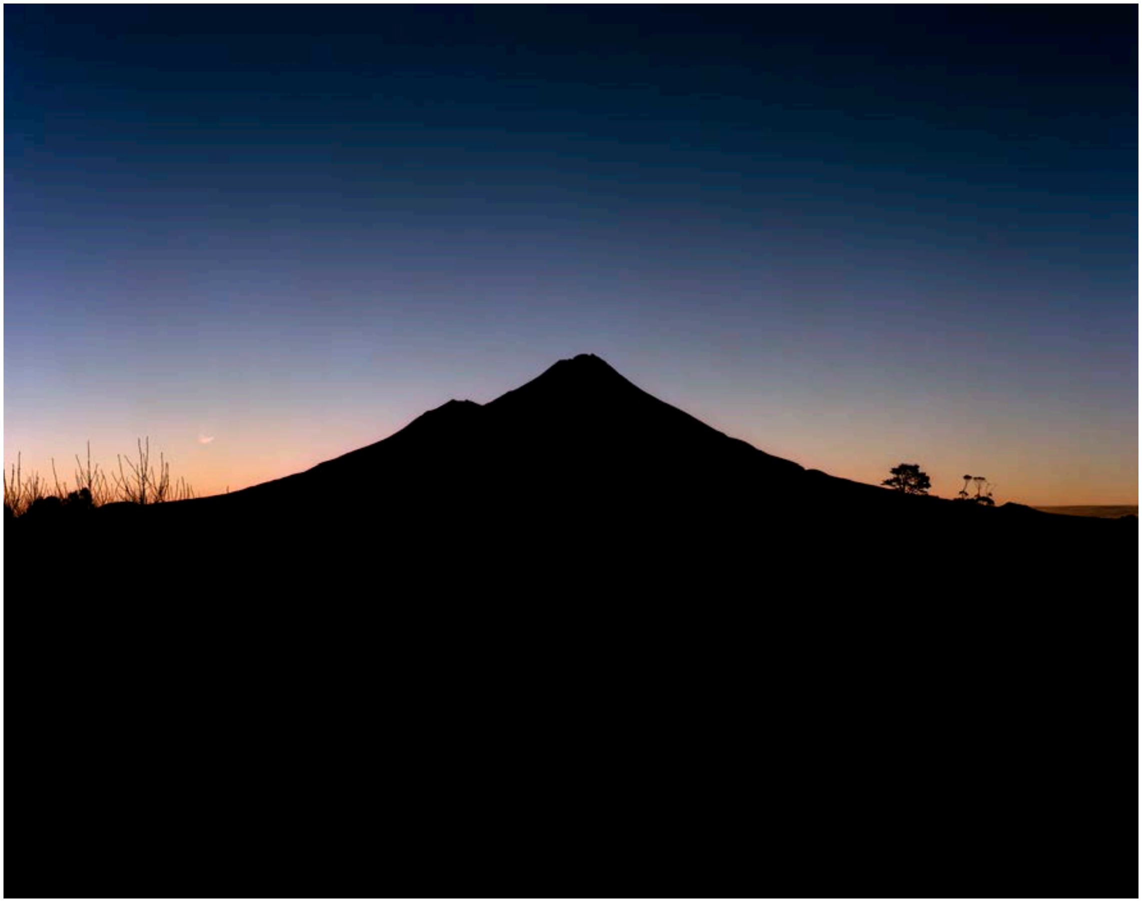
Hubbert, M.K. *Nuclear Energy and the Fossil Fuels*. Texas: American Petroleum Institute, 1956.

Hubbert, M.K. *Two Intellectual Systems: Matter-energy and the Monetary Culture*. Summary, by M. K Hubbert, of a seminar he taught at MIT Energy Laboratory, 30 September 1981, at <http://www.hubbertpeak.com/hubbert/monetary.htm>

International Energy Agency (IEA). Key World Energy Statistics 2012. Paris: 2005. (available as a downloadable pdf from: <http://www.iea.org/publications/freepublications/publication/name,31287,en.html>)

Rosenblum, N. A World History of Photography. 2007. (4th ed). New York: Abbeville Press, 1984. p.15-38.

Strahan, D. The Last Oil Shock: A Survival Guide to the Imminent Extinction of Petroleum Man. London: John Murray (Publishers), 2007.



Mt. Taranaki, 20th July 2012

The Peak of Mt. Taranaki and Shell Station, Inglewood, 15th April 2012

Marsden Point Oil Refinery from Reotahi Bay, Whangarei Heads, 24th August 2012

Kapuni Production Station, Kapuni, 16th April 2012

Oil Tanker, Marsden Point, Whangarei, 28th August 2011

Marsden B Power Station in the process of being dismantled, Marsden Point, 27th August 2011

Site of the former Marsden B Power Station, Marsden Point, 24th August 2012

Natural Gas Pipes, Inglewood, 15th April 2012

Kupe Production Station, Inaha, 19th April 2012

Oil Rig, McKee Oil Field, New Plymouth, 14th April 2012

McKee Production Station, New Plymouth, 15th April 2012

Pohokura Production Station, Motunui, 18th April 2012

Pohokura Production Station #2, Motunui, 18th April 2012

New Plymouth Power Station, Port Taranaki, New Plymouth, 17th April 2012

Maui Production Station, Oaonui, 17th April 2012

Maui Production Station #2, Oaonui, 17th April 2012

Horopito Motors, Horopito, 21st July 2012

Kupe Natural Gas Field (unmanned Wellhead Platform), Tasman Sea, 20th July 2012

Peak Oil and implications for NZ
April 2011

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University of Otago Physics Dept.

Introduction

It should seem obvious to any objective observer, carefully monitoring the current world situation, that the biosphere and the world economy are fast approaching limits to growth and limits to complexity (Meadows, 1972, Meadows, 2004, Catton, 1982). The two visible signals that foreshadow these approaching limits are anthropogenic induced climate change and peak oil. This present report is an update of my previous End of Oil essay (Lloyd, 2005) with particular reference to NZ.

In terms of the effect of depleting oil supplies specifically on NZ it is suggested that the extended effects on the world and national economy will outweigh local effects such as increased petrol prices. It is also true that such extended effects are more problematic in terms of investigation, as they are likely to be more variable, depending as they do on the actions of many countries and many complex political and social systems with intertwining feedback mechanisms. The feedback systems in particular, will mean that the outcomes will probably be non-linear; meaning that if oil supply declines 1% a particular sector outcome may not necessarily also be of the order of 1%, the sector outcome may be much greater or for that matter much smaller. As the consequences of such non-linear effects will be highly variable and produce outcomes of considerable uncertainty the basic scenario planning will also take into account linear interactions between world oil supply and availability of petroleum products in NZ. This report proposes a set of four possible future scenarios with and without non-linear interactions.

In terms of prior work in this area, the Otago Regional Council contracted the Christchurch based Centre for Advanced Engineering (CAE) in 2006 to undertake a “High Level Assessment of the Risks and Vulnerabilities to Energy Supply in the Otago Region” but this assessment concentrated on short term disruptions to primarily the electricity sector and did not really address the long term issue of peak oil. Nevertheless the report does contain extensive material devoted to existing oil and gas supply and should be read in conjunction with the present report (CAE, 2006). The CAE report looks at oil supply disruption scenarios but does not broach the more controversial and difficult area of long term oil depletion. At a national level, a report was undertaken for the NZ Ministry of Transport in 2008 titled “Managing transport challenges when oil prices rise” (Donovan et al., 2008) which contains pertinent mitigation possibilities in the NZ context. In addition there has been an increasing number of reports produced internationally dealing with the peak oil and associated issues, these will be documented in the main text.

Peak oil and climate change

Before embarking on the report proper it may be useful to look at how a report on peak oil might be compared with climate change reporting. Anthropogenic climate change has been a topic of international interest at least since the mid-1970s; the substance has been intensively researched by many thousands of international physical scientists, social scientists, economists and politicians among others. Climate change research has a major international bureaucracy including the IPCC and the UNFCCC. In addition there are a host of related international agencies, national agencies and NGOs attending to climate change science and issues relating to climate change. Climate change reporting thus has had a vast background literature at its disposal including the definitive IPCC reports. Peak oil on the other hand, although having an equally long history, has nowhere near the background documentation or for that matter any national or international bureaucracy dealing with its investigation. There is an international association for the study of peak oil (ASPO) and a NZ branch of ASPO but in terms of numbers and scientific credibility there is no comparison with climate change. The peak oil problem has, however, inspired a good many books in popular literature (see: http://www.peakoil.net/publications/books) but the number of peer reviewed scientific papers, although growing, is small by comparison with climate change (see: http://www.peakoil.net/publications/peer-reviewed-articles). A search of "peak oil" as a topic in international journals (September 2010) returned a little over 200 articles (well over half of these published over the last two and a half years) whereas "climate change" returned over 42,000 articles starting as early as 1982.

In terms of popular support the positions are somewhat reversed, especially locally in NZ. The implications of climate change have spawned a formidable opposition in the form of climate change deniers. A recent survey of 366 landowners in the Otago region found for instance that only around 30% of the respondents believed in anthropogenic climate change, whereas some 56% thought that oil supply would be problematic for NZ in the near future (Schaefer, 2010). Nationally around two thirds of NZ survey respondents recently (2009) indicated a belief in climate change, a similar number to international surveys (Schaefer, 2010). In term of resources, an international poll by Reuters suggested that around 70% of 15,000 respondents thought oil had already peaked.

The relative lack of consensus background material will mean, however, that the present report will need to include somewhat more technical material than the climate change report, as such material tends not to be available elsewhere. This comment is especially true of the interaction between oil availability and economics, which is a much under researched topic.

