Role and analysis of "Oil Peaking Philosophy" in understanding Crude Oil market- A quantitative approach

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DECLARATION BY THE GUIDE

This is to certify that the dissertation report on **Role and analysis of "Oil Peaking Philosophy" in understanding Crude Oil market- A quantitative approach** submitted to the University of Petroleum & Energy Studies, Dehradun, by Gaurav Dwivedi, in partial fulfillment of the requirement for the award of the degree of Master of Science(Oil Trading) is a bonafide work carried out by him under my supervision and guidance.

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EXECUTIVE SUMMARY

The peaking of world oil production presents the world with an unprecedented risk management problem. As peaking is approached, liquid fuel prices and price volatility will increase dramatically, and, without timely mitigation, the economic, social, and political costs will be unprecedented. Viable mitigation options exist on both the supply and demand sides, but to have substantial impact, they must be initiated more than a decade in advance of peaking.

Dealing with world oil production peaking will be extremely complex, involve literally trillions of dollars and require many years of intense effort. World oil demand is expected to grow 50 percent by 2025. To meet that demand, ever-larger volumes of oil will have to be produced. Since oil production from individual reservoirs grows to a peak and then declines, new reservoirs must be continually discovered and brought into production to compensate for the depletion of older reservoirs. If large quantities of new oil are not discovered and brought into production somewhere in the world, then world oil production will no longer satisfy demand. That point is called the peaking of world conventional oil production. When world oil production peaks, there will still be large reserves remaining. Peaking means that the rate of world oil production cannot increase; it also means that production will thereafter decrease with time.

When world oil peaking will occur is not known with certainty. A fundamental problem in predicting oil peaking is the poor quality of and possible political biases in world oil reserves data. Some experts believe peaking may occur soon. The problems associated with world oil production peaking will not be temporary, and past "energy crisis" experience will provide relatively little guidance. The challenge of oil peaking deserves immediate, serious attention, if risks are to be fully understood and mitigation begun on a timely basis. Oil peaking will create a severe liquid fuels problem for the transportation sector, not an "energy crisis" in the usual sense that term has been used. Peaking will result in dramatically higher oil prices, which will cause protracted economic hardship in the world. However, the problems are not insoluble. Timely, aggressive mitigation initiatives addressing both the supply and the demand sides of the issue will be required.

In the developed nations, the problems will be especially serious. In the developing nations peaking problems have the potential to be much worse. Mitigation will require a minimum of a decade of intense, expensive effort, because the scale of liquid fuels mitigation is inherently extremely large. While greater end-use efficiency is essential, increased efficiency alone will be neither sufficient nor timely enough to solve the problem. Production of large amounts of substitute liquid fuels will be required. A number of commercial or near-commercial substitute fuel production technologies are currently available for deployment, so the production of vast amounts of substitute liquid fuels is feasible with existing technology. Intervention by governments will be required, because the economic and social implications of oil peaking would otherwise be chaotic. The experiences of the 1970s and 1980s offer important guides as to government actions that are desirable and those that are undesirable, but the process will not be easy. In looking at the issue of oil, it is important to note that this summary does not address the broader issue of sustainability or the environmental impact of using non-renewable energy sources. It simply focuses on the importance of oil, the impact of falling supplies and the potential for alternative solutions. No current modern economy is ultimately sustainable as all depend on the increasing supply of limited natural resources. The energy and materials we use from wood through to metals; animal and plant life; natural environments and even the land on which we grow food are all being used up or abused. Whilst some resources are so extensive as to be virtually inexhaustible, some are not, and oil shortage is going to be the first major one to bite.

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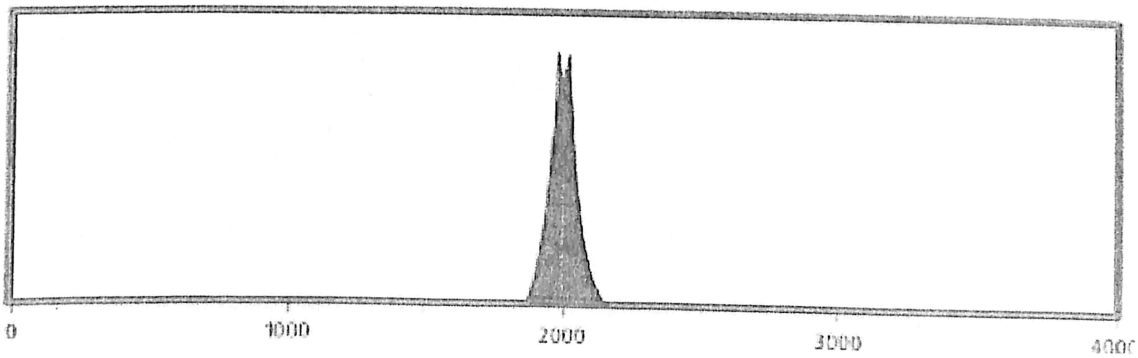
CHAPTER 1
INTRODUCTION

The imminent (or current) peaking of the rate of world oil production is barely discussed publicly in government, business and policy circles. Peak Oil, as this transition is called, will irreversibly alter the delivery rate of liquid fossil energy to fuel economic growth. As demand outstrips the rate at which oil can be supplied, we can expect higher prices, volatile markets, physical fuel and power shortages, international geopolitical strife and wars. The magnitude of the problems will increase as supply rates decline. The implications are profound, both for our ability to maintain our standard of living in the developed countries and for the chance of economic growth at all in the developing ones. There is a cognitive disconnect between the actual situation and public awareness, resulting in a dangerous policy and preparation gap.

That world oil production must peak one day is fact, not theory. All finite resources face an extraction/production curve. The rate of production increases as high quality, easy-to-access resources are exploited first and extraction technologies improve. Marginal production diminishes to zero at the point of maximum extraction, after which the rate declines. As production continues, the remaining, lower quality, resource becomes increasingly more difficult, and expensive, to reach and extract.

Figure 1 depicts projected world oil consumption on a millennial timescale.

Figure 1."The Flame in the Darkness". The consumption of the world's accessible oil endowment will occur over a two-century span of human history.



Source: CommunitySolution, modified from Hubbert, 1956.

A number of experts project that world production of conventional oil could occur in the relatively near future, as summarized in Table-1. Such projections are fraught with uncertainties because of poor data, political and institutional self-interest, and other complicating factors. The bottom line is that no one knows with certainty when world oil production will reach a peak, but geologists have no doubt that it will happen.

Table 1. Projections of the Peaking of World Oil Production

Projected Date	Source of Projection	Background & Reference
2006-2007	Bakhitari, A.M.S.	Oil Executive (Iran)[1]
2007-2009	Simmons, M.R.	Investment banker (U.S.) [2]
After 2007	Skrebowski, C.	Petroleum journal editor (U.K.) [3]
Before 2009	Deffeyes, K.S.	Oil company geologist (ret., U.S.)[4]
Before 2010	Goodstein, D.	Vice Provost, Cal Tech (U.S.) [5]
Around 2010	Campbell, C.J.	Oil geologist (ret.. Ireland)[6]
After 2010	World Energy Council	World Non-Government Org.[7]
2012	Pang Xiongqi	Petroleum Executive (China)[8]
2010-2020	Laherrere, J.	Oil geologist (ret., France) [9]
2016	EIA nominal case	DOE analysis/ information (U.S.)[10]
After 2020	CERA	Energy consultants (U.S.) [11]
2025 or later	Shell	Major oil company (U.K.) [12]

[1] Bakhtiari, A.M.S. *World Oil Production Capacity Model Suggests Output Peak by 2006-07.* *Oil and Gas Journal.* April 26, 2004.
[2] Simmons, M.R. ASPO Workshop. May 26, 2003.
[3] Skrebowski, C. *Oil Field Mega Projects - 2004.* Petroleum Review. January 2004.
[4] Deffeyes, K.S. *Hubbert's Peak-The Impending World Oil Shortage.* Princeton University Press. 2003.
[5] Goodstein, D. *Out of Gas – The End of the Age of Oil.* W.W. Norton. 2004
[6] Campbell, C.J *Industry Urged to Watch for Regular Oil Production Peaks, Depletion Signals.* *Oil and Gas Journal.*. July 14, 2003
[7] *Drivers of the Energy Scene.* World Energy Council. 2003.
[8] Pang Xiongqi *The Challenges Brought by Shortages of Oil and Gas in China and Their Countermeasures.* ASPO Lisbon Conference. May19-20, 2005.
[9] Laherrere, J. Seminar Center of Energy Conversion. Zurich. May 7, 2003
[10] DOE EIA *Long Term World Oil Supply.* April 18, 2000. See Appendix I for discussion.
[11] Jackson, P. et al. *Triple Witching Hour for Oil Arrives Early in 2004 – But, As Yet, No Real Witches.* *CERA Alert.* April 7, 2004
[12] Davis, G *Meeting Future Energy Needs.* The Bridge National Academies Press Summer 2003.

This paper presents the world oil demand/supply situation from a physical constraints perspective, then takes a strategic decision management/game theory approach to look at our options for action. Chapter 2 reviews current and projected oil demand and discusses the energy requirement for economic growth, briefly inventories world oil supply, concentrating on the uncertainty of reported reserves, potential rate-limits to production, and the likely timing of the onset of an oil demand/supply gap. Chapter 3 summarizes the potential to fill that gap using substitute fossil and renewable fuel alternatives, technological innovation and conservation. Chapter 4 defines the game, identifying the players, the rules, the underlying states of nature and their probabilities, and the stakes. It presents a matrix of speculative, but plausible societal outcomes, depending on whether the transition is abrupt or gradual, and whether we prepare for it or not. Chapter 5 identifies potential strategic actions (tactics) that might be undertaken by the markets, governments, the private sector, and/or social groups to balance demand with reduced supply. Chapter 6 integrates the options and risks into a management decision framework. Four likely strategic approaches are considered, the potential outcomes and risks evaluated, and an optimal approach selected. Chapter 7 considers business and behavioral impediments to achieving a managed transition.

Oil is Not Just a Commodity

Oil is the world's single largest traded commodity, accounting for over half the total value of all commodity transactions. The U.S. Department of Energy's Energy Information Administration (EIA) estimates that U.S. expenditures on oil in 2005 were $1 trillion, representing 8.7% of gross domestic product (GDP). With the U.S. currently importing about 60% of its oil, over 12 million barrels per day (mbd), the daily cash exodus from the U.S. at $70/barrel is more than $840 million. Fortunately, the major world oil exchanges and the Organization of Petroleum Exporting Countries (OPEC) all still denominate oil sales in dollars. Oil, however, is much more than a commodity. The capacity to produce oil is a capital asset, like land, buildings and equipment. Yet oil removed from the ground is neither depreciated nor replaced. Simultaneously, oil could be considered a form of labor, since its principal attribute is its ability to do work and its energy replaces labor formerly provided by traction animals or people. As Rep. Bartlett describes it:

One barrel of oil, 42 gallons of oil, equals the productivity of 25,000 man-hours. That is the equivalent of having 60 dedicated servants that do nothing but work for someone. We can get a little better real-life example of this. A gallon of gas will drive a 3-ton SUV...20 miles at 60 miles an hour down the road. That is just one little gallon of gas, which, by the way, is still cheaper than water.

The large increases in productivity in the developed world over the past three centuries are the result of workers controlling ever-increasing supplies of cheap energy with ever-greater efficiency. Technology is the enabler, but oil does the work. In short, oil is:

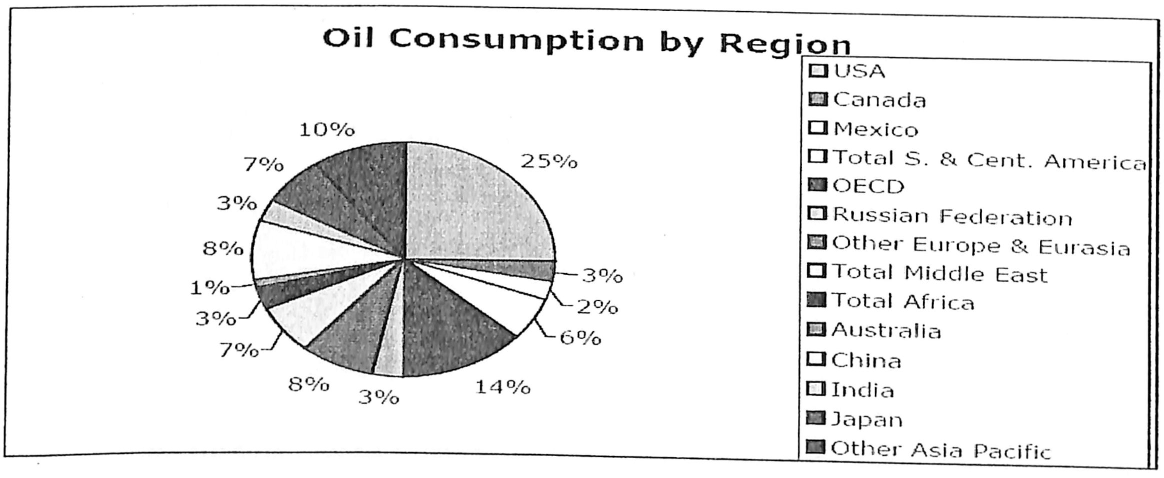
- the densest, portable form of energy known to man
- the current basis of economic wealth
- the factor of productivity underlying economic growth, and
- the major daily cash/debt flow in the world economy

Oil is a blessing and a curse. It brings easy wealth and confers power. But it also brings war. Some even make a convincing case that oil functions like the gold standard formerly did, to anchor the value of currencies; they argue it would be more accurate to view our wealth denominated in oil rather than dollars.

Heavy Users

It is difficult to find anything in the industrial world that does not depend on cheap oil in some way for its production and distribution. The global economy is built around cheap transportation for just-in-time manufacturing and inventory management. The U.S. has only 5% of the world's population, but it consumes 25% (almost 21 mbd) of the 84 million barrels per day that the world produces (Figure 2). The U.S. and countries of the Organization for Economic Cooperation and Development (OECD) are all heavy users, as is Japan, and increasingly, China and India. In general, the higher the level of development and GDP, the more oil per capita a country consumes. Per capita oil use in the U.S. was over 3 tons per year in 2004, triple that of China and India. The world uses oil to meet two types of energy needs: mobile and stationary. Mobile use (cars, planes, ships) consumes the lion's share, more than 50% of oil consumption worldwide, but 70% in the highly mobile U.S. (Figure 3). About 22% of U.S. oil is used for industry and agriculture, including the production of petrochemicals and plastics. Stationary energy use is for heat and electricity. Combined residential, commercial, and electric utility use of oil in the U.S. is only about 8% of total oil used.

Figure 2. Percentage of total oil production consumed by the major oil-using countries and regions in 2004.



Source: BP Statistical Review World Energy 2005.

