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Running on Empty:
How Peak Oil Will Influence the Future Viability of the Canadian Armed Forces

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Abstract

The world demand for petroleum-based liquid fuels is increasing year over year to grow the economies of the industrialised world and feed the demands of the emerging economies. Oil production, however, will peak in 2020, and decline thereafter, resulting in a global shortage of the resource that fuels the economies of the industrialized world. The peak of oil production is referred to as Peak Oil and is widely referred to by doomsday prophesiers predicting an apocalypse in our lifetimes. This paper provides a more balanced and practical view of Peak Oil, and shows how the reality of future oil shortages must be addressed from a Canadian military standpoint.

The imbalance between supply and demand will generate pressures for industrialised nations struggling to maintain their economies, if not their very survival, and these pressures pose obvious risks of widespread regional conflicts and, potentially, war. Canada's armed forces have historically played a role in resolving international disputes and will most likely be involved in future conflicts as well. Peak Oil is approaching fast and today there is no adequate replacement for oil that provides the same energy return for energy invested, nor is one realistically foreseen. Oil, therefore, will be what fuels the military vehicles of the near future.

With increasingly expensive and limited fuel, Canada's military will need to be highly fuel efficient in order to make overseas military deployments viable. This paper argues that legacy military equipment must be made more fuel efficient and future procurements will require increased fuel efficiency to be a highly ranked requirement, on

par with both fighting ability and speed, to ensure the military is capable of deploying in the future.

Introduction

The peak of oil production, coupled with the forecast increase in world demand, necessitates decisions today in order to ensure the viability of future Canadian Forces operations. Over the past century, our lives have come to be defined by petroleum; it now pervades our lives. Oil, or something derived from it, is everywhere. Our cars and trucks are propelled with it; the roads are covered in it; the plastic signs on stores are made with it; even that Chicken McNugget, bought at the quintessential eatery of a globalized economy facilitated by cheap petroleum, contains it: tertiary butylhdroquinone – a form of butane.[1] Oil has facilitated the growth of vast industrialized farms, which are tilled by vehicles consuming it, enabling the production of enormous quantities of food in soil fertilized with chemicals derived from it, then brought to booming populations on vehicles propelled by it. Globalisation, lubricated with cheap oil, has generated a lifestyle that would have been impossible without it. Without it, Winnipeg would not have freshly-caught tuna and Toronto would not have fruit from Asia. China's massive manufacturing export industry would not exist on the scale it does today. Without cheap oil, modern militaries would not function, as they too rely on oil to propel the ships through the sea, the planes through the air and the vehicles to the battle. Oil has, unquestionably, created the industrialized world, and made mass production and consumption possible on a truly global scale.

There is no doubt that the demand for oil is increasing at an exponential rate as states such as China and India transition from predominantly agrarian to more

[1]Michael Pollan, *The Omnivore's Dilemma: A Natural History of Four Meals* (New York, New York: Penguin Books, 2007), 113.

industrialized economies. This demand will mean that oil production must be maintained at levels to not only permit the currently industrialized economies to grow, but also to power those developing economies. This increase in world demand and the forecast resultant fuel shortages will lead to world oil price increases. Increased costs may well result in militaries having to increase their budgets to acquire the needed fuel and lubricants which, in turn, necessitates planning by today's force development staffs to account for and provide fuel security.

This paper will be divided into three parts. Part One will deal with Peak Oil Theory and its relevance to oil security. Part Two addresses the difficulty industrialised states will have in preserving their current prosperity. Lastly, Part Three describes solutions that will make the Canadian Forces viable in the future.

Part One will commence with an analysis of the biotic and abiotic theories of oil origination and the validity of these theories, and will include an in-depth explanation of what Peak Oil is and how the theory is defined. This will include an examination of the Hubbert Curve, how it may be used to predict oilfields peaking, and an analysis of how the total sum of the world's oilfields relate to the overall peaking of oil resources. The Hubbert prediction for the Gulf of Mexico will be compared with more modern fields peaking in both Oman and the North Sea and this prediction will be extrapolated to predict future production in Saudi Arabia. How OPEC has inflated their reserve figures will be discussed when addressing various arguments for the date of oil peaking and why some arguments are more reliable than others will thus be illustrated. The Peak Oil date, for the purposes of this paper, will be determined using a wide range of sources. The difference between an “energy crisis” and a true “oil shortage” will be described and why the difference is pertinent to the planning measures required today.

Part One will conclude with a discussion of energy and a description of alternative energy sources that could be used in lieu of oil, such as ethanol and biodiesel. It will be further shown that popular theories suggesting that these sources can replace our current and future diesel and gasoline needs are not valid.

The relevance of Peak Oil to energy security will be discussed in Part Two of this paper as energy security is fundamental to the maintenance of an industrialised economy and is required to prevent collapse. This paper will highlight how states such as ours that rely on oil to fuel our place in the globalised economy and maintain our standard of living will be in greater competition with the emerging industrialised states for the same resources. This competition will lead to increased global instability and risk of conflict.