Crying wolf! Getting the timing right

As suggested in the 2005 End of Oil essay predicting the end of any natural resource has the problem of dealing with presumed errors of past predictions? In particular, the predictions of the pre-1980s appeared to go spectacularly wrong in light of the next two decades. The aftermath of these early doomsday pronouncements has led to a numbing of the public, even the informed public, against further pronouncements of this variety.

The predictions, with regards to non-renewable resources, have been one area which has been particularly subject to poor timing. The first Club of Rome report, which came out in 1972 (Meadows et al., 1972), suggested that the world would be limited by two fundamental restrictions, either lack of resources or by an increase in pollution. The long term predictions were severe and suggested, in most scenarios, drastic world population declines sometime around the middle of the twenty first century, this century. Unfortunately the report focused more on minerals rather than energy and on the pollutant effects of chemicals other than CO2. The anthropogenic greenhouse effect was just coming on to the world's radar at this time and was not yet quite thought to be a serious threat. The latest report in this series was produced in 2004 and did not contradict or substantially alter the substance of the 1972 scenario predictions (Meadows et al., 2004).

The difficulty with energy resources, which differentiates them from other mineral resources, is that they cannot be extracted at lower and lower concentrations, as once the energy needed to make the energy transforming devices becomes greater than the useful energy obtained there will be a net energy loss.

Up until recently the availability of fossil fuels has not been a problem and the high energy returned on energy invested (EROEI) for coal, oil and gas have ensured continued world economic growth for the last 200 years or so. The energy returned on energy invested is the amount of oil (or rather energy) that is needed to extract and process oil from the reserve base. The early oil in the US in the 1930s and oil up to the present, in parts of the Middle East, was very easy to get, having an EROEI of around 50 to 1 or greater. That is it took only one barrel of oil to extract and process 50 barrels, a very favorable ratio. That good fortune along with ratios of up to 80:1 for coal meant that high economic growth rates could be maintained during most of the 20th Century.

Our worldview has been shaped by past economic growth and in fact the construction of the world economic system has been shaped by this continued growth to the extent that it now seems difficult to conceive of a future outside of that necessitated by economic growth. Newspapers are continuously full of prominent people exhorting more growth. With the knowledge of environmental effects this plea has often changed to exhorting more sustainable growth.

But oil is now getting more difficult to extract with EROEI ratios closer to 12:1 for deep sea oil and even lower for non conventional oils such as the Canadian tar sands (4:1). The difficulties in the Gulf of Mexico with BPs well drilled in 5000 feet of water and going down to 30,000 feet illustrate the risk and energy needed in the extraction process. A peak oil commentator, Richard Heinberg, recently suggested that the 2010 problems in the Gulf of Mexico would be typical of the difficulties of extracting oil, post peak, and that we may now have reached peak oil.

Thus the question we must answer is what will happen to the world economy in times of declining energy supplies?

Physical reality versus economic reality:

Will the future look like the past? The problem is that the world economic picture, painted by economists on a background of free trade and globalisation, has failed to take into account the physical reality of energy in general and fossil fuel resources in particular; especially in terms of the state of the world's crude oil supplies. An examination of oil supplies will lead us to the conclusion that we have essentially been misled by a system of unrestricted marketing and growth dominated economics. A recent paper, questioning the existing paradigm, has tried to forge a marriage between physics (thermodynamics) and economics with far reaching conclusions (Ayres and Warr, 2009). The authors explored the question: "whether energy consumption causes economic growth or whether it is simply a consequence of the level of economic activity?" and found the former. That is useful energy, in the form of work is necessary for economic growth and that with declining fossil fuel supplies the only alternative available will be improving energy efficiency. Once such improvements run out then, in the absence of any other resources becoming available, the world economy must decline. This is a serious assertion with wide ranging consequences: can it be correct? Ecological economists, such as Herman Daly, have been saying for many decades that the only hope for the world is to give up the doctrine of never ending growth and to move towards a steady state economy but the allure of never ending growth has usually been all pervasive and such pronouncements mostly ignored (see Box 1 on growth).

Growth as the world economic paradigm

A recent book by Tim Jackson, the Economics Commissioner on the UK Sustainable Development Commission and Professor of Sustainable Development at the University of Surrey called "Prosperity without growth" clearly framed the dilemma:

- *Growth is unsustainable – at least in its current form. Burgeoning resource consumption and rising environmental costs are compounding profound disparities in social well being.*
- *De-growth is unstable – at least under present conditions. Declining consumer demand leads to rising unemployment, falling competitiveness and a spiral of recession.*
  - Jackson (2009)

In addition the world financial system is predicated on growth, without growth the interest on capital cannot be paid back and in a world with a high level of indebtedness the difficulty of paying back loans can become impossible in a declining economy. It is of no surprise then that governments and financial institutions everywhere are overwhelmingly always trying to stimulate growth. But as Jackson also suggests, never ending growth in a finite world is physically impossible, and as the world is coming to realise, we are now fast approaching the limits to growth. Jackson poses the dilemma as a major impossibility theorem.

Jackson continues to suggest that the dilemma can only be resolved by a complete change in both the world economic system and in our western consumer culture. In addition he suggests a new definition of prosperity, one which does not include increasing wealth. Nothing less than radical change it seems can prevent economic growth from colliding with ecological security. But it is generally a change that most people are not going to come to terms with easily. In particular the media, advertising and popular culture all emphasise growth, competitive spirit and unbounded striving for ever more "stuff". Any suggestion otherwise is not going to be popular! (Lloyd, 2009, Sims et al., 2010, Sorrell, 2010).

Box 1: Growth as the world economic paradigm

Oil and growth

How does oil fit into this picture? Well there is no escaping the fact that the world economy is dominated by crude oil supply, which together with natural gas and natural gas liquids accounts for around 60% of the commercial energy used by the world. Figure 1 is taken from the oil company BP's "Statistical Review of World Energy 2009" (BP, 2010).

As of mid 2010, the world was using some 86 million barrels of petroleum (all liquids, that is including LPG and non conventional liquids) a day: an amount, which equates to some 31 billion barrels a year or around 4.5 cubic kilometers a year. As can be seen in Fig. 1 the decline in all world energy in 2009 was the first such decline since the last oil crisis in the early 1980s. In addition, the recent increase in world coal consumption comes about as the world is also grappling with the implications of climate change and pressure to reduce coal use.

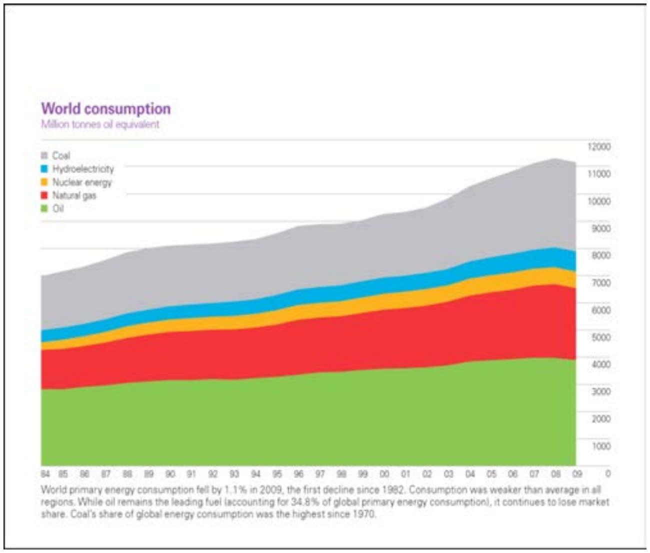


Fig. 1: World energy supply 2009 from BP Statistics 2010

Ayres and Warr, the authors mentioned above, realized that it was not just energy that keeps the world economy ticking along but the "work" that comes from energy being transformed to productive purposes. In this respect the energy sources in Fig. 1 are not all equal and that electricity production from coal, natural gas, and oil used for transportation are the critical resources in terms of economic production. In addition transport is critical for the movement of goods and people to enable the productive process. Finally oil is the world key strategic resource, powering the various national armies, navies and air forces of the world. Thus oil tends to punch above its weight in terms of importance as a resource, which is why the peak oil movement is particularly focused on this variety of energy supply.

How much oil is there?

The question of how much conventional oil exists has not changed substantially since the 2005 essay and appears to have stabilized on a number around 2,400 billion barrels. The important question asking how long will the world's oil endowment will last, was first considered by King Hubbert as early as 1949 (Lloyd, 2005).

The baton Hubbert carried in his quest to alert the world as to the problems that will occur after peak oil was passed to Colin Campbell and John Laherrere. These two geologists published a famous paper in Scientific American in 1996 titled 'The End of Cheap Oil'. As one of the founders of the peak oil movement Colin has been publishing his account of the world oil and gas situation for a number of years based on his work with the energy information company Petroconsultants in the late 1990s. His estimates, which show a peak in all liquids between 2008 and 2010, are shown in Fig. 2, and are obtained using an Estimated Ultimate Recovery (EUR) of 2450 billion barrels of all liquids (i.e. including natural gas liquids) in good agreement with the previous mentioned estimates for crude oil (2400 billion barrels). The peak for gas is difficult to see from the figure, as gas is 'stacked' on top of oil, but by disentangling the two it comes around 2018.