Projected Demand Growth for Liquid Petroleum

Demand growth projections depend on assumptions about future rates of economic growth in the various countries. In June 2005, the EIA projected world oil demand would grow to 119 million barrels/day by 2025, representing an average demand growth of 2% per year. Demand growth is expected to be highest in the developing world, especially China and India, as they invest in industry and adopt automobile lifestyles. Between 2003 and 2004, U.S. demand grew 2.4%, while Chinese demand grew by 15%. However, the U.S. increase (484,000 bbl/day) was more than half the Chinese increase (893,000 bbl/day) in terms of volume. As of December 2005, the world had consumed just over 1 trillion barrels of oil. At a projected growth rate of 2%, the world will require another 1 trillion barrels of oil over the next 35 years, as much as it has consumed in its entire history to date. Figure 3 illustrates the exponentially increasing volume of oil that would be needed to sustain a 2% annual growth rate. Oil required beyond 2040 has not been discovered – its existence is hypothetical to purely speculative.

Figure 3. Quantity of oil needed to sustain 2% demand growth.

<table>
<tr><th colspan="3">QUANTITY OF OIL NEEDED TO SUSTAIN 2% DEMAND GROWTH
(Doubling Time = 35 Years)</th></tr>
<tr><td>1850 – 1969
500 Billion Bbl
(Produced and</td><td>1970 – 2005
500 Billion Bbl
Consumed)</td><td rowspan="2">2041 – 2075
2 Trillion Bbl
Unconventional Oil
+
Undiscovered Oil
(Hypothetical and Speculative)</td></tr>
<tr><td colspan="2">2006 – 2040
1 Trillion Bbl
(Proven and Probable Reserves)</td></tr>
</table>

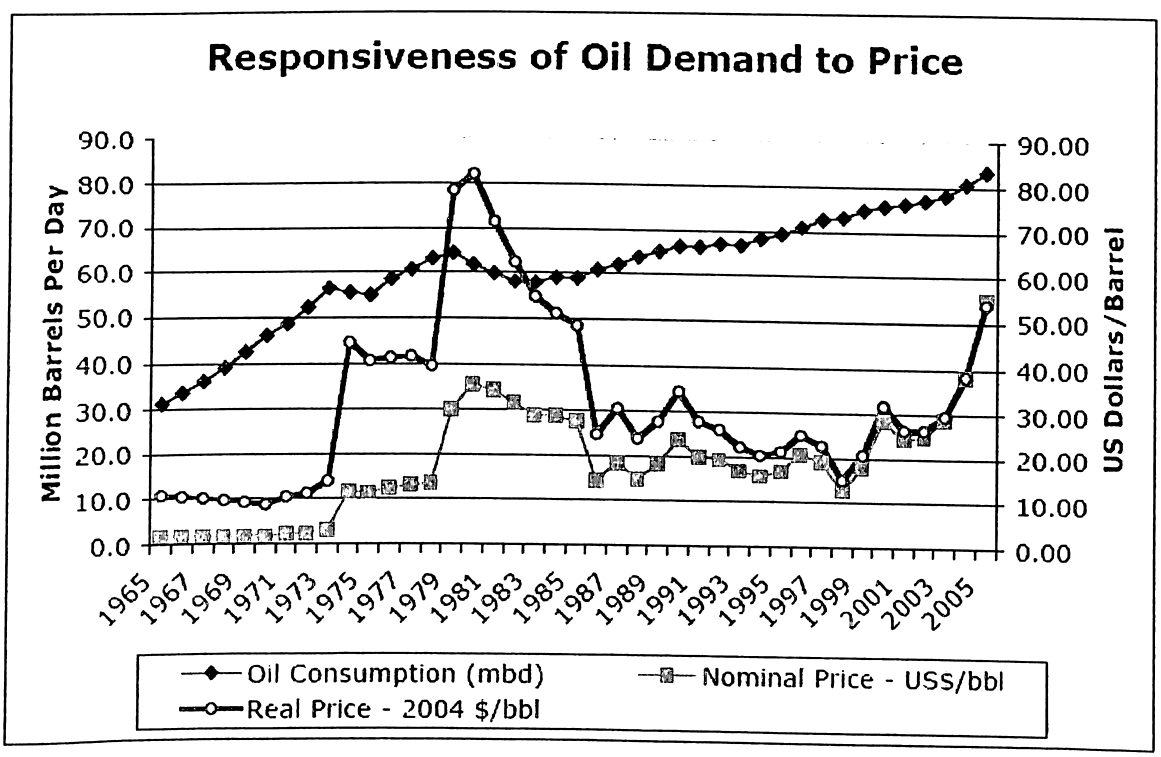
Source: British Petroleum

Where is all this yet-to-be-discovered oil really going to come from? Official projections from the DOE EIA assume that US demand will have to be met from increased imports. IEA projections assume that world demand will be met until at least 2030 by increased production from the Middle East.

Price Elasticity of Oil Demand

Demand for oil has traditionally been considered relatively inelastic with respect to price in the short term, meaning a 10% increase in price is expected to result in a demand drop of only about 2-3%. That's the theory. However, as Figure 4 shows, over the past 7 years oil demand has behaved as if it were insensitive to price. Although consumption fell slightly in the early 1980s due to the OPEC price hikes, demand has risen steadily since. Between 1999 and 2005 demand rose 15%, despite a 5-fold increase in price.

Figure 4. Responsiveness of oil demand to price.



Source: Data from BP Statistical Review 2005 and EIA Short Term Energy Outlook, October 2005.

This unexpected behavior could indicate that oil costs represent too small of a fraction of consumer income for them to care about price. Or, it could reflect the fact that almost 70% of oil consumption in the U.S. is for transportation. The just-in-time global industry and agriculture cannot readily shift out of oil use for transportation. Individuals can reduce discretionary travel, but cutting work-related driving means switching jobs or vehicles. It seems that people will more readily give up other consumption - like eating out - to continue driving while they wait for the price to come back down. In the short term, food producers absorb the added costs, reducing their already low margins.

Energy and Economic Growth

The growth of the Industrial Age has paralleled the growth of energy supply and in fact could not have occurred without it. The early Industrial Age, which began in England, was powered by coal, which yielded far greater energy density than wood and enabled an age of industrial machines and mechanized transport. Because of cheaper, more abundant energy, society was revolutionized, restructured around factories and machines and the flow of goods and trade they engendered. Oil didn't gain its economic foothold until the late 1800's. Its original value was as lamp oil to replace the rapidly depleting whale oil supplies. Oil was scarce and pricey until Colonel Drake drilled his famous well in Titusville, Pennsylvania, in 1869, issuing in the age of cheap abundance. It was John D. Rockefeller who decided to find use for all that surplus oil. Enter the combustion engine and Standard Oil of New Jersey, and the rest is history. Oil offered the greatest energy density of any substance yet known to man. It rapidly replaced coal as the primary energy source, long before the coalfields were mined out. Oil ushered in the age of submarines and flying machines, the military industrial complex, the personal auto and the American Dream of a home in the suburbs. And every year since then, there has been more oil available than the year before.

Economic Implications of a Reduced Oil Supply Rate

What would happen if oil production could not keep up with demand? The most obvious result is that oil would cost more and the price would become volatile. Because it is the lifeblood of so many aspects of business and standard-of-living in the developed world, oil scarcity and price increases will have far-reaching consequences. Six of the most likely impacts are highlighted below:

Increased Competition for the Remaining Resource: Tight oil markets will increase geopolitical strife as countries maneuver to assure their long-term access to oil. "Energy security" will drive international policy. Oil scarcity will cause bidding wars between the agricultural, petrochemical, transportation, heating and electric power sectors. Previously sub economic oil substitutes may become competitive.

Transportation Costs will Rise Significantly: Trucking, jet travel, trains and ship transport will all become more much more expensive. Commuting will consume a bigger portion of family income. Jet travel will become prohibitively expensive for leisure travel for the middle class.

Agricultural Costs will Rise: Reduced oil supplies will raise the prices of petrochemical feedstock for pesticides and herbicides. Equipment fueling costs associated with planting, growing and harvesting will also rise. Finally transportation costs to market will rise. The impact to farmers will be higher costs and decreased profit margins.

The Cost of Living Will Rise: While transportation cost increases may not outweigh the cost savings of cheap foreign labor, they will cause the cost of goods sold to rise. Higher oil related costs of manufacturing, food production and transportation will need to be passed on to customers. The poor and middle class will be hardest hit. As of May 2006, the consumer price index (CPI) had risen over 17.23%35 since oil began its price rise in 1999.

Contraction of the Global Economy: Consumers will lose discretionary purchasing power at the same time that factor costs rise and cheap goods from just-in-time global fabrication/assembly companies become uncompetitive. The clothing, grocery, auto, and electronics industries, among others, will be dramatically affected, as will tourism. Global recession is distinctly possible.

The Re-Emergence of Regional and Local Economies: High oil prices will make local agriculture both necessary and cost-competitive again.

CHAPTER 2

LITERATURE REVIEW

Recently, numerous publications have appeared warning that oil production is near an unavoidable, geologically-determined peak that could have consequences up to and including "war, starvation, economic recession, possibly even the extinction of homo sapiens" (**Campbell in Ruppert** 2002) The current series of alarmist articles could be said to be merely reincarnations of earlier work which proved fallacious, but the authors insist that they have made significant advances in their analyses, overcoming earlier errors. For a number of reasons, this work has been nearly impenetrable to many observers, which seems to have lent it an added cachet. However, careful examination of the data and methods, as well as extensive perusal of the writings, suggests that the opacity of the work is—at best—obscuring the inconclusive nature of their research.

Some of the arguments about resource scarcity resemble those made in the 1970s. They have noted that discoveries are low (as did Wilson (1977) and that most estimates of ultimately recoverable resources (URR)[2] are in the range of 2 trillion barrels, approximately twice production to date. But beyond that, Campbell and Laherrere in particular claim that they have developed accurate estimates of URR, and thus, unlike earlier work, theirs is more scientific and reliable. In other words, this time the wolf is really here. But careful examination of their work reveals instead a pattern of errors and mistaken assumptions presented as conclusive research results.

Gaston, (1983) discussed Hubbert Peak in Air University Review. He warned right in the beginning that the article "makes no attempt to predict the future," because "human beings can neither predict nor control the future. If anyone still suffers from the delusion that the ability to forecast beyond a very short time span is available to us, let him look at the headlines in yesterday's paper, and then ask himself which of them he could possibly have predicted a decade or so ago."

Heinberg, (2003) is the author of **The Party's Over,** many peoples' first introduction to the subject of peak oil. It was the first book to explain the concept in a clear and accessible way for people with no background in petroleum geology (myself included).

However, while many writers are still chewing over whether or not peak oil is a reality, and haggling over the exact date when it might occur (2006? 2010? 2030?), Heinberg is moving on, exploring its implications and what can be done to prepare for this historic transition. His next book, Powerdown, did this, exploring options for societies beyond the peak, setting out the case for a Government-initiated national 'powerdown', as well as the need for grassroots relocalisation.

CHAPTER 3

OBJECTIVES

OBJECTIVE OF THE STUDY

- To stimulate thought and discussion about the issues surrounding Peak Oil amongst people of different backgrounds and viewpoints.
- To present the world oil demand/supply situation from a physical constraints perspective.
- To find relation between alternative uses and oil peaking.
- To list probable actions with respect to Oil peaking.
- To find Changes in the global oil market.
-

SCOPE OF THE STUDY

The paper will discuss the future outlook of the global oil market in the contexts of a rapidly expanding Asian economy and the impact of the timing of oil peaking (dependent in part on the oil demand outlook) on the entire oil supply chain (from upstream to downstream); prospects for a smooth or disruptive transition to alternative sources of transportation fuels; and, the geopolitical consequences of oil peaking. The paper will conclude that the changes in the global oil market since 2004 are structural in nature and that we are unlikely to see a return to the oil price cycles of the 1985-2000 period unless the world were to enter into a major global recession. In contrast to the decade from the late 1970's to the mid 1980's, high oil prices are not likely to lead to a sharp contraction of oil demand (no near term substitution for transportation fuels) nor to a sharp increase in oil production.

METHODOLOGY

The exact timing of Peak Oil is extremely difficult to predict because the publicly available data on remaining oil reserves is astoundingly poor. Much of the "data" is crafted specifically to meet political and financial requirements. Essentially, companies and countries keep two sets of books.

Primary data can not be collected because of geographical constraints and Oil is found in different Countries and Continents. There is no data transparency or verification. Knowing any data I used would be suspect and immediately obsolete, I decided to generate all my graphs and tables from a single, commonly cited source – the Annual Statistical Review of World Energy, published in July 2005 by British Petroleum (BP). The research included detailed quantitative analysis of all secondary data by using quantitative methods like a simple game theory. A qualitative risk assessment approach is also required.

LIMITATIONS

For this paper I consider only oil production, not natural gas, which has it's own very significant peak issues. That means this paper concentrates on energy use for transportation, not for electric power generation. For alternative energy, it means only considering those forms that can substitute for oil as a mobile fuel – no wind, hydro, solar, or nuclear power, which provide stationary energy.

CHAPTER 4
GLOBAL SCENARIO: TAKING INVENTORY OF PETROLEUM SUPPLY

It's impossible to take an accurate inventory of in-the-ground petroleum supply because we can't see the data. First, the oil is underground, within and under layers of rock. Product coming out of an oil well can be measured, but geologists can only infer the volume of oil in the ground using remote sensing techniques, interpreted with a thorough knowledge of petroleum properties and occurrence. Estimating oil field size and recovery is a highly technical, but subjective art. In addition, oil reserve data are often held as state or company secrets. Publicly reported reserve figures may be significantly over- or understated for political or financial reasons, as the introductory quote to this chapter clearly shows. The public numbers are not verifiable. This absence of verifiable supply data is at the heart of the peak oil debate. Not surprisingly, a wide spectrum of world oil inventory estimates exists, from dire to cornucopian. To plan intelligently, managers (or anyone!) must examine the various oil supply projections to decide the odds of them being correct and the risks if they are not. This chapter discusses the underlying geologic reality of oil production, then considers the assumptions, biases, and uncertainties behind the most prevalent viewpoints on future oil supply.

The Geologic Production of Petroleum

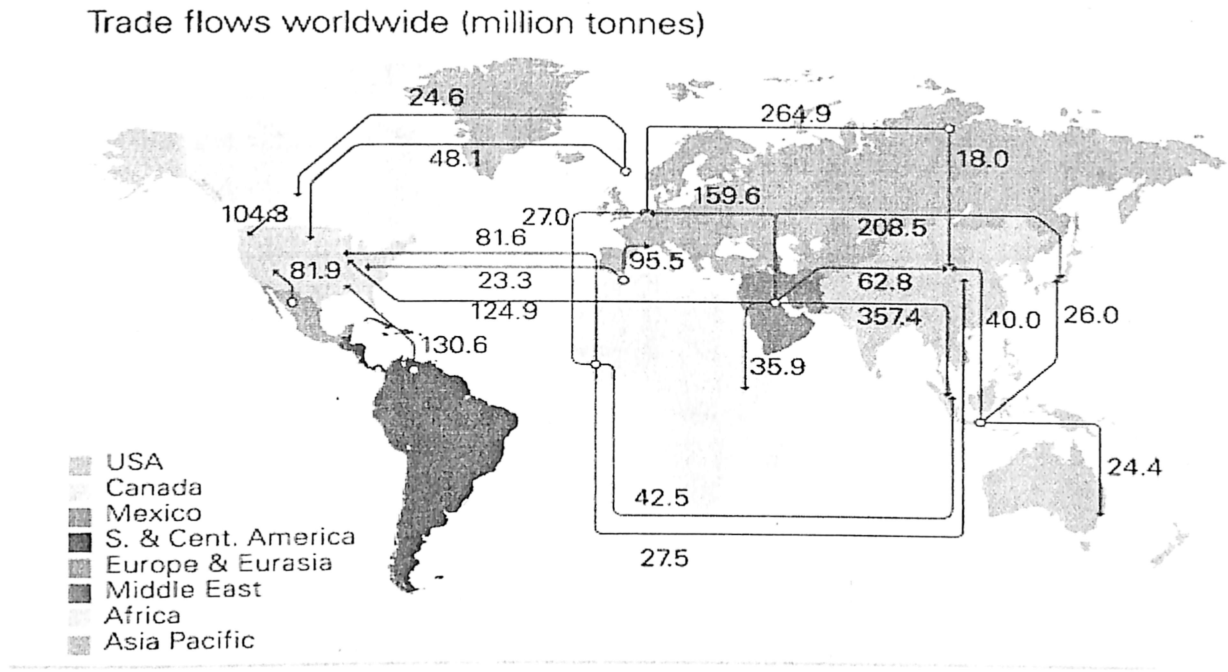
Companies talk about "producing" oil, and the input costs of all the classic factors of production – capital, labor, etc. But oil companies are really in the exploration and extraction business, exploiting and depleting a finite resource that was "produced" by earth processes over millions of years under very specific geologic circumstances. Through a century of testing their theories with a drill bit, exploration geologists have a very good understanding of the conditions needed to form an oil deposit. Simply put, the prerequisites are 1) an organic-rich source rock; 2) a burial history long and deep enough to thermally alter (cook) the organic matter into oil; and 3) a sealed trap in a nearby reservoir rock.

Where the Oil Is and Where It Goes

Significant petroleum occurrence is restricted to a limited number of geologically predictable places on earth where the above conditions were met. The vast majority of oil is found in restricted sedimentary basins along the current or former edges of continents. River deltas, continental margins, deserts and arctic areas are the four present-day locations most likely to hold oil or gas deposits beneath them. The most prolific oil-producing conditions are found in the Middle East in the "Oil Triangle" of Saudi Arabia, Kuwait, Iraq and Iran. In North America, oil is concentrated in the Gulf of Mexico and in basins along the edge of the Rocky Mountains. Other significant oil-prone areas include Russia, the Caspian Sea and the Atlantic continental margins of Africa and South America.

A surprisingly high proportion of the world's oil - 47% - comes from a relatively few giant oil fields, which each produce at least 100,000 barrel/day. Among these 116 fields, four aging "super giants" together produce around 8 million bbl/d - about 10% of the world's daily production. The remaining 53% of the 84 million barrels of oil that the world consumes daily comes from over 4,000 smaller fields, each producing less than 100,000 bbl/d, and from old "stripper wells" past their prime that still produce a few barrels a day. Since the earth's oil endowment is concentrated in so few places, a thriving trade has evolved exporting oil from producing to consuming countries. Figure 5 shows the most significant oil import/export relationships in 2005, based on volume. These trade dependencies are a major factor shaping the geopolitical landscape. For example, through the 1950's the US was the largest oil producer and exporter in the world. But by the 1970's it had become a net oil importer. This reversal in producible oil endowment relative to annual oil consumption forced major U.S. foreign policy shifts. Dependent on trading relationships, the U.S. could no longer afford to be isolationist. Currently, the U.S. produces about 8% of the world's daily supply from 2.5% of the world's reserves. This supplies roughly 40% of U.S. daily consumption. The remaining 60% is imported, principally from Mexico, Canada, Venezuela, West Africa, and Saudi Arabia.

Figure 5. Major trade flows of oil from producing to consuming countries



Source: British Petroleum (BP).

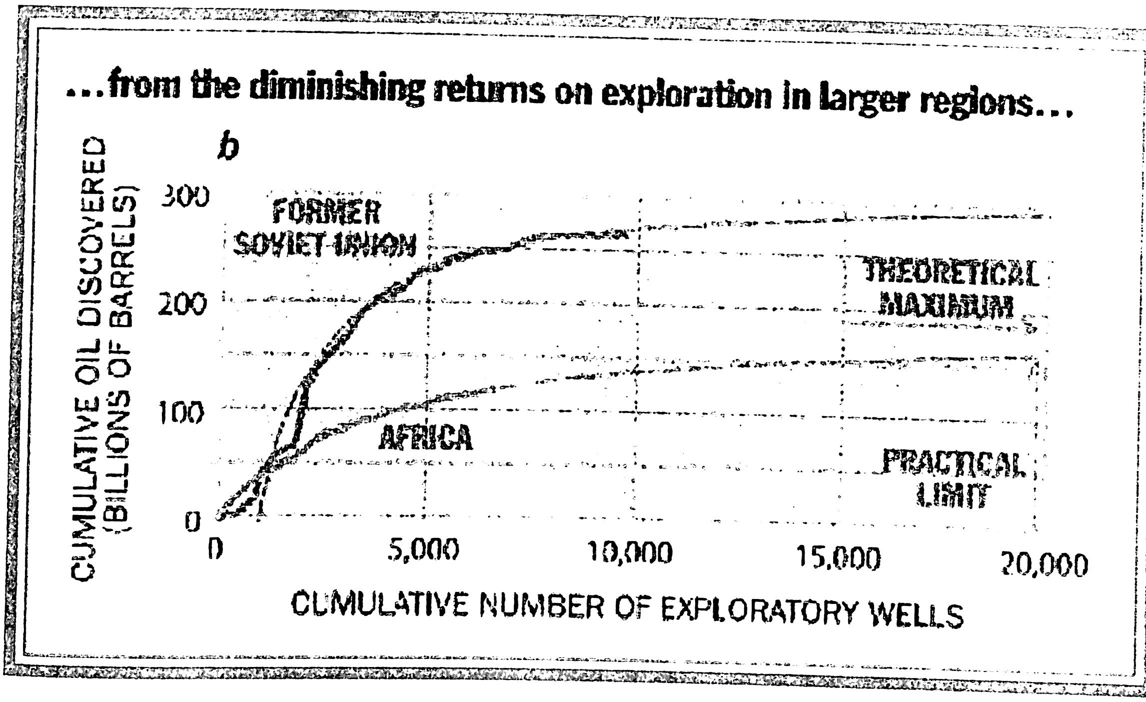
Diminishing Returns of Production

The oil industry is not exempt from the law of diminishing marginal returns. Oil discovery and production rates increase early on as experience and innovation increase efficiency. Then marginal returns diminish to zero as production efficiencies decrease. After reaching a maximum output, marginal returns become negative and output declines.

Oil Field Discovery Rate

The world's readily accessible oil basins have already been explored for the easy oil. Geology didn't create many supergiant oil fields, and no new ones have been discovered in the past 30 years (see Appendix A). In each region, the largest fields are usually discovered early on, being "too big to miss". Subsequent exploration wells ("wild cats") discover less and less new oil, resulting in the classic "creaming curve" of cumulative production per number of wells drilled (Figure 6). Most reported oil well "hits" are the result of infill or step-out drilling in already discovered fields.

Figure 6. Example "Creaming Curve" for oil discovery. The big fields in a region are found early. Later exploratory wells discover less and less oil.



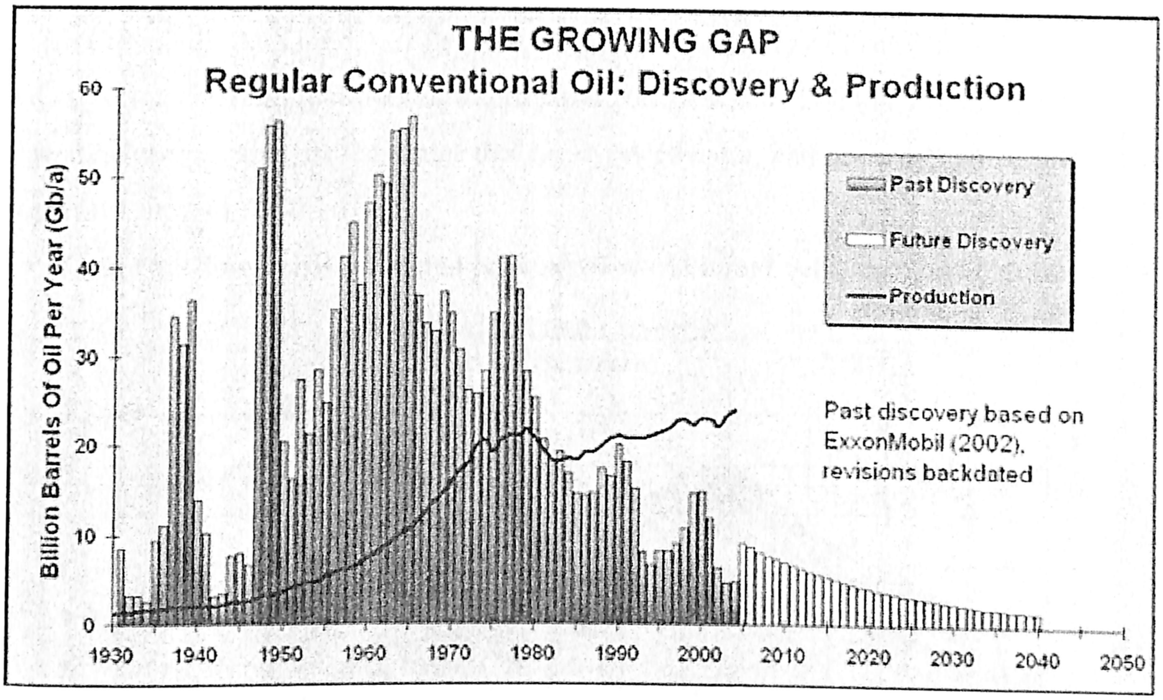
Source: Colin J. Campbell, and Jean H. Laherrere, "The End of Cheap Oil"(*Scientific American*, March1998: 77-83).

Although annual company reports don't highlight it, oilmen fully understand that the business of oil "production" depletes the finite resource base that is their product. If oil supplies are to grow, then the annual volume of oil discovered must exceed the amount consumed. As CEO of Halliburton, Dick Cheney described the dilemma:

From the standpoint of the oil industry...for over a hundred years we as an industry have had to deal with the pesky problem that once you find oil and pump it out of the ground you've got to turn around and find more or go out of business. Producing oil is obviously a self-depleting activity. Every year you've got to find and develop reserves equal to your output just to stand still, just to stay even.

At the 2005 rate of 84 mbd, 30 billion barrels of new oil must be discovered each year just to replace depletion of the existing stock. However, that hasn't happened since the 1980s, when net annual discovery (new oil minus depletion of existing fields by pumping) went negative (Figure 7). The world oil discovery rate peaked in the 1960s. These days, a banner discovery year for oil is 10 billion barrels. The obvious, but sometimes ignored reality is that the volume of oil ultimately produced cannot exceed the area under the discovery curve. Every year since 1982, the world has dipped deeper into its oil endowment.

Figure 7.



Source: Campbell, Association for the Study of Peak Oil (ASPO).

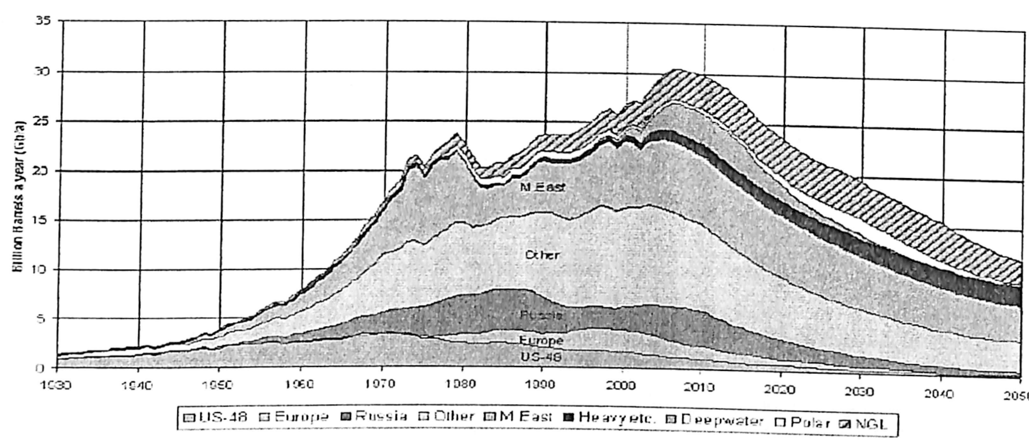
Diminishing Oil Quality

The preferred crude oil is "sweet" and "light", because it can easily be refined into the most desired products, like gasoline and diesel. "Sour" (high sulfur) and heavy crude oils are less sought after, because they require special refining equipment to process the impurities. Large amounts of hydrogen must be added to heavy oil at the refinery to create the desired outputs of lighter hydrocarbon products. Naturally, sweet, light oil deposits were preferentially exploited first. Spare capacity and planned future production increasingly consists of sour and heavy oil. Current Canadian oil production from tar sands is an example of production moving down the marginal quality curve.

Hubbert's Peak: World Oil Production Peaking and Decline

When will maximum world oil production - the infamous Hubbert's Peak - occur? Given the poor data reporting, the uncertainty about reserves and future discoveries, and the need for a rear-view mirror to identify the peak year, no one can say for sure. Geologist Colin Campbell, the founder of the Association for the Study of Peak Oil (ASPO), believes that conventional light to intermediate oil peaked in 2004 or 2005 (Figure 8). Based on current data, he estimates that heavy, deepwater, and polar oils will peak sometime around 2010-2012.

Figure 8. Campbell's predicted peaking of world liquid petroleum and natural gas



Source: Campbell 2005, Assoc. for the Study of Peak Oil (ASPO).