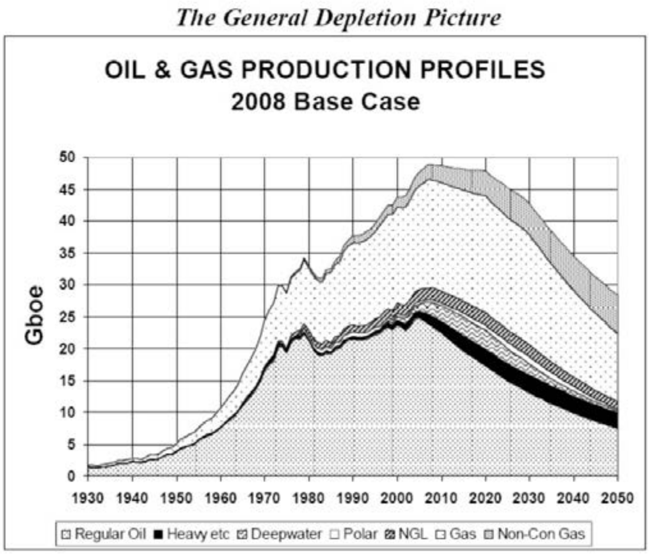


Fig. 2: Oil and Gas depletion profiles (Campbell 2009)

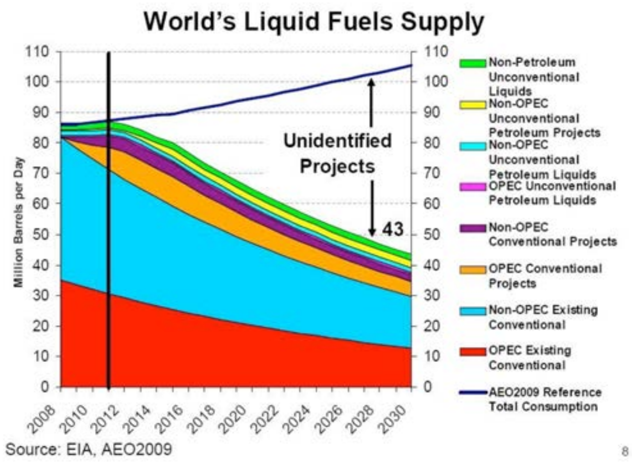


Fig. 3: EIA depletion profile for world liquids Sweetnam (2009)

Mainstream agencies such as the International Energy Agency (IEA) and the Energy Information Agency, of the US Department of Energy (EIA), have historically disagreed with the peak oil people and until very recently have avoided even mentioning peak oil. Just a year or so ago, however, the IEA chief economist Fatif Birol informed the public that we had "better leave oil before oil leaves us" and the EIA published data in March 2010 which shows world oil supply declining after 2011. The figure below shows the EIA data where unidentified projects are well, "unidentified"! And, according to many other researchers, they are possibly unlikely to ever be identified.

In confirmation of such estimates, Sadad Al Husseini, previously production manager for the world's largest oil company Saudi Aramco, gave his views on oil availability in a recent interview, when asked how much oil remains globally he replied 'I think I would say 900 billion proven, perhaps 1,200 billion probable and potential. But that's about the limit.' And the total barrels referred to include the Canadian tar sands and other heavy oils but not NGLs (Al Husseini, 2009).

In summary it looks as if the balance of evidence is suggesting peak oil either has already occurred or will do so in the imminent future and certainly by the end of the coming decade. The reaching of peak oil means that instead of having doubling times in oil extraction and consumption of between 10 and 20 years, as occurred during the 20th Century, we will now have a decline, with the availability of oil, possibly halving every 20 years (see later).

There is the possibility of course of further fields being discovered, including ones in NZ, but overall the production from such fields will be overtaken by the overall decline in existing fields. In a recent paper in Energy Policy, Alekleltt et al. posits a gentle decline (see Fig. 4) suggesting that by 2030 the world may be producing as much as 76 million barrels per day (Aleklett et al., 2010).

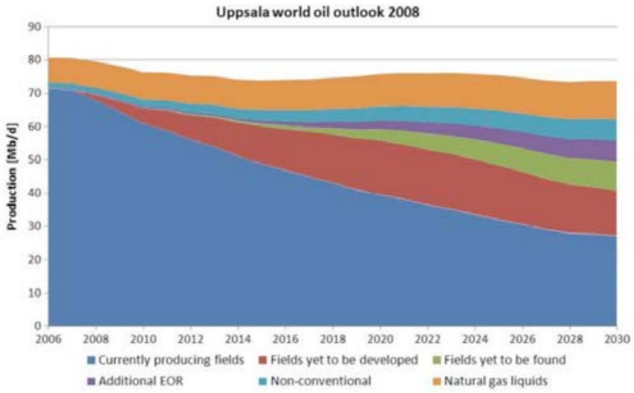
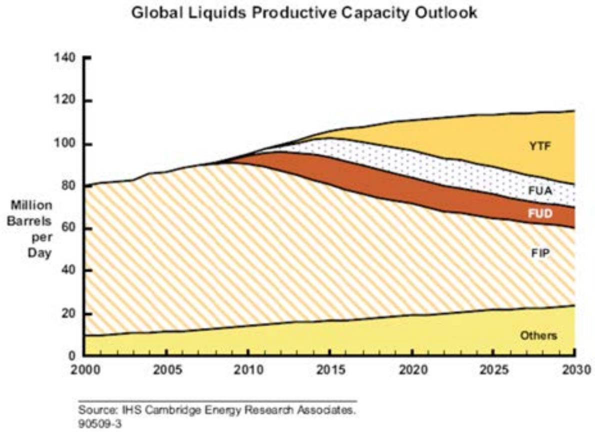


Fig. 4: Uppsala world oil outlook 2008

In order to make sure that this report has some balance, Cambridge Energy Research Associates (CERA) is much more optimistic about future oil supply. In their recent report "The Future of Global Oil Supply: Understanding the Building Blocks" CERA stated: "IHS CERA's reference case for global liquid productive capacity shows growth through 2030 to around 115 million barrels per day (mbd) and finds no evidence of a peak in supply appearing before that time" (CERA, 2009). After 2030 they see an undulating plateau rather than a distinct peak (see Fig. 5). They have, however recently admitted that demand in OECD countries may have peaked and that future growth may be entirely in the developing economies. A peaking of demand in OECD countries with constant or declining population is certainly possible with efficiency gains, but for the major consumer, the US, and other countries with an increasing population, peaked national demand means declining oil availability per person.



- fields in production (FIP)
- fields under development (FUD)
- fields under appraisal (FUA)
- yet-to-find (YTF) resources

Figure 5: CERA projections for global liquids production

Krumdieck et al. (2010) from Canterbury University have used data from existing expert predictions as to the date of peak oil, obtained from Hirsch (2005), to estimate the probability of supply in the future, but this assessment discounts the more optimistic estimates such as CERA 2009, due to their being unlikely.

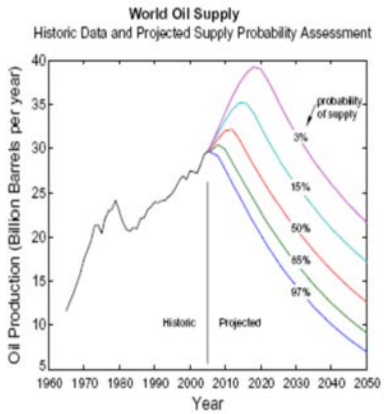


Fig. 6: World Oil supply probability assessment from Krumdieck et al 2010

The decline rates

With the increasing consensus that peak oil has been reached or is imminent, the next question to be answered is what are the likely decline rates? In the absence of NZ finding major additional oil fields, it is not the produced oil that will matter; it is the final available oil that will reach the international market that NZ has access to, and this oil may be much less than the oil left in the ground for at least two reasons. One is that the energy needed to extract the difficult to get oil is becoming greater, leaving less net oil for the market. The other reason is that the oil producing countries have both above average levels of GDP growth and high population growth and thus are consuming more and more of their own product; leaving less oil to reach the open market (see Fig. 7 and 8). Putting in some numbers here; the present EROEI for oil is around 35:1 (world average 2010). The current "difficult" fields (e.g. deep sea) are estimated to have EROEI ratios of around 12:1. It could be suggested that by 2030 most oil would be coming from difficult fields yielding an EROEI ratio of around 17.5:1, meaning an annual decrease in available oil of at least 0.15% pa. For oil producing countries, OPEC daily internal consumption has increased by 2 million barrels per day over the last 6 years, meaning an average decrease in available oil of around 0.3 million barrels day per annum, other producers internal consumption could easily add a further 0.2 million barrels per day per annum leading to a self consumption decrease in available oil of around 0.5 million barrels per day, per year (as of 2010).

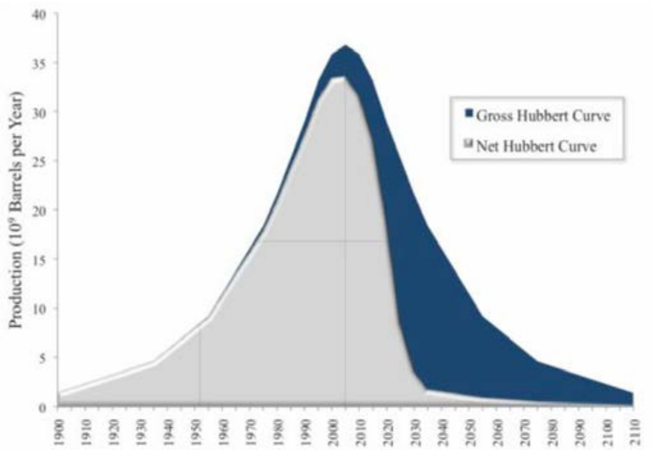


Fig 7: EROEI implications for peak oil

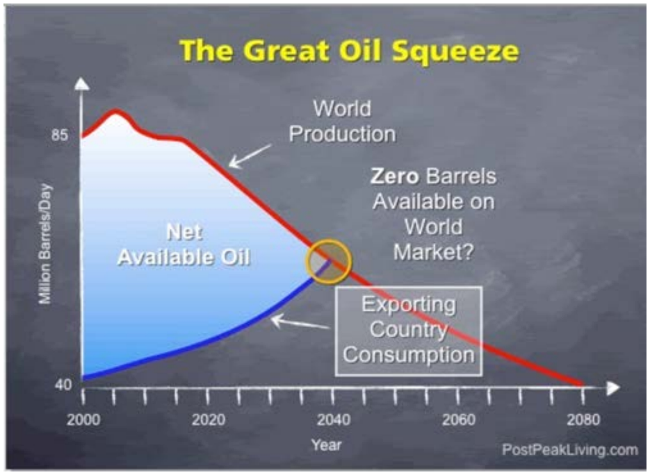


Fig. 8: Increased consumption by oil producing countries will decrease available oil exports.