A search for a concrete date for Peak Oil – one a manager could plan around - uncovers a simmering debate. Many industry analysts estimate that the world will hit Peak Oil production between 2005 and 2020. Many expect the "peak" to be a plateau. The official agencies, USGS, EIA and IEA lean towards 2035 or later. The demand-based predictions of the EIA, for example, are that oil supplies will not peak until sometime between 2021 and 2067. There are many uncertainties involved in accurately predicting when world oil production will peak. On the supply side these include: unreliable reserve estimates; the rate of new oil discovery; weather or political disruptions of existing or planned production; and infrastructure constraints, such as the availability of seismic exploration vessels, drilling rigs, tankers, refineries, and skilled professionals. On the demand side, the main uncertainty is economic growth; demand and investment capital could both wither in an economic recession or depression. These factors collectively may end up determining the peak oil production rate and date more than geology does. Since the peaking of individual countries will cumulatively determine the world oil production peak, it is critical to know which of the major producing countries have already peaked. Table 2 lists all countries that produced more than 1 million barrels/day of oil in 2004, their maximum historical production and the year it occurred. It is evident that, by 2004, 11 of these 19 countries had already peaked. A twelfth, Mexico, is widely expected to have peaked in 2005 based on reports that the super giant Cantarell field has entered decline. The linchpin country for Peak Oil is Saudi Arabia, due to it's large contribution to the world's daily supply (about 9.5 mbd in 2005). When the super giant Ghawar field, which provides more than half of Saudi daily production, peaks, the world will have passed peak oil production.

Table 2

Current and Maximum Historical Reported Production in the Top Oil Producing Countries

Maximum Oil* Production of Top Producers
Thousand barrels daily

Country	2004 Production	Maximum Production	Year Maximum Production
Saudi Arabia	10,584	10,584	
Russian Federation	9,285	11,484	1987
USA	7,241	11,297	1970
Iran	4,081	6,060	1974
Mexico	3,824	3,824	2005**
China	3,490	3,490	
Norway	3,188	3,418	2001
Canada	3,085	3,085	
Venezuela	2,980	3,510	1998
United Arab Emirates	2,667	2,667	
Nigeria	2,508	2,508	
Kuwait	2,424	3,339	1972
United Kingdom	2,029	2,909	1999
Iraq	2,027	3,489	1979
Algeria	1,933	1,933	
Libya	1,607	2,139	1979
Brazil	1,542	1,555	2003
Kazakhstan	1,295	1,295	
Indonesia	1,126	1,685	1977
TOTAL WORLD	**80,260**		
OPEC	32,927		

2004 Data from BP Statistical Review of Data 2005

* Includes crude oil, shale oil, oil sands and NGLs (natural gas liquids - the liquid content of natural gas where this is recovered separately). Excludes liquid fuels from other sources such as coal derivatives.

** Based on 2005 reports that the Super Giant Canterell field is in decline

Source: British Petroleum (2005)

There are many vested interests, as well as honest differences of opinion, in the public debate about Peak Oil. The various beliefs depend on whether people trust officially reported numbers and what they are willing to define as future oil reserves. The debate usually boils down to widely disparate estimates of how much oil (or oil-equivalent) resources are left to produce. That's actually the wrong question. The critical issue from a practical standpoint is: How much oil can be produced at a meaningful rate in the immediate and foreseeable future? To make any sense of the wide range of reported future estimates, we must first understand the general terminology of oil resource and reserve accounting.

Oil Resources versus Accessible Reserves

The words "oil supply" have no agreed meaning. Under the broadest definition, oil resources can be interpreted to include the earth's entire petroleum endowment plus any other substance (natural gas, coal, biomass, etc.) that we can convert into oil. But not all resources are accessible, much less recoverable. As the next chapter will discuss, the alternatives are not truly oil equivalents from the perspective of either energy density or return on energy invested. To get a realistic inventory of liquid petroleum, we must restrict ourselves to counting oil reserves, not resources. That is, we must only count oil that is actually likely to be producible. Reserve accounting is not standardized from company to company, nor even from country to country. Therefore, summing individual country reserves yields unrepresentative totals. Most of the western world reports their reserves as P2 (probability 50%) based on the following definitions:

Proven (P1 or P-90) Reserves have a 90% certainty of existing and being producible at today's prices using existing technologies.

Probable (P2 or P-50) Reserves have a 50% probability of existing and being economic at today's prices using existing technologies.

Possible (P3 or P-10) Reserves are hypothetical to speculative with only a 10% chance of existing or being economic

Clearly, reserves are not static. In addition to growing through exploration, they can grow or shrink) with market conditions. If prices rise, some reserves that were previously sub-economic will be reclassified as proven or probable. But price spikes cannot call new oil into existence or overcome the geologic production constraints. The most commonly used public reserve numbers are published by British Petroleum in their annual statistical review of world petroleum data. Table 3 reports official reserves for the major oil-producing countries. But, as their standard caveat explains, BP doesn't necessarily use the numbers they publish.

Table 3

Countries with the Largest Reported Oil Reserves

	Thousand million barrels	Share of total	Reserves Production ratio
Saudi Arabia	262.7	22.1%	67.8
Iran	132.5	11.1%	88.7
Iraq	115.0	9.7%	*
Kuwait	99.0	8.3%	*
United Arab Emirates	97.8	8.2%	*
Venezuela	77.2	6.5%	70.8
Russian Federation	72.3	6.1%	21.3
Kazakhstan	39.6	3.3%	83.6
Libya	39.1	3.3%	66.5
Nigeria	35.3	3.0%	38.4
USA	29.4	2.5%	11.1
China	17.1	1.4%	13.4
Canada	16.8	1.4%	14.9
Qatar	15.2	1.3%	42.0
Mexico	14.8	1.2%	10.6
Algeria	11.8	1.0%	16.7
Norway	9.7	0.8%	8.3
Angola	8.8	0.7%	24.3
United Kingdom	4.5	0.4%	6.0
Rest of World	94.5	8.0%	
TOTAL WORLD	**1188.6**	**100.0%**	**40.5**
of which: OECD	82.9	7.0%	10.9
OPEC	890.3	74.9%	73.9
Non-OPEC	177.4	14.9%	13.5
Former Soviet Union	120.8	10.2%	28.9

Source: British Petroleum (BP).

Reserve accounting is further complicated because, over time, countries have changed what they report as oil. Historically, only production of "conventional" oil was reported, including the coveted "light, sweet crude", the less favored "heavy, sour crude" and associated gas condensate liquids. Now, countries include "non-conventional" oil, which encompasses not only deep-water oil and polar oil, but also oil synthesized from "oil sands" and "oil shales". Combining these two fundamentally different types of oil in the reports gives the false impression that 1) reserves of conventional supplies are growing, 2) that these additional reserves will give the same energy returns per investment as conventional oil, and 3) that they can be produced at the same rate as conventional oil. This masks the decline of conventional oil fields.

Three Camps: Peak Oilers, Official Agencies, Optimists

Although we don't know the exact shape that the Peak Oil curve will take, it is safe to estimate that after the first half the ultimately recoverable reserves (URR) of oil have been consumed, the world will be at or near peak oil production. Expressed as a ratio, Peak Oil will occur approximately when

$$\frac{\text{cumulative production}}{\text{ultimately recoverable reserves}} = \frac{1}{2}$$

At the end of 2005, cumulative reported world oil production was just over 1 trillion barrels. Three camps have emerged, based on their beliefs concerning the value of the denominator:

1) **The Peak Oil Crowd**: URR = approximately 2 Trillion bbl
Peak is now or within 10-15 years. It is urgent to start preparing.
2) **Official Agencies**: URR = approximately 3 Trillion bbl
Peak is several decades off. There is plenty of time to prepare.
3) **Technology Optimists**: URR = at least 7-8 Trillion bbl oil equivalent
Peak is so far away as to not be a concern.
Each group includes different assumptions in their estimates of the ultimately recoverable oil, which are generalized and briefly discussed below.

The Peak Oil Crowd

The Peak Oil Crowd tend to work in the earth sciences, the oil industry, agriculture, or logistics – all physical, observational practices. They think that official reserves are overstated for political and financial reasons, especially those of OPEC and Russia. They believe that up to 90% of the world's accessible oil has already been discovered and that additional reserves will become much harder to find and produce and much more expensive. They don't agree on the exact date that Peak Oil will occur or the shape of the peak, but most place the date between 2005 and 2020. Many believe that production could increase, then plateau for a period of 5 to 10 years due to increased deepwater production before starting to taper off. Others believe the peak is imminent and the decline will be precipitous. Although they agree that alternative fuels could slow the decline, Peak Oilers often do not count alternative oil sources in reserves. They don't believe the alternatives can provide the same amount of energy as oil, nor be produced at a meaningful rate. Critics call them "doomers" and practitioners of "junk economics" who fail to account for reserve growth, the impacts of technological innovation, or the effects of pricing on curbing demand and introducing new supply.

Official Agencies

The oil supply numbers published by the highly respected International Energy Agency are quoted as gospel by government and policy people throughout the world. According to IEA projections issued between 2000 and 2005, world oil supply will grow until at least 2035, or even 2050. The IEA quotes their source of data as the U.S. Geologic Survey, World Petroleum Assessment 2000 (based on 1995 data). However, the 3.3 trillion barrel URR estimate from the USGS study is regarded as unrealistically high by many geologists and analysts. The 2000 Assessment is 44% higher than the 2.3 trillion bbl URR estimate that the USGS had reported in 1998. In addition to assuming improbably high reserve growth, the 2000 survey assumed a five- fold increase in the oil discovery rate, which has not occurred. Hence, many critics regard the USGS and IEA reserve estimates as political numbers.

Technology Optimists

This group tends to consist of economists, industry spokesmen, technophiles, and other optimists who believe strongly in the power of the market and human ingenuity. They profess faith that things will work themselves out once price sends its signal. The optimist camp does not limit itself to accessible reserves. It considers all the lower-grade hydrocarbon resources to be potential candidates for replacing oil as soon as price is high enough to make their extraction and conversion profitable. Critics say that they confuse resources with viable oil reserves that can be produced economically at a useful rate and that they are relying on faith in hypothetical technological innovations that are not yet even in the R&D stage.

Geopolitical Realities of the Distribution of Remaining World Oil

Almost 75% of the officially reported reserves in the world are located in OPEC countries (Table 2). More than half of that – some 42% of the remaining reported oil in the world - is located in Saudi Arabia, Iraq and Iran. After the Middle East, Russia reports the largest percentage (6%) of the total reserves. The U.S. and its two largest suppliers – Canada and Mexico – have only 5% of the world's reserves between them. These are principally in the Gulf of Mexico and the Canadian oil sand deposits in Alberta. Americans tend to think that oil production is controlled by the international oil companies (IOCs), but approximately 75% of the world's oil supply is nationally owned. The IOCs have drilling access to only about 25%. Much of this is through contracts to develop nationally owned oilfields, where the national oil companies (NOCs) lack the technical or financial resources to develop their fields. The IOCs are aggressively seeking greater access to this oil through partnerships and privatization. The remaining unexplored areas with geologic potential for large oil fields are in deep water off the margins of Africa and Brazil, in the South China Sea and in polar regions. Countries adjacent to these areas are currently jockeying over offshore drilling boundaries.

Is There a Rate Limit to Production?

Clearly, it is critical to offset depletion of existing oil fields with new discoveries if the oil supply is to be replaced, much less grow. However, in the short term, the corollary issue of maintaining the current rate of production is more important to the functioning of the world economy. Each year, the additional oil brought into production must exceed the annual decline rate of existing production, or net production will fall. The two issues are analogous to replacing assets versus keeping a positive cashflow.

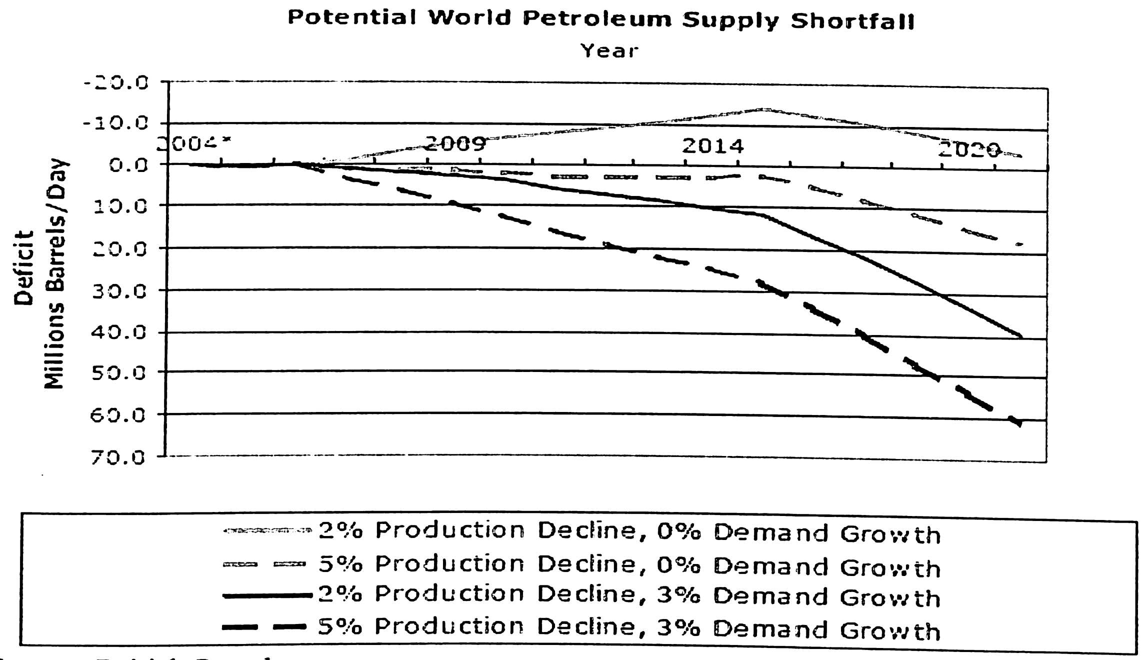
The Growing Gap: So Much Depletion, So Few New Megafields

New fields don't come online overnight. It takes 4-10 years to bring a new discovery into production. Managers know what is "in the pipeline" and petroleum analysts track it closely. There were 16 new megafields (at least 500 million barrels) reported in 2000, 11 in 2001, and 5 in 2002. No new megafield discoveries were reported in 2003 or 2004. According to Skrebowski, the next five years should see about 3.5 million barrels/day of new production come onstream each year, principally from deepwater fields. Cumulatively adding up to 16.6 mbd new production by 2011, this could offset production declines from existing fields for a few years. However, being principally deepwater fields, the new production will likely ramp up quickly, then decline rapidly. Based on North Sea experience, it is reasonable to expect production to start declining within 10-12 years.

The potential shortfall is obvious. If the new field numbers prove accurate, the current rate of production might be sustained, or even grow, until 2015. But it could prove very difficult to meet any signficant growth in demand. Figure 9 illustrates the supply/demand deficit. Once demand exceeds the supply rate, the world will tip from a buyers' to a sellers' market for petroleum. The incipient demand gap will be recognized by price increases, price volatility, and market uncertainty. Production could still increase from year to year, but it won't fill the gap.

This inventory delivery data should set off alarm bells for any competent business manager. The inescapable conclusion: just-in-time delivery of future oil supplies is not a prudent operating assumption. Even if a new supergiant field were discovered this year (and the odds of finding another Ghawar are exceedingly small), there would still be a major world production gap for several years while the new discovery came on line.

Figure 9. Projected oil supply deficit at demand growth rates of 0% and 3%, given current production decline rates of 2% to 5%. New production estimated at 3 mbd per year, with new fields entering decline after 10 years.



Source: British Petroleum

Production and Delivery Constraints

Other production constraints besides Peak Oil can create a demand gap. There are numerous physical, technological, and logistical challenges involved in bringing oil from the ground to market. These include:

- geological limits to withdrawing the oil from the reservoir
- technological limits to withdrawing oil from the reservoir
- infrastructure limits, including the availability of drilling rigs, production platforms, tankers, and pipelines
- refinery capacity to process high volume or heavy/sour oils
- skilled worker shortage due to aging work force, two decades of consolidations and layoffs, and lack of training/recruiting new hires

Any of these constraints can limit the rate of petroleum production. The EIA Short-Term Energy Outlook (September 2005) offered this sobering projection:

Moreover, only weak production growth in countries outside of the Organization of etroleum Exporting Countries (OPEC) is expected. With the loss of production in the Gulf of Mexico from the hurricanes, production declines in the North Sea, and the slowdown in growth in Russian oil production, non-OPEC supply is projected to increase by an annual average of only 0.1 million barrels per day during 2005 before increasing by 0.9 million barrels per day in 2006. In addition, worldwide spare production capacity is at its lowest level in 3 decades; and in reality, only Saudi Arabia has any spare crude oil production capacity available. Lastly, the continued geo-political risks, such as the insurgency in Iraq and potential troubles in Nigeria and Venezuela, have boosted the level of uncertainty in world oil markets.

We can't produce our way out of the demand gap. Once demand exceeds the limiting production rate (refining capacity today, peak oil tomorrow), the supply/demand equation can only be solved by oil demand reduction through demand destruction, by substitution, energy efficiencies, and conservation.

Descending Hubbert's Peak

After oil production has passed Hubbert's Peak, some of the current capacity constraints (like refineries) will no longer be limiting factors of production. However, the diminishing marginal production of conventional oil will be an ever-increasing constraint for business and life as usual. Closing the supply/demand gap will create significant new operational realities in a world where every year there is less easy oil available than the year before. Near the top of the production curve, the decline rate will be low. If we are lucky, production will remain flat for a while, creating a plateau. But on the far side of the curve, the production decline rate will increase, possibly quite rapidly. During this period, demand will have to be reduced dramatically, year after year, if it is to stay in line with the decreasing supply. The strategic management question of the century is: How will this demand gap be resolved and how long will it take? The answer will depend on whether supply can be increased to meet the anticipated demand, and/or oil substitutes can make up the difference. If not, then demand must be destroyed to match the available supply.

CHAPTER 5

SUBSTITUTE FUEL OPTION & TECHNOLOGY

In 2006, with oil prices soaring, alternative fuels and energy conversion technologies are suddenly in the media and on investors' radar. As investment money moves to the new endeavors, the free market theory goes, technological innovation will lower the marginal cost, thereby bringing the price down and keeping energy affordable. After all, ingenuity is the hallmark of our species. Is there any reason to suspect it might not work in the case of oil? This chapter provides a cursory review of the alternative fuels that are most often cited as energy sources to replace oil.

The Fossil Fuel Options

Oil Sands

An estimated resource of 4 trillion barrels of oil is contained in heavy oils and oil sands, including the extensive tar sand deposits in Alberta, Canada. Of this, 800 billion barrels is estimated to be recoverable. Canadian oil sands production became marginally profitable when oil hit $35/bbl; they are currently a very hot energy investment. The sands are strip-mined or heated in-situ to release the bitumen. Enormous quantities of water and natural gas are required to generate the steam heat. The natural gas also provides the source of hydrogen needed to create synthetic crude from the bitumen. Competing demands for both gas and water and scarce supply make them limiting factors that will drive up the production price. A new natural gas pipeline is planned from the MacKenzie Delta to Alberta to provide energy for tar sand extraction. French oil company Total has even proposed building a dedicated nuclear power plant in Alberta, exclusively to provide steam and hydrogen for the oil sand production. The potential oil volume of oil sand resources is often touted as greater than worldwide reserves of conventional oil. However, achievable daily production of oil from the sands is rate limited. Canada produced about 1 mbd from oil sands in 2005, and expects to ramp up to a mere 4 mbd by 2030 . Oil sand production could thus help offset declining oil production, currently estimated at 1.5 to 4.5 mbd/year, but is unlikely to provide a significant percentage of the world's liquid petroleum needs. In addition, the environmental impacts associated with oil sand production are severe.

Oil Shale

The saying out West is "Oil shale is the energy of the future and always will be." There are vast deposits of "uncooked" oil source rock in Utah, W. Colorado, and Wyoming. The total estimated oil shale resource is about 3 trillion bbl oil. Many attempts at commercial extraction have been tried and abandoned over the past 95 years. The target oil rock is 1000 feet below the surface. Underground mining has been proposed, as have open pit mines 2000 feet deep. The rock must be retorted to 1000 degrees Fahrenheit to convert the kerogen in the shale to liquid oil. Voluminous quantities of water and energy are required. The residual rock is contaminated with arsenic and occupies a greater volume than before the oil extraction, creating massive environmental disposal problems. Oil shale re-emerged as a hot alternative energy investment in 2005 when oil hit $60/bbl. The RAND Corporation estimates that U.S. oil shale could provide 25% (5 mbd) of the U.S. current consumption of 20 mbd for 400 years. Shell is currently planning a 10-acre pilot project on Mahogany Ridge, Colorado for in-situ recovery. Like the oil sands, daily production of the oil shale will be rate-limited. Assuming the pilot works, Shell hopes to produce 100,000 bbl/day by 2020. That's a 7-minute supply at current world consumption rates. On the downside, the energy required to produce 100,000 bbl/d shale oil will require building a $3 billion dedicated power plant, Colorado's largest, which would consume 5 million tons of coal/year. Currently, the world's greatest commercial production is from Estonia, which has no oil, coal or natural gas, but produces 16,000 bbl/d of shale oil.

Gas-To-Liquids (GTL)

Very large reservoirs of natural gas exist around the world, many in locations isolated from gas-consuming markets. Significant quantities of this "stranded gas" have been liquefied and transported to various markets in refrigerated, pressurized ships in the form of liquefied natural gas (LNG). Japan, followed by Korea, Spain and the U.S. were the largest importers of LNG in 2006. LNG accounted for an important fraction of all traded gas volumes in 2003, and that fraction is projected to continue to grow considerably in the future. Another method of bringing stranded natural gas to world markets is to disassociate the methane molecules, add steam, and convert the resultant mixture to high quality liquid fuels via the Fisher-Tropsch (F-T) process. As with coal liquefaction, F-T based GTL results in clean, finished fuels, ready for use in existing end-use equipment with only modest finishing and blending. This Gas- To-Liquids process has undergone significant development over the past decade. Shell now operates a 14,500 bpd GTL plant in Malaysia. A number of large, new commercial plants recently announced include three large units in Qatar -- a 140,000 bpd Shell facility, a 160,000 bpd ConocoPhillips facility, and a 120,000 bpd Marathon Oil plant. Projects under development and consideration total roughly 1.7 MM bpd, but not all will come to fruition. Under business-asusual conditions, 1.0 MM bpd may be produced by 2015, in line with a recent estimate of 600,000 bpd of GTL diesel fuel by 2015 -- the remaining 400,000 bpd being gasoline and other products.

Coal-to-Liquid (CTL)

Synthetic gasoline can be created from coal (carbon) by adding hydrogen using the Fischer-Tropsch method. The Germans employed the technique to produce aviation fuel and diesel for their army during World War II when they were cut off from crude oil supplies, and South Africa under apartheid used an updated variation of the method.106 Since the U.S. has the most abundant coal resources in the world, gasoline from coal is often suggested as one of our easiest substitutes. While the U.S. deposits are large, they are being looked to for many competing future uses. As natural gas becomes scarce, coal-gasification is already being substituted to produce hydrogen needed for refineries. Coal-fired power plants are also being commissioned at a high rate now that natural gas appears less abundant. The estimated U.S. coal reserve life of 250 years (at 2004 consumption rate) rapidly drops to 30 – 50 years if it is used to meet U.S. gasoline demand, too. Another problem is that coal requires more energy to mine than in the past. Like oil, much of the easy-to-access high-grade anthracite has been mined; the remaining resource is lower grade lignite. Today, coal is being strip-mined in Appalachia by removing mountain tops. CTL suffers from the usual environmental complaints about coal: mine wastes, sulfur emissions, acid rain, health effects, global warming, etc.

Biofuels and hydrogen are widely touted as renewable alternatives for liquid petroleum. Both have gained near-mythic status in the popular vernacular as environmentally benign fuels that will power the vehicles and economies of the future. But neither is truly "renewable" nor "green"; both depend on large fossil fuel inputs. And once again, rate, scale, and net energy are critical considerations.

Biofuels (Corn Ethanol, Cellulosic Ethanol, Biodiesel)

Ethanol created from biomass can be used directly in existing cars. In the U.S., the usual ethanol feedstock is corn. Cornell University agricultural scientist David Pimentel, who has done extensive studies on corn-to-gasoline, points out a fundamental input-yield problem: It takes about 70% more energy to grow and process corn ethanol than the combustion of that ethanol yields. He calculates a net energy loss of 54,000 Btu per gallon of corn ethanol, and notes that it can only be profitable when subsidized. "Abusing our precious croplands to grow corn for an energy-inefficient process that yields low-grade automobile fuel amounts to unsustainable, subsidized food burning" he says. It should be noted that many others, including the U.S. Department of Agriculture, calculate low, but positive, net energy for corn ethanol. Much depends on which input costs are included, whether irrigation is used, whether external costs are considered, and how many miles the corn and finished ethanol have to travel. More hopeful is recent research into the use of "cellulosic" ethanol from switch grass or sugar cane waste, because it can grow in less fertile soil and requires fewer energy inputs.
However, land requirements are still large, and significant energy is required to convert the biomass to ethanol. Weisz notes that the net energy production of solar to biomass (via photosynthesis) to fuel is about two orders of magnitude less than direct conversion of solar to energy through photovoltaics. In summary, small-scale use of biodiesel from recycled waste product can be an economic gasoline substitute. But large-scale crop growing dedicated to producing biofuels is probably not a best use of resources. So far, the return on energy for biofuels production is marginal to negative. In addition, the

external costs of soil erosion and groundwater mining must be considered, as should the opportunity cost of using farmland to grow oil instead of food.

Hydrogen

The future "hydrogen economy" has been highly touted as the replacement to the oil economy in the popular press. But its debut keeps receding into the future. No one is realistically expecting affordable hydrogen cars before 2020 or 2030. In addition to the safety and storage issues, switching transportation to hydrogen would require a complete rebuilding of our auto, pipeline and fuel station infrastructure. Beyond that, it's not clear where the hydrogen would come from. There are no naturally occurring deposits of elemental hydrogen. It must be separated from compounds where it has bonded with other elements. The preferred source of hydrogen is a fossil fuel - natural gas (methane, CH_4) - which yields four hydrogen atoms for every carbon atom. Recently, however, natural gas has become so scarce and expensive in the U.S. that refineries have turned to coal gasification to produce hydrogen. Hydrogen can also be obtained by electrolyzing water, but the energy required to split the H_2O molecule is greater than the energy delivered by the hydrogen, so the process is a net energy loss. Therefore, hydrogen should not be thought of as a fuel source itself, but as a carrier or storage medium for energy from other sources. There is already a billion dollar/year market for hydrogen to make fertilizer and upgrade heavy oil in petroleum refineries. As conventional oil peaks, demand for hydrogen to synthesize light oil from heavy oil and oil sands will soar. This in turn will increase demand for natural gas as a source for the hydrogen.

Energy Return on Energy Invested (EROEI)

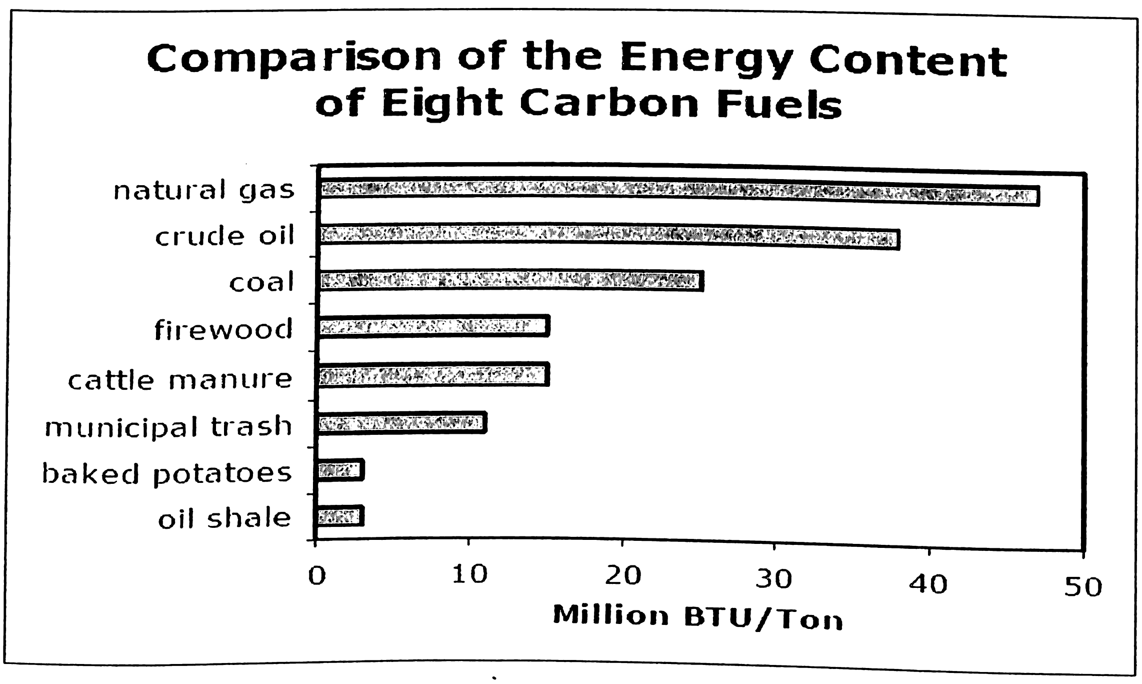
There are many factors that should be considered when evaluating substitute fuels. The governing economic reality is that producer costs must be less than consumer costs. Another critical question is: How much energy is delivered to society versus consumed in the activity of producing each unit. This difference is net energy, also expressed as energy return on energy invested or EROEI.