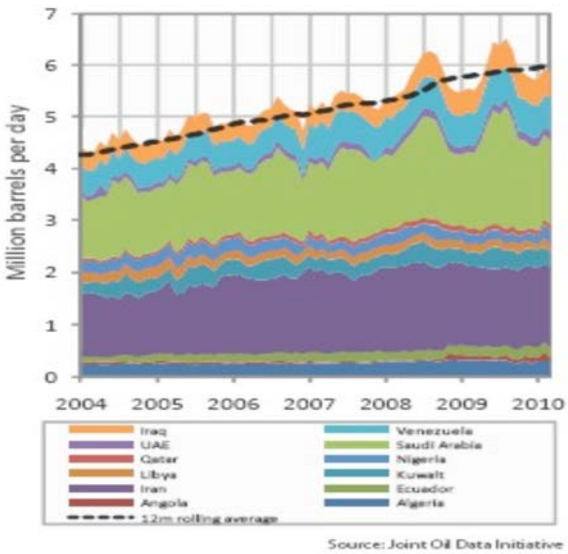


Fig. 9: actual increases in oil consumption by OPEC countries

Robert Hirsch was an energy consultant to the most recent Bush administration in the US. He wrote an important report in 2005 to the US Government suggesting that if the world was to avoid liquid fuel declines after peak oil, mitigation measures would need to be put in place up to 20 years before the peak (Hirsch 2005). In a more recent paper, in the journal Energy Policy, he suggests three scenarios: a best case scenario where maximum oil production is followed by a relatively flat production before a decline of 2-5% pa., a middling scenario where there is a sharp maximum production and then a linear decline of between 2-5% pa., and finally a worst case scenario caused by exporter withholding with rapidly (> 5%) declining oil availability (Hirsch, 2008). The best case scenario would be consistent with the Uppsala world outlook 0.6% decline until 2030. Recently (September 2010), Hirsch has suggested that a flat plateau is the more likely option.

For the purposes of this paper we suggest two scenarios of oil decline, roughly consistent with the above. Note we have not considered the worst case scenario as the outlook here is too traumatic but this scenario will be consistent with the non-linear and 4% oil decline (see later).

- Somewhere a plateau or a 0.6% decline until 2030 after which a 4% decline
- A 4% decline starting from around 2012

The Hirsh (2008) paper, however, does not consider in detail interactions with the world economy, although his newly released book "The Impending World Energy Mess" redresses this matter to some extent.

Oil and the Economy (is oil money?)

One way of assessing the future financial liability of NZ is to assume oil will increase in price as oil depletes and then assess what will happen in terms of people's ability to pay for oil products such as petrol and diesel. But money is not a disembodied quantity; it is related to the real world by means of what people can exchange it for.

Thus the question may change from: how much oil will cost in the future as oil depletes? To: how much will money be worth in the future when oil depletes?

The relation between energy and money must be very close to the extent that a substantial part of the token that money represents must be energy; and therefore oil. Except possibly for bare land, all items of trade, food, minerals, motor cars and other consumer goods rely on energy for their manufacture and crude oil forms the largest share of the world's energy mix, followed by coal and gas. If we plot world energy supply against world GDP we should see a close relationship.

Oil currently (2010) provides around 35% of the world's commercial energy supply so first let's look at oil and money. Figure 10 shows a logarithmic plot of oil consumption during the past 70 years as well as a plot of the logarithm of world GDP. The logarithmic plots mean that the slopes of the curves give the rates of increase of the respective parameter (i.e. oil consumption and GDP).

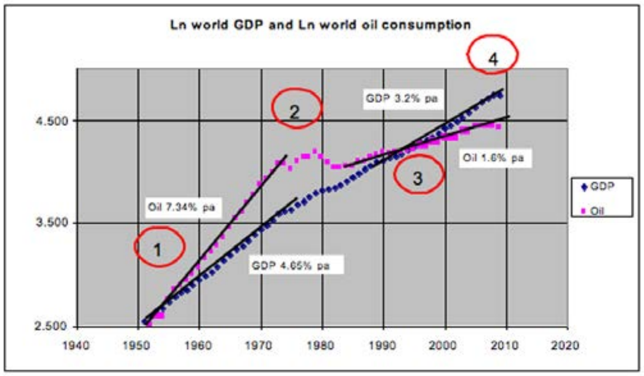


Fig. 10: Oil supply and world GDP

The oil data comes from BP statistics (from 1967 until 2009) and Realty earlier. There are four regions of interest on the figure, the first region is from 1950 to 1974 and the data for this time shows that the increase in world oil supply was around 7.3% p.a. compared to the increase in world GDP of around 4.6% p.a. Or in other words a 1% p.a. increase in oil supply facilitated a 0.63% p.a. increase in world GDP. The second region of interest is the period of the 1970s oil crisis when turmoil in the Middle East hiked prices and restricted supply. During this time the world changed the relation between oil and GDP dramatically. Energy efficiency was improved and energy intensity, that is the ratio of energy use to GDP, decreased, such that in the third period, from the mid 1980s until recently, the increase in world GDP to increase in world energy supply reversed and during this time a 1.6% p.a. increase in oil supply was able to facilitate a 3.2% p.a. increase in GDP. That is the world GDP increased at double the oil supply increase. Now a change in the increase by a factor of two means that if we plot oil use against the square root of the world GDP the slopes should be the same on average. The plot for this relationship since 1985 is shown in Fig. 11.

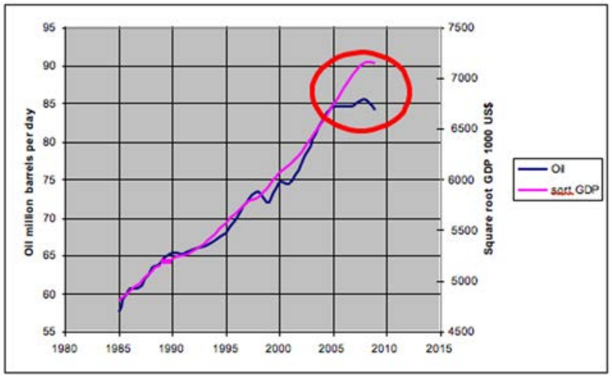


Fig.11: World oil production in million barrels per day plotted against the square root of world GDP in constant US$

As can be seen, the relationship is very close, except after 2005, the fourth region of interest. How can that be? World GDP still increases at 3.2% per annum until 2008 but oil production is pretty much flat. At first sight it looks as if world oil use has been decoupled from the world economy? If we look at changes in the supply of other energy sources it is also obvious that the recent increase in coal use could have made up for the lack of oil, but if we investigate where the increased coal is being used we will find that it is largely in developing countries, including of course China and India. And it is China that has been transferring its products (and thus substantial embodied energy) to the rest of the world by virtue of the country being the world factory.

Another reason for the apparently decoupled GDP oil relationship over the last 5 years (mainly exhibited by the so called "rich" countries) is debt. Fig. 12 shows public debt (i.e. Government debt) taken from the Economist (Magazine) Intelligence Unit over the past decade.

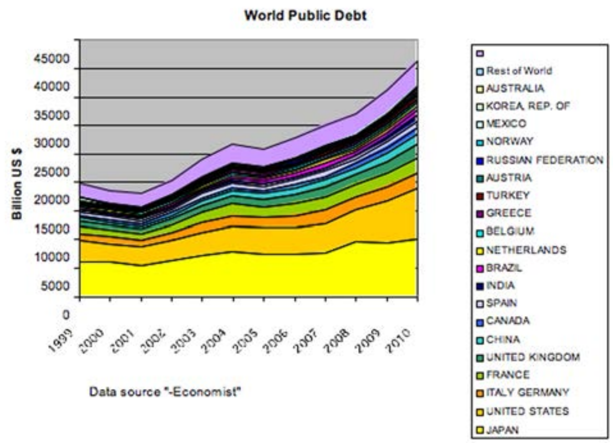


Fig. 12: World Public Debt: data from Economist (2010).

Here it can be seen that of the top 21 indebted countries, 17 are the rich economies of Europe, North America and Japan, the same countries that have had declining oil consumption over the last few years (exceptions China India and Brazil). Here again the crucial question is which comes first a declining oil supply causing a declining economy or a declining economy causing a declining oil supply? While the Ayres' paper would claim the former and many other more "conventional" economists would claim the latter, it is likely that the truth is somewhere in between i.e. a very close coupling between economic growth and oil supply, each feeding on the other. It has been shown elsewhere that richer people tend to spend more money on energy and oil for transport in particular than poorer people (Lloyd, 2006).

Thus, the primary question that needs to be answered in this investigation of how oil depletion will affect NZ, depends critically on how the world economy will react to oil depletion.

Economics and the price of oil

The classic economic theory of depleteable resources (including of course fossil fuels) was considered by an American economist, Hottelling, as far back as 1931. Hottelling formulated the rule, which is now named after him, that the price of non-renewable resources should follow the interest rate (Hotelling, 1931). This law can be seen to follow from the argument that for the oil producers it does not matter if they produce a given quantity of oil today at a price $X or at a time in the future at $Y, such that if they put the $X in the bank today they would have the equivalent money $Y at the future time. Hottelling used sophisticated mathematics to show that this conclusion was true but the problem is that in practice it has not happened. That is, the price of oil has not followed the interest rate. Fig. 13 shows the price of oil for the last 150 years or so taken from the BP statistical review. The green line shows the price of oil in constant dollar terms and it can be seen that over the period of highest increase in production (the first half of last century) the price of oil steadily declined. It was not until the oil crisis of the mid and late 1970s that the price increased substantially.

This increase was due to a manipulated market and political events (OPEC and wars) not market forces based on the long-

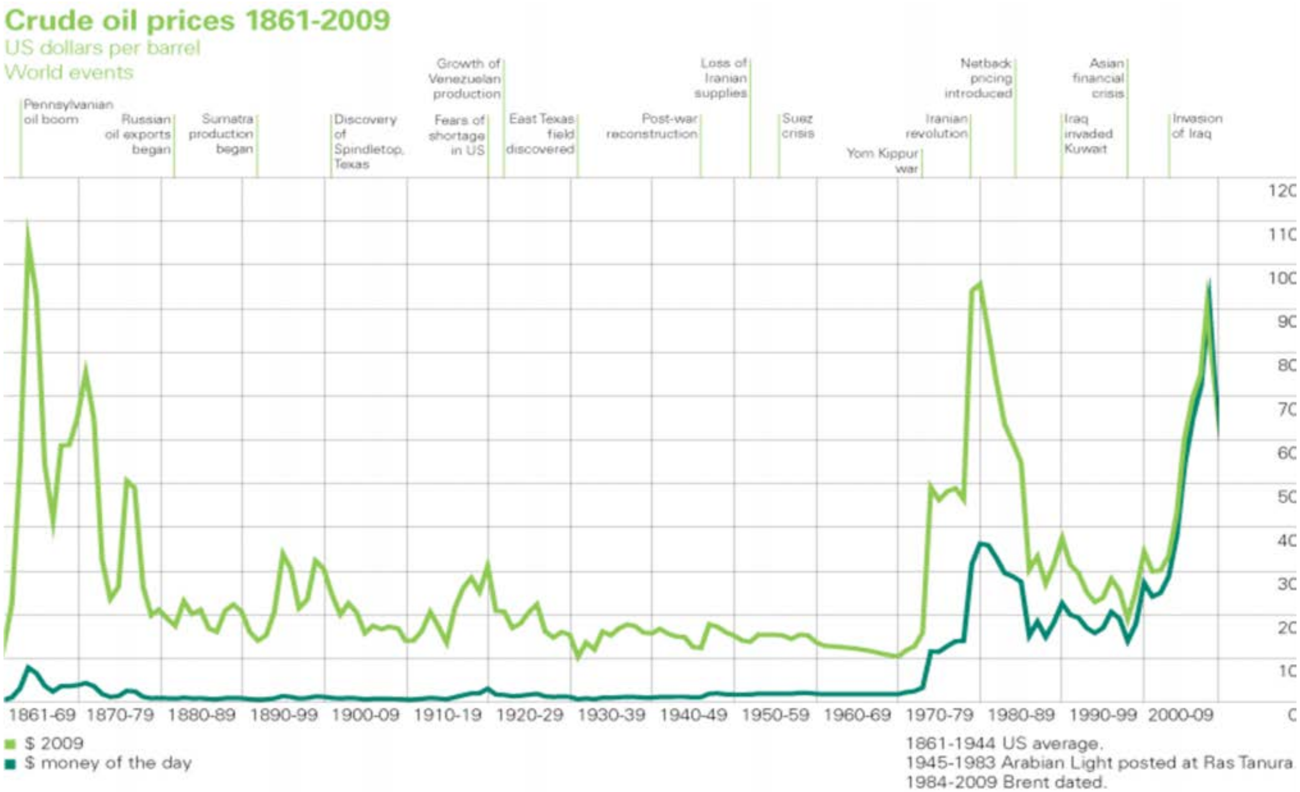


Fig. 13: Price of Crude Oil as per BP statistics 2010

term supply of oil. Thus the price of oil has not given the right signal to the consumer that the peak of oil extraction is near, perhaps until recently. In particular the flurry of activity from the conservation movement in the 1970s and especially following the oil crisis, was dissipated by the crash in oil prices that occurred in the mid-1980s.

The price crash of the mid-1980s took the wind out of the sails of any effort to convince the world that something should be done with regards to energy conservation and to urgently research renewable energy options so that they could be brought on-stream in an orderly manner as suggested by Hubbert. The buoyant world economy in the latter years of the 20th century driven by globalization and the international concerted move to deregulate vertically integrated energy supply companies, has kept energy costs lower than necessary to give price signals that would trigger the appropriate investments in really sustainable options. These trends, together with other major political events, have substantially neutralized any effort to look at the future of the world energy situation in a rational manner.

But the largest oil producers in the world, the Saudis have known for a long time that the price of oil substantially influences the world economy and have manipulated the supply to control oil prices for most of the 20th century. More recently at the 2009 ASPO meeting in Denver USA, Sadad Al Huseini the Saudi Aramco production manager (quoted earlier), emphasized that:

> "*There is a ceiling to what the global economy can afford for energy. Roughly speaking, o***nce you get to five to six percent of the global GDP being spent on oil, that's about the ceiling***. You cannot just assume that people will pay the price at higher and higher costs. For that reason, I do think we do have a boundary, we do have a limit to what is available with current technologies, in terms of supplementing supplies*".
> (emphasis added)

In terms of the future Sadad suggested:

> "*However, you can mitigate demand. You can be more efficient, and that may be the hidden opportunity whereby, through improving the energy efficiency, we can use far less of the oil and gas to make them go a lot further.*
>
> *So yes, in a way there is a plateau, but the plateau is not a crisis; it's an opportunity to be more efficient*".
>
> - Al Husseini (2009)

As of 2010 the world is using around 31 billion barrels of oil per annum and the world GDP is roughly US60 trillion. Thus at 6% of world GDP the Al Husseini limit equates to oil being US$ 120 per barrel. Now the lower limit is dictated by the extraction costs (really the EROEI) and appears to be around US$60 per barrel but this value is increasing as oil becomes harder to find. If the Al Husseini limit applies in a depleting regime then as oil depletes the cost of oil can rise but at a rate dictated by the rise (or fall) in world GDP. With a constant world GDP, the price of oil might be expected to rise at roughly the rate of depletion. That is with a 4% pa depletion rate, the price of oil could rise at 4% pa to keep the cost per GDP constant. But with the close relationship between oil and money, the feedback between the two is likely to produce highly non-linear effects as mentioned. The field of system dynamics as pioneered by Jay Forrester and the Club of Rome, has published Limits to Growth reports that have previously investigated such effects (Meadows et al 1972, Meadows et al., 2004). The results show that the usual economics "ceteris paribus" stipulation (all other things being equal) cannot work when it comes to tightly coupled systems and that feedback must be taken into account.

Because highly non-linear systems are difficult to model and the outcomes often unpredictable, especially once social and political aspects are taken into account, the present report will consider two additional parameters in putting forward future post peak oil scenarios that is:

- a linear interaction between the world oil supply system and the world economy and a
- non-linear interaction driven by closely coupled feedback loops

Before such scenarios are developed further a review will be made of recent peak oil reports; which have started appearing rapidly during 2010.

Recent peak oil reports

In February 2010 the UK Government produced a report on peak oil "The Oil Crunch:
A wake-up call for the UK economy" The report noted that:

- **General** "*National and local government policies (particularly those on the social, economic and financial fronts) should explicitly acknowledge the potential for high oil prices and promote appropriate contingency planning*."

- **Transport** "*A mix of technological solutions and policies to incentivise behavioural change and modal shift from the car to public transport are identified as key priorities*".

- **Retail and Agriculture** "*These sectors are both hit by a secondary dependence on oil. Retail, because of its dependence on sophisticated just-in-time deliveries (transport), and agriculture because of its dependence on oil-based crop and soil treatment products as well as fuels for cultivation and produce transport*."
(UK ITPOES, 2010)

Also in February 2010 the US Department of Defense produced a report on the "Joint Operating Environment" investigating strategic issues facing the US defence forces. The report made extensive comments on future energy demand and that: "*To meet that demand, even assuming more effective conservation measures, the world would need to add roughly the equivalent of Saudi Arabia's current energy production every seven years*." (JOE, 2010)

In terms of the effects of an energy crunch, the report was particularly pessimistic suggesting that:

"*While it is difficult to predict precisely what economic, political, and strategic effects such a shortfall might produce, it surely would reduce the prospects for growth in both the developing and developed worlds. Such an economic slowdown would exacerbate other unresolved tensions, push fragile and failing states further down the path toward collapse, and perhaps have serious economic impact on both China and India.* ***At best, it would lead to periods of harsh economic adjustment***."

In March 2010 the French newspaper, Le Monde reported an interview with Glen Sweetnam, director of the International, Economic and Greenhouse Gas division of the Energy Information Administration at the DoE. In this report the U.S. Department of Energy admits that "*a chance exists that we may experience a decline*" of world liquid fuels production between 2011 and 2015 "*if the investment is not there*".

In April another UK report this time by FEASTA: The Foundation for the Economics of Sustainability produced a report titled "*Tipping Point: Near term implications of a peak in global oil production: an outline review*" (Korowicz, 2010). This report concluded that: "*Our civilisation is structurally unstable to an energy withdrawal. There is a high probability that our integrated and globalised civilisation is on the cusp of a fast and near-term collapse*". The analysis in the report postulated their indicative models (scenarios): a linear decline, oscillating decline and systemic collapse. The scenarios and outcomes in the FEASTA report are disturbingly similar to those used in this report (see later) (Korowicz, 2010).