Predictably, the EROEI for oil has diminished over time. Hall and Cleveland note that in

1930, oil's EROEI was around 100:1, meaning that 100 units were delivered for every unit expended in finding and producing it – a net gain of 99 units of energy. By 1970, the EROEI had fallen to 25:1; Today it can be as low as 3:1 for deepwater production. By comparison, EROEI for the Canadian oil sands is about 1.5:1, giving a net gain of only 0.5 units. When EROEI reaches 1:1, production of a resource is no longer useful from a net energy perspective. Each unit of energy produced must be reinvested in producing the next unit. When the ratio is less than 1, obtaining the resource is a net energy loss. For example, the EROEI of corn ethanol is about 1:1.3. Even if net energy is positive and the alternative fuel can be produced without a financial loss, it won't have the same energy content as a barrel of oil. Energy density determines how much work a fuel can do.

Thus, it will take 1.55 times more ethanol than gasoline to drive 100 miles. Steve Andrews and Randy Udall compiled the following energy density reference chart:

Figure 10



Source: Modified from Andrews and Udall (2005).

Although nothing can truly substitute for oil's current role in our economy, alternative fuels will increasingly be used to synthesize or replace oil in the future. This will help compensate for oil depletion, but it won't allow overall oil consumption to increase. The alternatives can't scale to replace current rates of production, much less the expanded rates needed for growth. All involve paying a higher cost and greater inconvenience to obtain a lower net energy. All are limited in their delivery rates, require large and limiting inputs of other natural resources (land, water, natural gas, etc.) to produce, and create significant environmental impacts from mining, waste disposal or carbon release.

There are no cheaper surrogates to substitute into. Aside from EREOI, the economic impacts of higher energy prices to consumer and producer prices must be taken into account. At a higher price for lower-energy substitutes, people will be much less satisfied than they were with cheap oil.

Technology to the Rescue

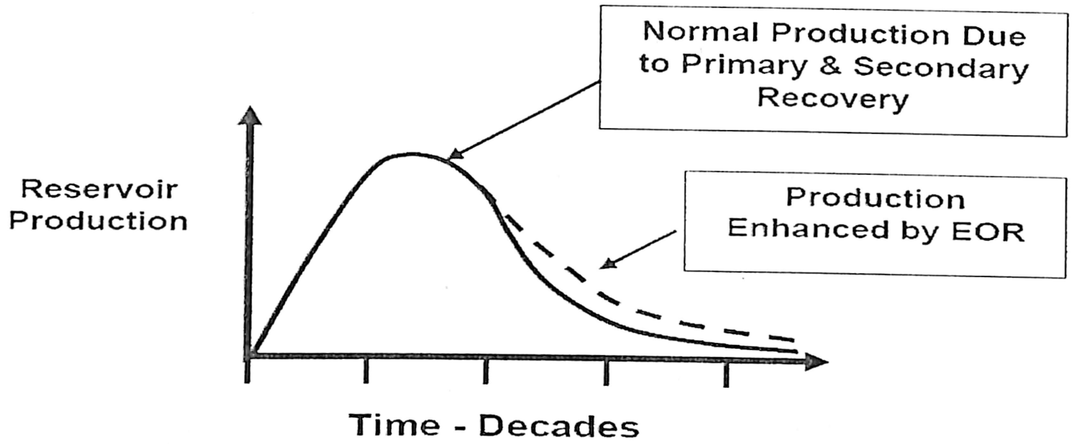
Optimists argue that Peak Oil will not be a great problem, because technological innovation will help find and develop new energy sources and make the old ones more efficient. They point to the exponential growth in technological advances over the past century, from horseless carriages and polio vaccines to space travel, genetic engineering and nanotechnology. Undoubtedly there will be significant technological breakthroughs in the years to come. But technology requires time, substantial capital and energy to develop. Consider any of the lifestyle-altering technology of the last century, such as cars, planes, computers, or the internet. Realistically, each took 20 to 30 years, or more, to move from idea through research and development to application to widespread adoption. So, a prudent manager will not rely on technologies that have not yet been conceived or proven to rescue them from a liquid petroleum gap over the next 20 years.

Improved Oil Recovery

Management of an oil reservoir over its multi-decade life is influenced by a range of factors, including 1) actual and expected future oil prices; 2) production history, geology, and status of the reservoir; 3) cost and character of production enhancing technologies; 4) timing of enhancements; 5) the financial condition of the operator; 6) political and environmental circumstances, 7) an operator's other investment opportunities, etc.

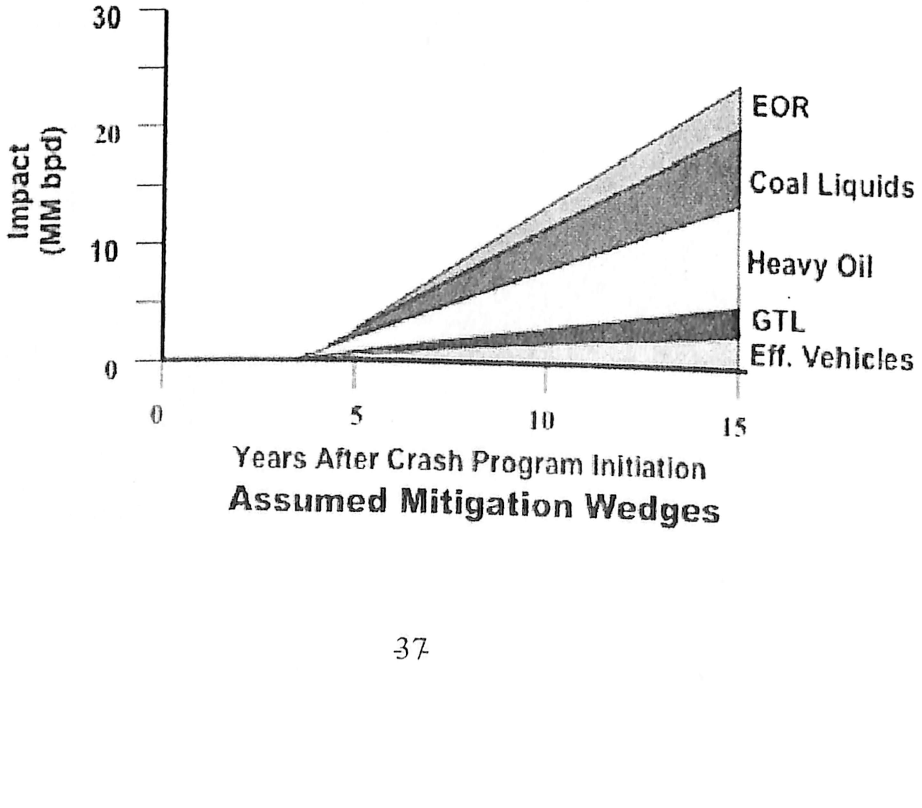
Improved Oil Recovery (IOR) is used to varying degrees on all oil reservoirs. IOR encompasses a variety of methods to increase oil production and to expand the volume of recoverable oil from reservoirs. Options include in-fill drilling, hydraulic fracturing, horizontal drilling, advanced reservoir characterization, enhanced oil recovery (EOR), and a myriad of other methods that can increase the flow and recovery of liquid hydrocarbons. IOR can also include many seemingly mundane efficiencies introduced in daily operations. IOR technologies are adapted on a case-by-case basis. It is not possible to estimate what IOR techniques or processes might be applied to a specific reservoir without having detailed knowledge of that reservoir. Such knowledge is rarely in the public domain for the large conventional oil reservoirs in the world; if it were, then a more accurate estimate of the timing of world oil peaking would be possible. A particularly notable opportunity to increase production from existing oil reservoirs is the use of enhanced oil recovery technology (EOR), also known as tertiary recovery. EOR is usually initiated after primary and secondary recovery have provided most of what they can provide. Primary production is the process by which oil naturally flows to the surface because oil is under pressure underground. Secondary recovery involves the injection of water into a reservoir to force additional oil to the surface. EOR has been practiced since the 1950s in various conventional oil reservoirs, particularly in the United States. The process that likely has the largest worldwide potential is miscible flooding wherein carbon dioxide (CO2), nitrogen or light hydrocarbons are injected into oil reservoirs where they act as solvents to move residual oil. Of the three options, CO2 flooding has proven to be the most frequently useful. Indeed, naturally occurring, geologically sourced CO2 has been produced in Colorado and shipped via pipeline to west Texas and New Mexico for decades for EOR. CO2 flooding can increase oil recovery by 7-15 percent of original oil in place (OOIP). Because EOR is relatively expensive, it has not been widely deployed in the past. However, in a world dealing with peak conventional oil production and higher oil prices, it has significant potential. Because of various cost considerations, enhanced oil recovery processes are typically not applied to a conventional oil reservoir until after oil production has peaked. Therefore, EOR is not likely to increase reservoir peak production. However, EOR can increase total recoverable conventional oil, and production from the reservoirs to which it is applied does not decline as rapidly as would otherwise be the case. This concept is notionally shown in Figure 11.

Figure 11. The Timing of EOR Applications



None of the alternatives discussed in this chapter is a silver bullet that can kill the oil supply/demand gap. But many of them could reduce the gap and collectively, with sufficient time, they might be able to fill it. In 2005 study by Hirsch, et al, used a "wedge analysis" approach to examine how quickly various mitigation measures – enhanced oil recovery (EOR), coal, heavy oil, gas-to-liquids (GTL), and efficient vehicles – might be able to realistically replace oil demand (Figure 12). The report postulates that mitigation efforts initiated at least 20 years ahead of Peak Oil could potentially align future supply with demand. But a significant supply shortfall would arise if mitigation efforts were started with shorter lead time.

A



B

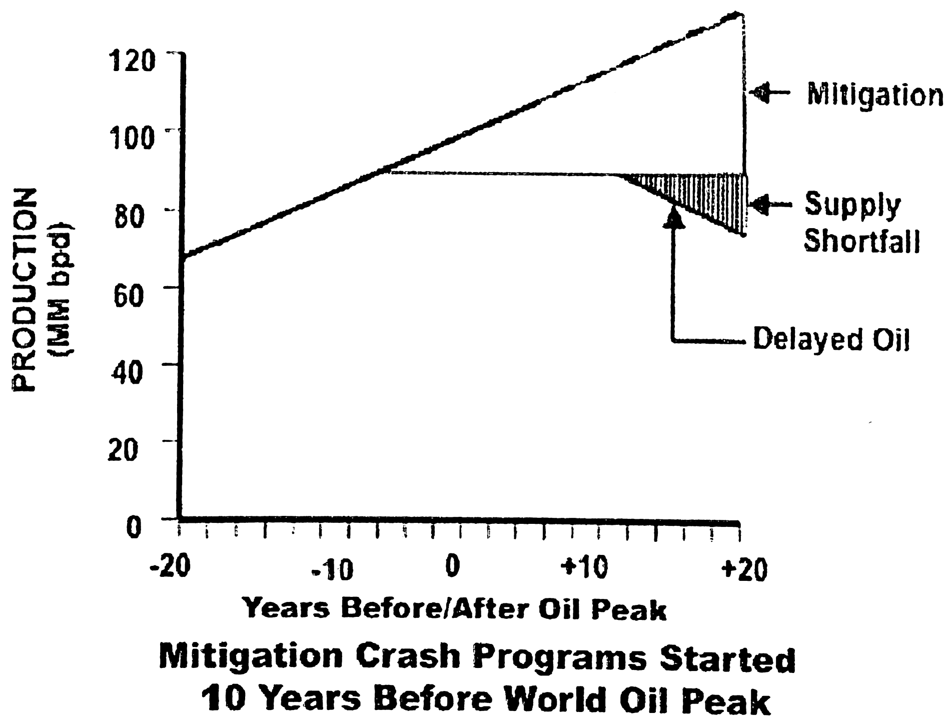


Figure 12. Mitigation "wedge analysis" showing A) the potential contribution of various oil replacement options for the first 20 years after initiation, and B) the supply shortfall that will result if mitigation not initiated until 10 years before world oil peak.

CHAPTER 6
SHIFTING TO REDUCED PETROLEUM ECONOMY

Why a gaming exercise to examine possible peak oil responses? It's a time-honored way to play out what-if scenarios without suffering any real consequences. Many government agencies, companies and even cities routinely play out emergency response scenarios. For this strategic management exercise, I've taken a simple game theory assessment approach. First, I designate a set of possible underlying "states of nature" with their probability of occurrence. I identify the players, the stakes (plausible outcomes or "pay-offs"), the rules, and the preferred outcomes. Next, I examine a variety of tactics that players could select to achieve their objectives. Then, I consider four obvious strategic approaches that could be chosen to transition from an oil-based economy, comparing their probable outcomes, desirability and risks, and selecting the approaches most likely to succeed. Lastly, I analyze some of the factors that could cause even the best approaches to fail.

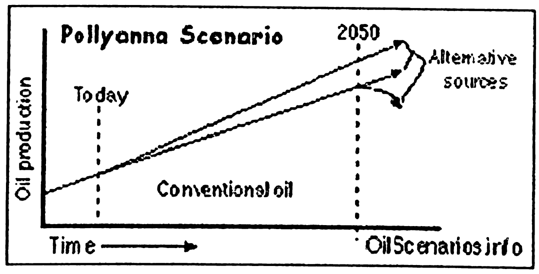
Identifying the "States of Nature"

Figure 13, reproduced on the next two pages, shows five schematic cartoons from the "Oil Scenarios" website that summarize the range of opinions on the availability of remaining world oil supply. Let's consider these five scenarios the possible "States of Nature" – the underlying, but unknowable geological endowment of recoverable oil that will govern the timing of world oil production peak. Only one scenario represents the actual situation, but we can't be certain which it is.

Figure 13. "States of Nature": Five peak oil scenarios (A-E) represent the range of opinion on the peaking date for conventional oil production, the steepness of the decline, and the extent to which other sources will provide alternative oil.

Source: Oilscenarios.info website.

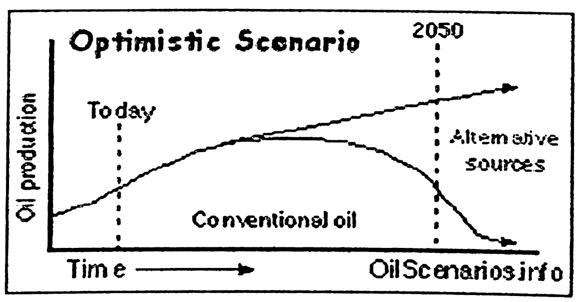
A.



Pollyanna Scenario

Oil production can be increased to meet all future demands for at least 40 years

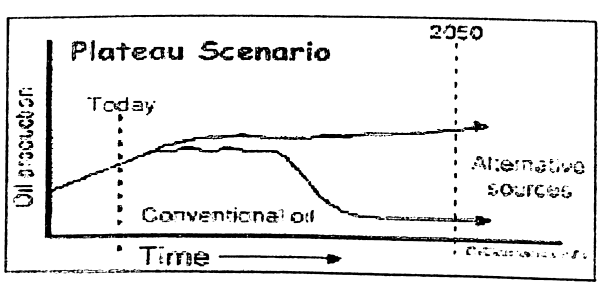
B.