Then in June 2010 Lloyd's Insurance UK and Chatham House released a white paper on energy issues "*Sustainable Energy Security: Strategic risks and opportunities for business*". One of the conclusions of this report was that: "*Traditional fossil fuel resources face serious supply constraints and an oil supply crunch is likely in the short-to-medium term with profound consequences for the way in which business functions today*." Of particular importance to communities was the observation that: "*The sooner that businesses reassess global supply chains and just-in-time models, and increase the resilience of their logistics against energy supply disruptions, the better*." And in this regard the report echoed the earlier UK report and singled out the vulnerability of food supply to the lack of resilience in supermarket supply chains (Froggatt and Lahn, 2010).

In September 2010 a report on peak oil was released by the Australia Institute titled "*Running on Empty: The Peak Oil Debate*", (Ingles and Denniss, 2010). This report added further credence to international acceptance of peak oil and noted that "*government interventions may turn out to be costly, misguided and perhaps ineffective*".

Also in September a Peak oil report was leaked from the German Military "*Peak Oil: Implications of resources scarcity on national security*" (reported in the Oil Drum, 2010). Unlike many of the other reports this report discussed the problems of the interaction between the world economy and a declining oil supply and suggested:

> "*In addition to the gradual risks, there might be risks of non-linear events, where a reduction of economic output based on Peak Oil might affect market-driven economies in a way that they stop functioning altogether, leaving the possibility of a relatively steady downward trajectory.*
>
> *Such a scenario could develop through an initially slow decline of trade and economic activity, combined with higher stress on government budgets from lower tax income, higher social cost and growing investment into alternative technologies.*
>
> *Investment will decline and debt service will be challenged, leading to a crash in financial markets, accompanied by a loss of trust in currencies and a break-up of value and supply chains – because trade is no longer possible. This would in turn lead to the collapse of economies, mass unemployment, government defaults and infrastructure breakdowns, ultimately followed by famines and total system collapse.*"

The wording regarding non-linear events occurring, as used in this German military document, is almost identical to that used in the present report and is seen as significant support for the current set of scenarios. In the summary the German document concludes:

> "*The report sees significant risks arising from an unavoidable peak in oil production, which go beyond gradual shifts in energy systems and economies. This will likely lead to economic change and new geopolitical risks that affect much more than just what we can anticipate. The overall ability to describe exact outcomes is very limited, as many scenarios are possible, and further research is required.*"
>
> - Oil Drum (2010)

In October a NZ Parliamentary Research Paper written by Clint Smith MED titled "*The Next Oil Shock*" presented a scenario for the future, which included the following:

> "*There is a risk that the world economy may be at the start of a cycle of supply crunches leading to price spikes and recessions, followed by recoveries leading to supply crunches.*"
>
> "*Key export-generating industries in the New Zealand economy including tourism and timber, dairy, and meat exports are very vulnerable to oil shocks because of their reliance on affordable international transport.*"
>
> - Smith (2010)

In summary: there appears to be an overall emergence of an institutional acceptance of the imminent likelihood of peak oil and a rather belated attempt to assess the future ramifications. The future ramifications, however, have so far often only been portrayed in generalities and global reports give little away in terms of specific details, obviously due to the unpredictability of such specifics. The more recent reports however are starting to point to significant economic disruption that is likely to follow a decline in oil supply due to a decline in world growth.

Oil in NZ

In terms of energy use per capita in NZ it is noteworthy that although the energy used in GJ/capita in NZ has been slowly declining since 2002 the national GDP has managed an increase for every year except 2008 – 2009 (see later). Whether this is an illustration of decoupling energy use from GDP as has happened for the world or just inertia in the energy system, will become apparent over the next few years.

The future

Thus what to do? Various commentators looking at peak oil have posited a wide range of scenarios ranging from the downright doomsday (Kunstler (2005), Heinberg (2003), German Military Report Oil Drum (2010)) to cornucopian, business as usual or better (CERA, most economists) at least until 2030. In terms of the CERA predictions, it should become obvious in the next few years to see if their suggestion of an increase to 115 million barrels per day can be realized. Although in this respect the close coupling between the economy and oil may obscure any decision, because if a depleting oil supply "causes" a declining world economy, (Ayres and Warr, 2009) then CERA may further suggest that that the supply situation is demand limited rather than supply constrained i.e. that a declining economy "causes" demand limitation. Hmmm! We will then have peak oil demand but never peak oil supply…

Climate change and coal to liquids

The interaction with climate change will also make it difficult to make any sense out of what will happen as oil depletes. Clearly oil is a special fossil fuel due to the fact that the present transportation sector is almost totally reliant on liquid fossil fuels. In the past, countries with a lack of oil (Germany during WWII and South Africa during Apartheid sanctions) managed to make adequate liquid fuels from coal. This process is relatively straightforward from a technological standpoint although in most cases the EROEI is considerably lower than that for obtaining liquid fuels from crude oil. The time, however, needed to implement such a transition on a global scale was estimated by Hirsch (2005) to be between 10 and 20 years. But, if the world does go down the solids to liquids route, peak liquid fuels could be postponed for a decade or two. The implication for climate change, on the other hand, would be catastrophic, as the process also emits large quantities of CO_2 and so unless carbon capture and storage (CCS) eventuates (unlikely) the CO_2 emissions to the atmosphere would ensure that the worst case IPPC scenarios were exceeded (note that world coal extraction/consumption has already accelerated over the last five years and the likely effects of global warming have increased).

Given some pressure at least from the international community in term of restraining coal to liquids production, what scenarios can be considered possible in light of the previous discussion of oil supply scenarios? Obviously quite a range exists in the literature as mentioned ranging from downright pessimistic to very optimistic.

Pessimistic Scenarios

Pessimistic scenarios range from an extreme of chaos and complete collapse of civilization with a regression in terms of population and energy use to pre-industrial times as forecast by the US geologist King Hubbert back in 1949 (Scenario III, Fig. 14) to a scenario of managed sustainability at a lower level of energy use (commensurate with the world average use today i.e. 2 kW per capita), steady state economies and steady state population levels (Hubbert, Scenarios I and II Fig. 14) (Hubbert, 1949).

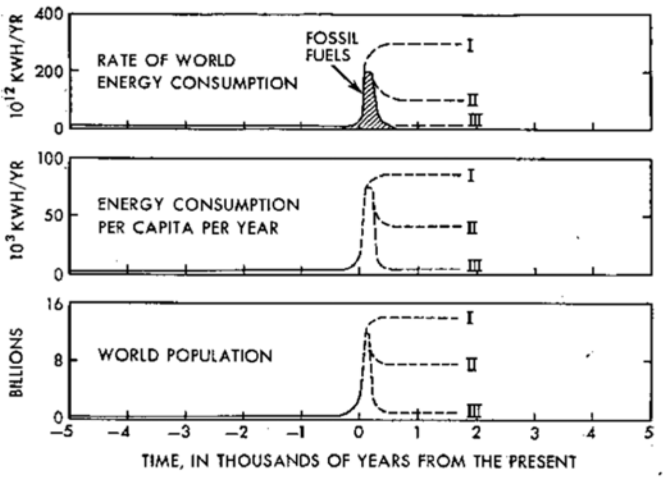


Fig. 11 - Human affairs in historical perspective from 5,000 years in past to 5,000 years in future (after Hubbert, 1962, fig. 61).

Fig. 14: Human affairs in historical perspective from 5,000 years in past to 5,000 years in future.

Optimistic Scenarios

Similarly the optimistic scenarios range in extremes from the business as usual situation, where new (but unproven) energy technologies (fast breeder reactor and fusion) will overcome depletion of fossil fuels and world economies will continue to expand indefinitely, pollution will be overcome using advanced technologies and population will be limited by the natural demographic transition (i.e. everyone will be wealthy and so not so many children will be needed) to variations of new economic systems powered by renewable energy at no or low levels of growth but commensurate with conditions at the lower end of OECD countries today, i.e. 4- 8 kW per capita.

Scenario analysis, linear and non-linear reactions.

In terms of the likelihood of such scenarios unfolding, the present analysis considers the extreme optimistic scenario (never ending growth) as highly unlikely, as resources other than energy such as metals, soil, and water would in all events prevent such a cornucopian excess (Meadows, 2004). The extreme pessimistic scenario would have no resource limits, as in a collapse situation resource use would decline severely, and so as such it is a distinct possibility, especially in light of the envisaged non-linear interactions between energy and the economy. In terms of practical planning for New Zealand however, it would be difficult to plan the future for such an extreme scenario, precisely due to the non-linear nature of the proposed collapse (see for instance Orlov, 2008).

The exception would be to ensure future planning incorporates optimum levels of resilience that could be expected to reasonably cope with extreme energy supply decrease events and non-linear economic contraction.

Thus, in terms of conventional planning purposes we might look at somewhere between the more modest of the pessimistic scenarios and the more modest of the optimistic scenarios with an eventual per capita world energy consumption of between 2 kW (the present world average) and perhaps double this amount (4kW). The present (2010) energy consumption per capita in NZ is around 8kW and so if done equitably such a range could suggest NZ reducing total energy consumption by a factor of between two and four. NZ has, however, the luxury of a high level of renewable energy supply for the electricity sector and so the main reduction would probably need to occur in the liquid fuel area.

Thus, rather than look at scenarios in terms of increasing price of oil it may be preferable to envisage decreasing levels of supply (as done by Krumdieck et al., 2010), and while economists may suggest that they would amount to the same thing, as supply is linked with price by the demand curve, the earlier arguments would suggest that feedback effects will not allow oil to go much above US$120 per barrel (2010 US $s) for any extended time and that a more likely event would be that the world and hence the NZ economy would need to contract to limit liquid fuel demand, exactly as happened during the 2008 financial crisis.

The question then, now amounts to what reduction in oil supply might we expect in the future? If NZ declines at the world average rate the existing offers range from:

- **Business As Usual (BAU)**: An increase from 2001 of around 1.6% p.a. to 2030 then a plateau for a decade, followed by an unidentified decline (the historical increase between 1990 and 2005 and the CERA prediction). **Probablity: Unlikely**
- **Peak oil**: A moderate decrease from 2012 of around 0.6% per annum to 2030 (Uppsala World Outlook, Aleklett et al 2008.).
  Probability: Very Likely
- **Peak oil**: A severe decrease from about 2012 of around 4% or greater per annum (EIA, assuming unidentified projects remain unidentified, also Hirsch 2008).
  Probability: Possible

Translation from physical oil deliveries to outcomes to real communities in NZ

The estimates of future world oil production from various sources are not that disparate. The business as usual outlook (CERA) is close to the peak oil decline outlooks but postponed by around 20 years. As the risk of BAU scenario unfolding is considered highly unlikely this scenario will not be followed up. In terms of declines it might be noted that the decline rates are from well head production and do not take into account the decreased EROEI for the downside supply or the increase in demand from the oil producing countries, meaning that less oil will be available on the world market. Both these effects will exacerbate the decline of oil available to NZ. On the other hand local discoveries of crude oil may improve NZ access to oil, but only if the NZ Government of the day took the rather unprecedented step of taking control of supply from the major oil companies.

Future Scenarios:

Below are my attempts at characterizing the future, consistent with recent peak oil reports. It must be emphasized, however, that it is difficult to make any sensible specific predictions for systems, which have highly non-linear interactions.

1. Linear, moderate decrease

Efficiency gains could mitigate crude oil declines with little adverse effects until around 2030, by which time either climate change difficulties or gas declines and coal peaking are likely to trigger non-linear responses, that is if the growth paradigm has not been revised by then and alternate energy systems are not implemented on a large scale. By 2030 it is likely that the climate change problems would be exacerbated by NZ post Kyoto commitments, costing NZ taxpayers up to 18 billion NZ$ in outstanding emissions units if substantial pre Kyoto forests are harvested at this time (Bertram and Terry, 2010). This scenario is similar to but a less severe version of the FEASTA "linear decline" (Korowicz, 2010).

2. Linear, severe decrease

Efficiency gains could mitigate crude oil declines until around 2015 - 2020 depending on when the declines start. China and developing economies will eventually be stressed by lack of petroleum supplies to fund further anticipated growth and the collapse of the world factory, among other problems, are likely to trigger non-linear responses elsewhere. This scenario is similar to the FEASTA "linear decline" (Korowicz, 2010).

3. Non-linear, moderate decrease

The oil supply decline will trigger a slowdown in world economies and the world will move to a period of stagnating recession alternating with periods of recovery. Evidence for this scenario has already appeared. The response, in terms of developing alternative technologies, is not known (Lloyd, 2010) but the world response in terms of economics has been to stimulate growth by going into (further) debt. What follows is likely to be a series of peaks and downturns in the world economy as the non-linear interaction unfolds and the world adjusts to both a declining oil supply and a declining economy. Transport fuel balance will be achieved not by increasing fuel prices but by decreasing activity. As suggested below there is current evidence for this scenario occurring already in NZ. This scenario is similar to the FEASTA "oscillating decline" (Korowicz, 2010) and the NZ 2010 Parliamentary Paper "*a cycle of supply crunches leading to price spikes and recessions, followed by recoveries leading to supply crunches.*" (Smith, 2010).

4. Non-linear, severe decrease

A 4% oil supply decline per annum will eventually trigger a run on the world stock markets triggering a substantial world depression necessitating a revision of the world monetary system. This scenario is similar to the FEASTA "systemic collapse", (Korowicz, 2010).

Suggested responses at the local level

It would be suggested that NZ should plan to adapt to somewhere between scenarios 1 and 3 with provision to ensure future planning incorporates optimum levels of resilience that could be expected to reasonably cope with more extreme energy supply decrease events and economic contractions i.e. scenarios 2 and 4. The suggestions below are not meant to be either exhaustive or definitive and the main suggested response is that communities convene a local task force to delineate specific responses generally consistent with the suggestions below. It is thought highly unlikely that the NZ national government would be conducive to participate in such a discussion until the non-linear effects become more obvious.

In addition to the rapidly expanding literature on peak oil in general it is apparent that several local councils and municipalities are engaging in preparing energy transition plans to cope with peak oil. Two recent examples are the (US) Report of the Bloomington Peak Oil Task Force and the (Australian) Sunshine Coast Peak Oil Background Study with an accompanying draft Sunshine Coast Transition Plan.

While the Bloomington report acknowledges the interaction between oil supply and the economy the report does not suggest the type of non-linear interactions given in this report and as such may underestimate the overall effect of peak oil on the economy. The suggested mitigation measures, however, are broadly compatible with the current report.

The Sunshine Coast background study examined the interaction between the economy and oil supply in more detail, pointing out that historically whenever the price of oil rose above 4% of US GDP a recession occurred in that country. The report also gave evidence that the current recession in the US has been primarily due to rising oil prices and that future rises above US$80 to $150 will "*certainly trigger* *another recession*". In spite of this evidence the report then, however, comes to the conclusion that: "*Future volatile and rising oil prices are therefore the key risk that Peak Oil brings to the Australian economy. Oil prices similar to those sustained during 2008 are also likely to constrain economic growth*." The report continues to examine the future in terms of rising oil prices but does not consider the non-linear interaction implicit in the argument that the price rise will trigger recessions.

The major difference between this report and the above two reports is my prediction **that balancing world oil supply and demand will occur primarily by economic contraction rather than oil price increases lowering demand**. As such traditional price elasticity indices used by economists will not be of much value. In many cases the recommended responses will be the same but there are likely also to be significant differences. For instance if peak oil causes the price of petrol to rise then transport substitution will come into play i.e. public transport, replacing private cars. If economic contraction occurs then the balance will be achieved by lack of jobs meaning transport is not required or affordable, but only for those out of work. Those fortunate to retain paid employment will still be able to afford petrol and thus private cars and those unemployed will have much reduced transport needs for both private cars and public transport. Clearly in the latter case more community support will be needed as the situation will give rise to greater social inequality and NZ already has one of the highest levels of social inequality in the OECD (Wilkinson and Picket, 2009).

Sector Responses

Economy

If the linear scenarios unfold it is likely that the world economy will slow down at a rate commensurate with declining fuel supplies. It is also likely that there will be a delay between the declining fuel availability and the economy as inefficiencies in transport are gradually eliminated, much as happened during the 1970s oil crisis, when the ratio between growth in oil supply and GDP growth changed dramatically. Evidence for this delay is seen in current world GDP figures. It is likely however, that the change will not be commensurate with the present case, as some of the transport inefficiencies have already been removed. Such economic changes will present declining personal incomes and decreased government spending for education, health etc. Again this process is currently evident. One of the main difficulties for the people of NZ will be declining incomes due to lack of employment. The main difficulty at the local government level will be declining house prices and a declining rate base. As of 28 October 2010 the prediction of declining house prices in NZ has already eventuated (ODT, October 2010).

Transport

Because liquid fossil fuels are the energy source of choice for all transport modes, the response of this sector to declining oil supplies may be significant. The earlier mentioned report to the Ministry of Transport NZ considered how central government, regional councils and local authorities might respond to the transport challenges associated with rising oil prices (2008). While the present report disagrees that that depleting oil reserves would occasion much higher oil prices, at least over the long term, the conclusions reached in terms of responses to planning issues are consistent with a prudent approach by a local authority to transport planning issues. Note that there are several areas, which we would disagree with in the MOT report, including the projection of oil prices and projections of world economic growth. Note also that the report gave erroneous values for the world oil reserves at 1 – 2 Giga Barrels remaining. The world actually uses around 31 Giga Barrels annually (The amount remaining should be 1- 2 Terra barrels or 1-2 Trillion barrels).

In terms of responses the NZ MOT report suggested that:

> "*Transport and land planning must therefore undergo a paradigm shift. That is to say to ensure that the transport is more resilient to sustained high oil prices, government agencies will need to fundamentally change the way in which transport problems are defined and solutions delivered*"
>
> - Donovan (2008).

A toolbox is given in the report for potential solutions using a new understanding of what an efficient transport system entails. The toolbox suggests structural changes, which would mean road users were faced with the true costs of using the road system.

The MOT report suggests that the estimated vehicle kilometres travelled by conventional vehicles in the future, in response to the recommended changes given, remain approximately level until 2028. Note that the future travel demand is assumed to grow by around 2.4% pa whereas the MOT report also realises that such a growth rate is likely to be optimistic in a situation of "high oil prices" (more likely deceasing oil supply and economic contraction). This report also agrees that 2.4% pa growth in transport fuels is highly unlikely particularly in view of recent historical energy use for transport.

Actual historical fuel use for transport in NZ

Fig. 15 and 16 show the energy use for transport in NZ since 1975. NZ consumption mirrors world consumption given in Fig. 10 with steady or declining usage during the oil crisis until 1990 a steady increase until 2003 and a flattening off of consumption until the present (2010).