Optimistic Scenario

Oil production in combination with conservation and alternative resources can meet the growing demands of society for the foreseeable future

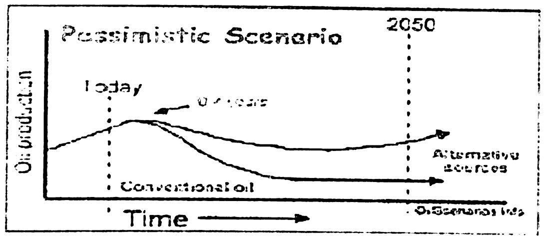
C.



Plateau Scenario

Fossil fuel production will plateau in the next decade resulting in a volatile energy market and restricted world economy however people will be able to adapt lifestyles to the changing energy environment

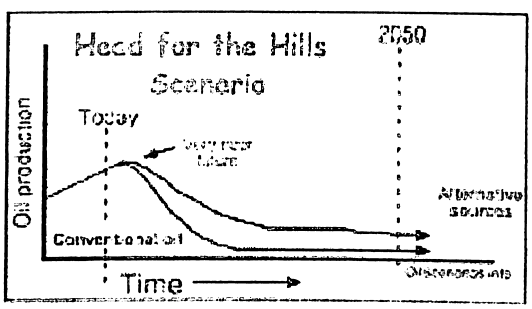
D.



Pessimistic Scenario

Oil production will not meet demand, forcing conservation and alternative energy use over the next decade however total energy resources will still decline slowly resulting in a gradually retracting world economy

E.



Head for the Hills Scenario

Oil production will peak and decline rapidly in the near future resulting in widespread energy shortages resulting in catastrophic collapse of many elements of modern society due to our lack of preparation

Probability of Occurrence

In my opinion, most evidence in the public domain supports the Plateau, Pessimistic, or Head-for-the-Hills scenarios. Therefore, I have ranked the probabilities of occurrence for the various states of nature as follows: A) Pollyanna – 4%; B) Optimistic – 12%; C) Plateau – 30%; D) Pessimistic – 40%; and E) Head-for-the-Hills – 14%. The reader may adjust the probabilities to reflect their own assessment. Such changes of a priori assumptions could provide input to further research and another academic paper. But for this paper, I assume the probabilities above.

The Players: Oil Haves, Heavy Users and Have-Nots

The geopolitical distribution of the remaining oil differs markedly from the distribution of its heaviest users (Table 4). Therein lies the motivation for much of the foreign policy and real war that has characterized the last century. More than half of the countries that are heavy oil users are also net importers. The U.S., an Oil-Have that is the heaviest user of all, imports more than 60% of its daily needs. Therefore, it will increasingly play the game from the perspective of a Have-Not. Clearly, China will be playing the transition endgame as a Have-Not, too.

Table 4

OIL ENDGAME - THE MAJOR PLAYERS

THE HAVES Top 15 Oil Reserve Countries			THE HEAVY USERS Top 15 Oil Consumers*			
2004 Data	Reserves Billion bbl	% Total		Daily MBD	Annual Billion bb	% Total
Saudi Arabia	262.7	22.1%	USA	20.5	7.5	25.4%
Iran	132.5	11.1%	China	6.7	2.4	8.3%
Iraq	115.0	9.7%	Germany	2.6	1.0	3.3%
Kuwait	99.0	8.3%	Russian Federation	2.6	0.9	3.2%
United Arab Emirates	97.8	8.2%	India	2.6	0.9	3.2%
Venezuela	77.2	6.5%	South Korea	2.3	0.8	2.8%
Russian Federation	72.3	6.1%	Canada	2.2	0.8	2.7%
Kazakhstan	39.6	3.3%	France	2.0	0.7	2.4%
USA	29.4	2.5%	Mexico	1.9	0.7	2.3%
Canada	16.8	1.4%	Italy	1.9	0.7	2.3%
Qatar	15.2	1.3%	Brazil	1.8	0.7	2.3%
Mexico	14.8	1.2%	United Kingdom	1.8	0.6	2.2%
Brazil	11.2	0.9%	Saudi Arabia	1.7	0.6	2.1%
Norway	9.7	0.8%	Spain	1.6	0.6	2.0%
United Kingdom	4.5	0.4%	Iran	1.6	0.6	1.9%
Total Rest of World	190.9	16.1%	Total Rest of World	27.1	9.9	33.6%
TOTAL WORLD	**1188.6**	100.0%	**TOTAL WORLD**	80.8	29.5	100.0%

*Heavy Users may be Oil-Haves (Shaded) or Have-Nots

All Data from BP Statistical Review 2005
OPEC reserves not discounted

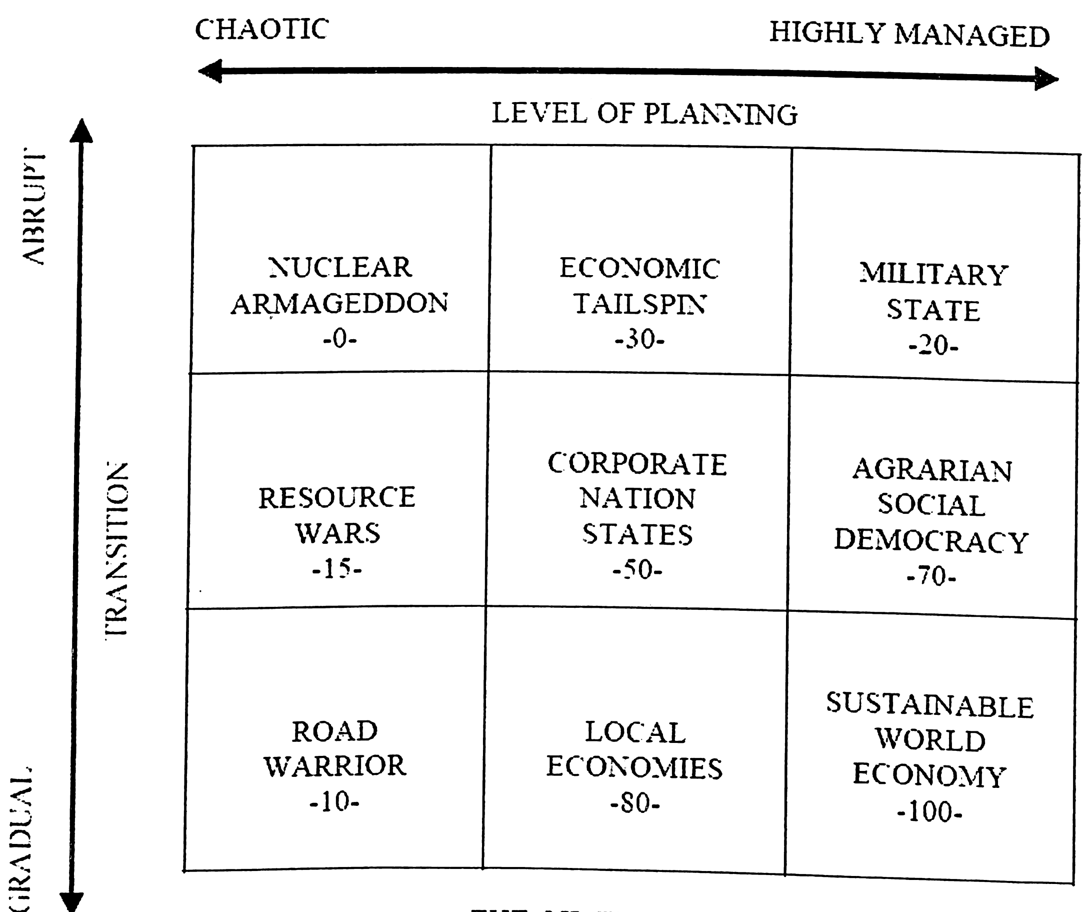
Source: British Petroleum

The Oil Endgame pits Oil-Haves against Heavy Users. Shaded countries have significant reserves, but also heavy consumption. They must balance the revenue benefit of exports with the need to provide oil for their own populations. Heavy Users that are net importers, like the U.S., will play the game as oil Have-Nots. Note that OPEC countries contain 75% of the reported reserves.

The Stakes: A Matrix of Plausible Outcomes

Figure 14 presents an array of speculative outcomes to the Peak Oil endgame. The envisioned outcomes are intentionally extreme to make the contrasts between them starker. But all have analogs in history or have been played out in speculative fiction.

Figure 14. The outcomes are scored on a subjective scale of relative desirability from 0 (low) to 100 (high).



THE OIL ENDGAME:
A MATRIX OF PLAUSIBLE OUTCOMES

Outcomes are sorted on the x-axis based on the degree of transition planning, which could range from zero (chaos/collapse) to a highly managed transition into a reduced petroleum economy. The Y-axis portrays the transition time allotted to prepare for life on the downward side of Peak Oil, which ranges from abrupt (little to no warning) to gradual (20-30 years preparation time, whether wisely used or not). The stakes are high. Extreme negative outcomes are possible, including nuclear obliteration, or collapse of civilization and a return to a pre-industrialized standard of living. Less severe, even positive, outcomes are also possible. At the positive extreme, the transition from fossil fuels is consciously managed to achieve a sustainably high standard of living for a majority of the world's people.

Preferred Outcomes

Saddle point of matrix (3x3) taking row minima and column maxima is 15 so there is no need of applying rule of dominance. Value of game is 15 which tells that the transition time allotted to prepare for life on the downward side of Peak Oil, which ranges from abrupt (little to no warning) to gradual, which is on y axis will leads to Sustainable World Economy as optimal strategy and the degree of transition planning which could range from zero (chaos/collapse) to a highly managed transition into a reduced petroleum economy, which is on x axis will leads to Nuclear Armageddon as optimal strategy.

These are not the only possible outcomes and the reader is invited to substitute different visions. The point is that some of the outcomes (e.g., Nuclear Armageddon, Military State, Resource Wars and Road Warrior) are highly undesirable and, in my opinion, should be avoided at all costs. However, these destructive outcomes are quite possible under either abrupt or unplanned (chaotic) transitions. The abrupt outcomes (Armageddon, Economic Tailspin, and Military State) are inherently unstable and would eventually devolve to other outcomes. Quasimanaged options (Economic Tailspin and Corporate Nation State) involve significant hardship and financial insecurity and portend the end of the Middle Class. The most satisfactory outcomes (Sustainable World Economy, Local Economies, and Agrarian Social Democracy) are achievable options only with sufficient transition time and focused preparation.

Chaotic/Collapse Outcomes

Nuclear Armageddon: Also known as "Last Man Standing" or "If I can't have it, you can't either", one of the have-not superpowers (e.g. U.S. or China) or a "rogue state" (e.g. Pakistan or Korea) exercises the nuclear option to prevent others from access to oil resources. This brings the game to an abrupt end.

Resource Wars: Code-named "War that will not end in our lifetime", increased competition for remaining petroleum supplies leads to a perpetual state of proxy wars, direct military intervention/occupation, and escalating terrorism until recoverable supplies are exhausted, or simply no longer worth fighting for.

Road Warrior: As petroleum supplies become increasingly scarce, civil society breaks down into tribal units scrambling to stay alive and defend their hoarded resources from marauders.

Semi-Chaotic to Quasi-Managed Outcomes

Economic Tailspin/Global Recession: The sudden and unforeseen onset of oil supply shortages undermines the economy, leading to price spikes, fuel delivery disruptions, reduced GDP, spiraling petroleum import deficits and a dollar crisis. Periods of nflation/hyperinflation alternate with recession/depression. A global recession ensues.

Corporate Nation-States: Under this variation of Return to Feudalism, arable land and resource ownership ends up concentrated in a small group of elites or companies. Everyone else works for them as tenant farmers, indentured laborers, or soldiers, in return for income or basic necessities and protection.

Local Economies/Community Solutions: Intentional communities develop around local agriculture, supporting local businesses and reaching decentralized agreements on resource usage and group governance. They concentrate on energy efficiencies and micro power to maintain a decent standard of living in a supportive social network. Interaction with the outside world is via telecommuting and mass transit.

Highly Managed Transition Outcomes

Military State: Due to oil shocks and supply disruptions, the government declares a state of emergency, imposes rationing and curfews and severely restricts movement of the population. Military police (or contract security) quell periodic civil uprisings. Picture New Orleans in the aftermath of Hurricane Katrina, but without the flooding.

Agrarian Social Democracy: A centralized planning decision directs a society-wide effort and national resources towards feeding the population. A significant portion of the population becomes farmers. Land ownership and farm operations are scaled to a low-energy, community level with significant participation of individuals in local decisions and governance (e.g., post-Soviet Cuba rather than the failed Soviet socialist model of huge collective, highenergy- input farms).

Sustainable World Economy: A full-scale, international cooperative effort is implemented to dramatically reduce energy consumption, enhance technological efficiencies and develop renewable energy sources and alternatives. The mitigation actions are initiated early enough to prevent severe energy disruptions and hardship. The world population stabilizes at a high level of sustainable human welfare.

CHAPTER 7
NEED OF STRATEGIC ACTIONS

The first thing is simply to inform yourself and make up your own mind on the above situation. The above is an analysis of the situation, but there are a lot of opinions! There are, for example, significant unknowns in both the timing and likelihood of events, so whether these are things to do today – or have in mind for the next five years or more no one really knows. It is better to be aware and forearmed.

What Can Individuals, Groups, Companies, Administration Do?

Individuals

This is a short-term list:

- be prepared to move investments into funds less affected by an oil driven economic owntum (these might be raw commodities), and visa versa in the up turns.
- consider every option for reducing usage of any form of energy, in particular that derived from oil and gas (home insulation, low power lights, solar water eating...)
- plan a low-energy lifestyle / business operation (avoid a lifestyle that requires a lot of travel)
- minimize any loans – but preferably get rid of them
- aim to increase the local element of your lifestyle / business – reduce travel, use local resources and facilities
- minimize exposure to the property market
- look for business / personal opportunities that will arise from energy shortage implement energy saving policies
- maximize use of renewable energy

- make provisions for supply interruptions including power, food and water

Companies

There are both strategic and tactical issues companies should consider. Many of the points made for individuals apply, however in addition:

- assess supply chain sensitivity to energy costs (transportation, energy sensitivity of suppliers)
- assess customer (both business and individual) sensitivity to energy costs
- diversify business operations to build resilience by balancing energy-sensitive operations with less sensitive ones
- establish means of reducing inter-office travel
- reduce individual commuting
- establish an energy efficiency strategy and monitor progress

Governments & Administrations

Geller has addressed energy policies in considerable detail – however it is fair to say that this was against a backdrop of global warming rather than energy shortage. The main points for a large economic region are:

- set up the market to encourage the development of diverse energy supplies (including renewables, nuclear and clean-burn coal) – in particular from domestic sources
- actively disadvantage oil and gas or, at least, put renewables on a level playing field.
- establish economic mechanisms to manage carbon based energy usage (the most ell developed one being Domestic Tradeable Quotas or DTQs)
- lead by example – reduce administrative energy demands and use the enormous purchasing power of public bodies to create demand for renewable energy
- focus heavily on energy efficiency – the return per $€£ invested is much greater than any other investment

- pro-actively drive research and development into new energy sources and energy conservation
- put in place policies that favour public transport and discourage individual transport
- educate the public & businesses - be open about the energy position
- re-align agricultural policies along low-fossil fuel input and sustainable lines
- avoid a proliferation of energy quangos and NGOs – but set up a clear set of energy focused departments within government operations
- work closely with markets, banks and investment managers to handle the impact of fluctuations in global energy prices
- assess the impact of increased energy costs on the economy – for example reductions in holiday visitors – increases in the cost of importing and exporting goods.
- reduce dependence on long-distance economic activity – e.g. encourage domestic production and localisation
- collate information on energy resources – both nationally and internationally – collect systematic information on the true oil reserve situation
- establish policies to discourage population growth
- pro-actively work on international cooperation on energy resource management and energy solution development – e.g. sign and follow the 'Rimini Protocol' so as to cut imports to match world depletion rate

Tactics are specific actions, or tools, which players have at their disposal to implement their strategic approaches to a problem. This chapter considers the most obvious types of tactics that might be employed within different sectors to advance diverse objectives in the oil endgame and to reduce sector exposure to peak oil impacts during the transition to a reduced petroleum economy. The range of tactics available are encompassed by:

1) **the free market** - passive action;

2) **government action** - centralized decisions to intervene through military action, policy, or spending;

3) **private sector action** - decentralized investment decisions and voluntary behavior changes by businesses and individuals taken to benefit the entity; and

4) **collective action** – community or societal actions taken to benefit the members of the group and ensure its survival.

Table 5

Potential Strategic Actions (Endgame Tactics) Available to the Different Sectors

MAR-KET	M-1	Let Market Pricing Equilibrate Supply and Demand
GOVERNMENT	G-1	Governments Secure the Oil - Nationalization - Trade and Development Agreements - Military Threat or Intervention
	G-2	Market Interventions - Price Caps - Rationing - Fuel Consumption Taxes - Subsidies and Incentives - Fiscal Policy
	G-3	Spending on Research & Development and Infrastructure
	G-4	Policy and Law - National Energy Policy - International Cooperation Policies
PRIVATE SECTOR	P-1	Protect Self Against Short-Term Price and Supply Shock
	P-2	Shift Values Towards Sufficiency & Long-Term Sustainability - Conservation/Reuse - Best Use of Finite Resources - Shift Investment Dollars - Renewable Energy, Education
SOCIAL GROUP	S-1	Reinforce Community Values by Exerting "Norming" Pressure
	S-2	Leverage Resources

CHAPTER 8
Effects on global market- What could possibly go wrong

How Will Peak Oil Affect The Global Economy?

Well the honest answer is no one ***really*** knows although the projections from those that have looked at it are not overly optimistic (and that is a euphemism). Current economic theory is based on growth and, ultimately, unlimited resources or substitutes for these resources. Traditional market economics assumes that if there is a shortage of something, the price increases until demand is dampened. However the increased price triggers more investment, which increases supply and thus prices fall. Things are thus kept in balance - so, in summary it has the view that:

economic 'stability' = economic growth = more energy each year.

However this assumes that you can produce more by investing more. This rule doesn't apply to limited natural resources as no amount of investment will deliver something that isn't there. Substitutes can be made. In terms of energy we have moved from wood, to coal and to oil and gas. Each step has forwarded industrialization as it employs a more concentrated and flexible energy source. After oil and gas there isn't an obvious step, no clear alternative, unless one considers nuclear power. If there were a clear alternative to oil and gas then market economic theory would still apply. But there isn't as far as anyone can see – and many have looked – so this does bring into question the applicability of the current market economic model when presented with shrinking resources. In practice much of the West (Europe in particular) has managed with modest energy consumption increases – whilst still raising GDP. The 'energy intensity' of the European economic activity has been falling. However this has largely been through the loss of high-energy industries (such as steel making) to emerging economies. The latter tend to be less energy efficient anyway and the overall effect is much the same in that global economic growth requires increasing energy consumption.

There are many people who are aware of this issue including university professors, senior petroleum geologists, commodity traders and energy experts. Some have done their own analysis on what will happen when oil production peaks. Broadly it is agreed that falling oil supply means economic recession. The other broad agreement is that it won't be a smooth ride. There are likely to be a number of 'oil crises' each creating a recession and reduction in demand, which will then be followed by falling prices leading to brief resurgence until supply limitations are hit again. Each oil crisis could be caused by terrorism, politics, war or production limitations. So, for a while the economic outlook will be rocky with no net growth or shrinkage then, once basic supplies really start to fall, largely downhill all the way, with brief ups as we go.

The broader consequences of this are so far-reaching that it is impossible to go into any depth here. A simple statement of the possible consequences sounds a bit like predicting the end of civilization – something that can't really be done in a few sentences. Also, no one knows what will happen. There are a few observations one can make though, under the following headings:

- Globalized economies
- Food production & costs
- Third World
- World domination & energy
- Transportation
- Money and debt
- Financial systems
- Domestic resources
- Complexity

A **globalised economy** requires cheap transportation. Unless oil can be replaced rapidly as supplies decrease then globalisation will necessarily go into reverse. People and goods simply will move less. They have to. It isn't a price issue – there is simply less oil so there must be less transport. Increasing efficiencies and substitute energy will offset the decline to some degree, however to increase efficiency requires replacement of inefficient transportation – and the new transportation takes energy to create. So this won't be an overnight switch.

The current high-volume **food production** system employs oil and gas to farm, produce fertilizers and pesticides, irrigate and distribute. Calculations show that (in the USA) each kcal of food uses 10 kcals of fossil fuel energy to produce. Non-US production methods may be less intense but will follow a similar pattern. Clearly, with this dependency, without using oil or gas we can't sustain the current world population. Certainly increasing oil costs will push up food costs and result in less production. The hardest hit are likely to be **Third World** countries now dependent on cheap volume food from the USA. An increasing proportion of human effort and oil resources will need to be invested in food production, and food production will need to be increasingly local as transportation costs increase. More radical moves to organic based production would also reduce the amount of oil and gas required to produce the same amount of food.

Today **global domination** (currently by the USA) requires access to large amounts of energy – essentially to power and move around a large fighting force. Furthermore the central position of oil in the operation of the international economy (especially as it affects the USA as oil is currently traded in $) means that reductions in supply – and changes in how it is traded – will have a significant impact on US global influence. There are all sorts of potential outcomes. For example, the USA could embark on an outright military takeover of key oil sources. US trade imbalances will only contribute to instability in the event oil production peaks and prices rise.

About 90% of all **transportation** is powered by oil. There are alternatives (bio-diesel, electric vehicles) and clearly many railways operate on electricity. Cars can be made a lot more efficient – especially in the USA. However there is a limit to how far you can go with efficiency and how fast the changeover can be made to more efficient vehicles. Production of bio-fuels is also limited. Calculations show that pretty much the entire agricultural land of the UK (irrespective of current use and suitability) would be needed to grow enough bio-diesel to meet just current UK diesel fuel needs. A similar calculation shows that we would need to build 50 nuclear power stations to produce enough hydrogen for UK transportation. Realistically, however, it would be possible to 'grow' enough fuel for 10% of current needs and generate enough hydrogen for another 10% - but nuclear power stations do take 10-15 years from inception to production. There is no obvious solution for air transport. In general then it seems highly likely that individual transport and air transport will become increasingly expensive and less common once oil supplies start to fall.

Based on reactions from economists it doesn't seem that there are any tools to manage a shrinking economy over the long term. The current primary economic tool, interest rates, is targeted at controlling **money supply** to manage inflation within an expanding economy. If inflation increases, the banks put up interest rates. However this works on the theory that banks need to match the amount of money in circulation to the size of the economy – and since the latter is growing modest inflation is acceptable and leads to a gradual increase the amount of money in circulation. But if the supply of a key primary resource starts to fall its price will increase leading to inflation and recession. It is likely that banks will be stuck between a rock and a hard place. Whilst raising interest rates will deflate the economy (by pumping money from those with loans to those with investments) it is also likely to worsen the recession and lead to deflation.

The World's **Financial Systems** rely on the issuance of currency against, essentially, a future 'promise to pay'. The USA is both central to World economy and typical in issuing government bonds – essentially loans. It is not clear that using money based on these loans will continue to be viable. At present oil, US Government Bonds, Dollars and Debt are on a sort of merry-go-round. As oil becomes scarce it increases in price in $ terms. This pumps more revenue out of the USA increasing its debt. This money is created by the US government issuing bonds that are bought by foreign national banks – and the US Dollars issued to the oil producers are re-invested in the USA. With spiralling oil prices this process cannot go on for ever. A failure to sell bonds would cause the World's reserve currency, the $, to collapse. The USA shows no signs of restraint and there appears to be no viable exit route from this cycle (which is more complex than this summary implies). If and when this does stop there could therefore be major international financial and economic disruptions – and any form of continuing economy will probably require a different mind-set and very different economic tools.

There is an overall trend throughout the world towards **globalisation** and increasingly complex economies and societies. Globalisation itself requires communication – both physical transportation of goods, cultures and ideas (through people movement) and information (mostly electronically). With low cost energy we can afford to have all this communication – and afford a huge diversity of solutions. Solution development also is aided by low cost access to a global market, which allows investment to be spread over a greater customer base. Increase the cost of and reduce access to energy, and the overall level of all forms of communication will fall – with the possible exception of electronic communication. It will also become more expensive to bring new ideas and solutions to market – so there will be fewer buyers – more losers and less diversity. Solutions will take longer to develop due to smaller markets and a longer return on investment. The overall upshot is **simpler solutions** an increased reliance on **domestic production, resources** and general communication – and a reduction in diversity and rate of change. Very simply it will be like going backwards in time in some ways.

CHAPTER 9
FINDINGS AND SUGGESTIONS

This analysis leads to the following findings and final thoughts.

World Oil Peaking is Going to Happen

World production of conventional oil will reach a maximum and decline thereafter. That maximum is called the peak. A number of competent forecasters project peaking within a decade; others contend it will occur later. Prediction of the peaking is extremely difficult because of geological complexities, measurement problems, pricing variations, demand elasticity, and political influences. Peaking will happen, but the timing is uncertain.

Oil Peaking Presents a Unique Challenge

The world has never faced a problem like this. Without massive mitigation more than a decade before the fact, the problem will be pervasive and will not be temporary. Previous energy transitions (wood to coal and coal to oil) were gradual and evolutionary; oil peaking will be abrupt and revolutionary.

The Problem is Liquid Fuels

Under business-as-usual conditions, world oil demand will continue to grow, increasing approximately two percent per year for the next few decades. This growth will be driven primarily by the transportation sector. The economic and physical lifetimes of existing transportation equipment are measured on decade time-scales. Since turnover rates are low, rapid changeover in transportation end-use equipment is inherently impossible.
Oil peaking represents a liquid fuels problem, not an "energy crisis" in the sense that term has been used. Motor vehicles, aircraft, trains, and ships simply have no ready alternative to liquid fuels. Non-hydrocarbon-based energy sources, such as solar, wind, photovoltaics, nuclear power, geothermal, fusion, etc. produce electricity, not liquid

fuels, so their widespread use in transportation is at best decades away. Accordingly, mitigation of declining world oil production must be narrowly focused.

Both Supply and Demand Will Require Attention

Sustained high oil prices will stimulate some level of forced demand reduction. Stricter end-use efficiency requirements can further reduce embedded demand, but substantial, world-scale change will require a decade or more. Production of large amounts of substitute liquid fuels can and must be provided. A number of commercial or near-commercial substitute fuel production technologies are currently available, so the production of large amounts of substitute liquid fuels is technically and economically feasible, albeit time-consuming and expensive.

It Is a Matter of Risk Management

None of the alternatives discussed in this chapter is a silver bullet that can kill the oil supply/demand gap. But many of them could reduce the gap and collectively, with sufficient time, they might be able to fill it. The 2005 DOE study by Hirsch, et al, used a "wedge analysis" approach to examine how quickly various mitigation measures – enhanced oil recovery (EOR), coal, heavy oil, gas-to-liquids (GTL), and efficient vehicles – might be able to realistically replace oil demand. The report postulates that mitigation efforts initiated at least 20 years ahead of Peak Oil could potentially align future supply with demand. But a significant supply shortfall would arise if mitigation efforts were started with shorter lead time.

Government Intervention Will be Required

Intervention by governments will be required, because the economic and social implications of oil peaking would otherwise be chaotic. The experiences of the 1970s and 1980s offer important lessons and guidance as to government actions that might be more or less desirable. But the process will not be easy. Expediency may require major changes to existing administrative and regulatory procedures such as lengthy environmental reviews and lengthy public involvement.

Economic Upheaval is Not Inevitable

Without mitigation, the peaking of world oil production will almost certainly cause major economic upheaval. However, given enough lead-time, the problems are soluble with existing technologies. New technologies are certain to help but on a longer time scale. Appropriately executed risk management could dramatically minimize the damages that might otherwise occur.

CHAPTER 10
CONCLUSION

It is by now obvious that world oil production faces serious constraints to expanding. Exploration and refining infrastructure is operating at capacity, yet it may not be profitable to invest in capital expansion. New oil discoveries have not offset the yearly depletion of existing fields since the 1980's. Whether or not world oil production will peak in 2005 or 2025 is not the critical question; we have already rolled over to a sellers' market because demand exceeds the rate at which oil can be supplied. With little sign of demand abatement from the US or Europe and skyrocketing demand from China and India, we are drawing down the capital of our oil endowment at an alarming rate. From this point onwards, we can expect supply disruptions, price spikes, and oil shocks. The petroleum-based world economy has therefore reached a tipping point. Fierce competition for the remaining oil resources will increasingly drive the markets, as well as national and foreign policies. The strategic choices we make now about how the 2nd half of the world's oil should be used will determine how violently and abruptly we descend Hubbert's Peak.

Since a finite resource problem cannot ultimately be solved from the supply side, we must use every tool at our disposal to reduce demand and develop substitute energy sources. Market pricing and oil shocks will undoubtedly play a significant role in demand destruction in the long run. But market solutions will exacerbate distribution inequity and political unrest by excluding all but the wealthy from oil. Cogent government energy policies to allocate oil and reduce demand will be required. The most effective are likely to include combinations of nonprice rationing, fuel consumption taxes, and incentives for conservation and alternative energy use.

However, the biggest hurdle to overcome in reducing oil consumption is human nature. Education and discussion of the issues surrounding peak oil are crucial if we are to manage our inevitable transition away from fossil fuels with any hope of preserving a civilized society. We must value the world's remaining oil resources as our primary, ever dwindling asset to build the bridge to the future.

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