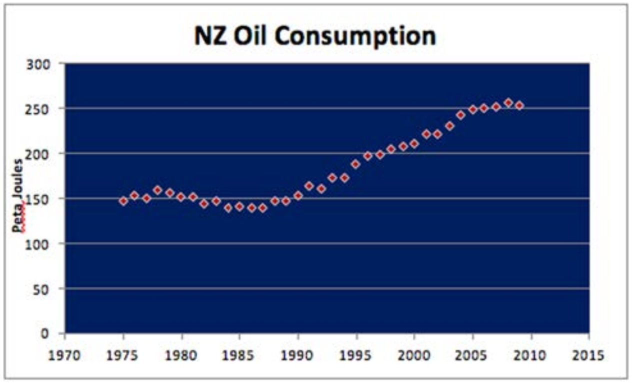


Fig. 15: NZ oil consumption for transport: 1975- 2009, EDF MED 2010

As can be seen over the last five years the absolute energy use for transport in NZ has been flat and so with increasing population the **per capita energy use for transport must have been declining at around 1% pa.** It is thus highly likely that supply declines of around 0.6% pa (Scenarios 1 and 3) will not cause serious problems in NZ, possibly until 2030 and certainly not until 2015. Note that the energy use for transport was flat to declining in NZ from 1978 until 1988: a 10-year period. During this time compressed natural gas became a popular substitute for liquid fuels. It would thus

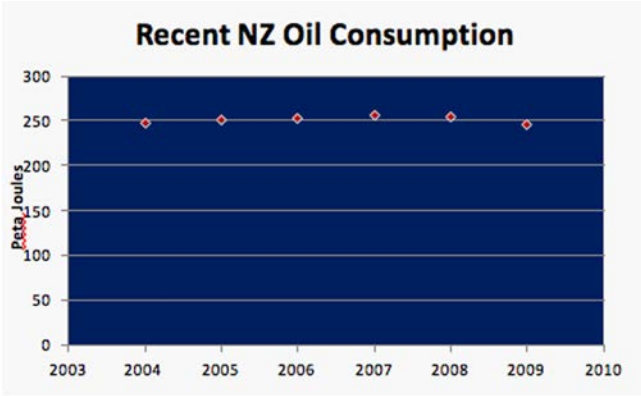


Fig. 16: NZ oil consumption for transport 2004 – 2009 EDF MED 2010

be wise for NZ to conserve its indigenous natural gas supply for a similar substitution as external liquid fuel availability declines.

General Recommendations

- **Ensuring local communities' water and wastewater systems have a high level of resilience.**
- **Investigating ways that local communities can enter the energy supply business with a priority on securing wind generation. Encouraging energy substitution activities: including using plantation waste biomass to replace other forms of heating supply for public buildings and residential dwellings, encouraging solar hot water system and hot water heat pumps, encouraging insulation retrofits for residential housing.**
- **Encouraging community food production and making community land available for this purpose where possible.**
- **Using the MOT transport tool kit for transforming city and extended transport opportunities around the city.**
- **Encouraging local community participation in the transformation process from pre peak oil high**

growth, high waste, high level of consumerism to a steady state economy with low levels of consumerism, low waste and lots of fun community activities that don't use anything other than personal energy. Literature on such a transformation can be obtained as part of the Transition Town collection (Hopkins 2008).

References

Alekllet, K., Hook, M., Jakobsson, K., Lardelli, M., Snowdon, S., and Soderbergh, B. *The Peak of the Oil Age – Analyzing the World Oil Production Reference Scenario in World Energy Outlook 200*. Energy Policy, Volume 38, Issue 3, March 2010. p.1398-1414.

Al Husseini, S. *A Lot of Money = A Little Oil*. Interview with Sadad Al Husseini. ASPO USA: Conference, Denver: Colorado, US, October 2009.

Ayres, R.U., and Warr, B. *The Economic Growth Engine: How Energy and Work Drive Material Prosperity*. Cheltenham, UK: Edward Elgar Publishing Ltd, 2009.

Bloomington Peak Oil Response. obtained from <http://bloomington.in.gov/peakoil> Accessed 28th October 2010.

British Petroleum (BP). *Statistical Review of World Energy*. downloaded from <http://www.bp.com/productlanding.do?categoryId=6929&contentId=7044622> October 2010.

Campbell, C. *Peak Oil Updates*, published in ASPO Ireland Newsletters <http://aspoireland.org/newsletter/>

Catton, W.R. *Overshoot: The Ecological Basis of Revolutionary Change*. Chicago: University of Illinois Press, 1982.

Centre for Advanced Engineering (CAE). *A High Level Assessment of the Risks and Vulnerabilities to Energy Supply in the Otago Region*. A report to the Otago Regional Council, August 2006.

Donovan, S., Genter, J., Green A., Guidera T., Hazledine, T., Hewison, G., Litman, T., Mumby, N., O'Reilly L., and Petrenas, B. *Managing Transport Challenges When Oil Prices Rise*. Report to the NZ Ministry of Transport (MOT), Research Report 357, August 2008.

Economist Magazine web site: <http://buttonwood.economist.com/content/gdc> downloaded September 2010.

Energy Data File, Published by the NZ Ministry of Economic Development, 2010.

Fitzharris, B. *Climate Change: Impacts on Dunedin*. Report prepared for the Dunedin City Council, March 2010.

Froggatt, A., and Lahn, G. *Sustainable Energy Security: Strategic risks and opportunities of Business*. Lloyds 360 Risk Insight White Paper, London, UK: Chatham House, 2010.

Heinberg R., *The Party's Over: Oil War and the Fate of Industrial Societies*. Gabriola, BC: New Society Publishers, 2003.

Hirsch, R.L., Bezdek, R., and Wendling, R. 2005. *Peaking of World Oil Production: Impacts, Mitigation, & Risk Management. US Department of Energy Report*. DOE NETL. <http://www.netl.doe.gov/publications/others/pdf/Oil_Peaking_NETL.pdf>

Hirsch, R.L. *Mitigation of Maximum World Oil Production: Shortage Scenarios*, Energy Policy 36, 2008. p.881–889.

Hopkins, R. *The Transition Handbook: From Oil Dependency to Local Resilience*. Devon: Green Books Ltd., 2008.

Hotelling, H. *The Economics of Exhaustible Resources*. Journal of Political Economy, 39, 2, 1931. p.137- 175.

Hubbert, M.K. *Energy From Fossil Fuels*. Science, New Series, 109, 1949. p.103-109.

Industry Task Force on Peak Oil and Energy Security (UK ITPOES). *The Oil Crunch: A Wake Up Call to the UK Economy*. Second Report, February 2010.

Ingles, D., and Denniss, R. *Running on Empty: The Peak Oil Debate*. Policy Brief #16, The Australia Institute, September 2010.

Jackson, P.M. Cambridge Energy Research Associates (CERA) *The Future of Global Oil Supply: Understanding the Building Blocks*. Special Report, November 2009.

Jackson, T. *Prosperity Without Growth*. London: Earthscan, 2009.

Joint Operating Environment (JOE). The United States Joint Forces Command <www.jfcom.mil> Joint Futures Group. Suffolk, Virginia, US, February 2010.

Korowicz, D. *Tipping Point: Near Term Systemic Implications of a Peak in Global Oil Production*. Foundation for the Economics of Sustainablity, UK, (FEASTA), March 2010.

Krumdieck, S., Page, S., and Dantas, A. *Urban Form and Long-term Fuel Supply Decline: A Method to Investigate the Peak Oil Risks to Essential Activities*. Transportation Research Part A: Policy and Practice, Volume 44, Issue 5, June 2010. p.306-322.

Kunstler, J.H. *The Long Emergency: Surviving the Converging Catastrophes of the Twenty-first Century*. New York: Atlantic Monthly Press, 2005.

Lloyd, B. *The End of Oil*. 2005. <http://www.physics.otago.ac.nz/eman/The%20End%20of%20Oil%20essay%201.pdf>

Lloyd, B. *The Commons Revisited the Tragedy Continues.* Energy Policy 35, 2007. p.5806–5818.

Lloyd, B. *The Growth Delusion*. Sustainability, 2009. 1, p.516-536.

Lloyd, B., and Forest, A. *The Transition to Renewables: Can PV Provide an Answer to Climate Change Challenges?*. Energy Policy 38, 2010. p.7378–7394.

Meadows, D.H., Meadows, D.L., Randers, J. *The Limits to Growth: A Report for the Club of Rome's Project on the Predicament of Mankind*. New York: Universe Books, 1972.

Meadows, D.H., Meadows, D.L., Randers, J. *Limits to Growth: the 30 Year Update*. White River Junction, VT: Chelsea Green Pub. Co., 2004.

Oil Drum. *Peak Oil: Implications Of Resource Scarcity On (National) Security*. Report of the Center for German Army Transformation, Group for "Future Studies" posted on the Oil Drum website: July 2010. <http://theoildrum.com>

Orlov, D. *Reinventing Collapse: The Soviet Example and American Prospects*. Gabriola Island, BC: New Society Publishers, 2008.

Schaefer, M. *Accelerating the Deployment of Wind Energy in New Zealand: The Adaptability of a Feed-in Tariff*. Unpublished MSc Thesis, Otago University, 2010.

Sims, A., Johnson, V., and Chowla, P. *Growth Isn't Possible: Why We Need a New Economic Direction*. Schumacher College, New Economics Foundation, London, 2010.

Smith, C. *The Next Oil Shock*. NZ Parliamentary Research Paper, October 2010.

Sorrell, S. *Energy Growth and Sustainability: Five Propositions*. SPRU Electronic Working Paper #185, March 2010.

Sunshine Coast Transition Plan and Background Peak Oil Paper. accessed from <http://www.sunshinecoast.qld.gov.au/sitePage.cfm?code=energy-trans-plan> 28th October 2010.

Sweetnam EIA – DOE Conference 2009 Obtained from: <http://www.eia.doe.gov/conference/2009/session3/Sweetnam.pdf>

Wilkinson, R., and Pickett, K. *The Spirit Level*. NY: Bloomsbury Press, 2009.