As a result of Peak Oil, Canada must put greater weight on the fuel efficiency of all new equipment and current fuel usage should be considered a capability deficiency that needs to be addressed. The increased risk of global instability and the need for a well equipped and capable armed force will be discussed. Due to the time lag between stating a requirement and the purchase of new equipment, and the length of time that new equipment will be retained for use by the military, force development considerations today have significant impact on a military’s capabilities well into the future.

Lastly, Part Three will argue that the capability deficiency extant today will, if not addressed, become even greater in the future due to the militaries of industrialised states becoming more heavily reliant on fuel with every new generation of vehicle. Fuel inefficiencies have caused problems in recent military engagements and examples will illustrate this trend. Solutions are being sought, mainly by the United States military. What has been done will be described to demonstrate where technological improvements are already well developed and where they are not. Furthermore, fuel efficiency is a significant capability for, without it, the equipment may be rendered useless for future Canadian Forces operations. Canadian procurement processes are lengthy and require forethought to ensure that the final product delivered meets the identified requirements. By using current complex procurement programmes and the length of time they take to reach completion, reasons for placing fuel efficiency as a fundamental requirement early on in a project will be provided. The cost of operations and the length of time Canada will be able to provide forces in theatre will be discussed. Examples of solutions that are currently available will be provided in this chapter.

Predictions about the peak of oil production, generally known as Peak Oil Theory, will be used to facilitate the discussion about considerations required today and will be defined later in this paper. The role of definitions in the prediction of oil scarcity or, indeed, in any discussion about oil, cannot be understated. It is often through the management or manipulation of definitions that conclusions are brought to defend either overly optimistic or pessimistic views. For this reason, this paper will dispense with the critical definitions here in the introduction. A definition of oil is required, as well as the terms “conventional” and “unconventional” as adjectives to define oil sources. Lastly the definitions of reserves will be provided: proven, probable and possible. The so-called 3-Ps are often used to muddy the waters of the oil debate and must be clearly understood.

Crude oil is a liquid petroleum hydrocarbon consisting of pentanes, a chain of five carbon atoms paired with twelve hydrogen atoms, from which diesel, gasoline and various other fuels as well as plastics are derived.[2] Oil is an extremely energy rich compound: for every calorie of energy put into its extraction and purification, many more calories of energy are available for use. In other words, it is a net provider of energy.

Conventional oil is easily defined as light to medium gravity hydrocarbons that occur in "porous and permeable reservoirs" and are of a viscosity to permit free-flow and pumping.[3] This is the oil that often comes to the mind of the layperson, often in the form of a tall black geyser bursting from the well head. Conventional oil is indeed the most sought after by geologists and oil companies. Unconventional oil, on the other hand, is not as easily defined. Unconventional oil is defined in this paper as a hydrocarbon that meets any of the following criteria: non free-flowing, oil that is heavier than water, occurs in tight formations such as shale or sand, recovered from the deep sea-bed or arctic waters, or is otherwise extremely expensive to extract or refine. The Canadian tar sands, for example, are defined here as unconventional due to the cost of recovery and its lack of viscosity.

The "three Ps": proven, probable and possible reserves, are defined by the oil industry and the owners of specific fields based on the best scientific guesses of the time, while also taking into account any need an oil company may have to modify the numbers for market reasons.[4] Proven resources (P1) are those with a ninety percent chance of

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[2]Centre for Energy, "Peak Oil," http://www.centreforenenergy.com/AboutEnergy/CanadianEnergy/Pricing/CrudeOil.asp; Internet; accessed 17 November 2009.

[3]David Greene, Janet Hopson and Jia Li, *Running Out of and into Oil: Analyzing Global Oil Depletion and Transitions Through 2050* (Oak Ridge, Tennessee: Oak Ridge National Laboratory, 2003), 7.

[4]Mathew R. Simmons, *Twilight in the Desert* (Hoboken, New Jersey: John Wiley & Sons, Inc, 2005), 268.

being recovered. Probable (P2) are those with a 50 percent chance of being recovered. This chance of recovery may change depending on the capabilities of developing technologies. Probable to proven reserve shifts often lead to a change in proven reserves and are a reason for why proven resources often shift up and, less commonly, down. The final P, that being possible (P3), are those reserves that are rather nebulous and are, at most, a scientific guess that could well change with higher fuel prices that may substantiate the higher costs of extraction.[5]

Lastly, a discussion about data sources may be instructive. Many states and organizations in the oil industry do not disclose accurate statistics. States, such as Saudi Arabia, who rely on a steady, easily accessible supply of oil to maintain a stable state under a dictatorship do not run the risk of discussing that oil may some day run out, and the state wealth along with it. Similarly, publicly-traded companies rely on favourable information to maintain stock prices and it is not in their interest to introduce uncertainty that destabilizes the market. The capacity of the Organization of the Petroleum Exporting Countries (OPEC) to maintain its high levels of production will figure significantly in this discussion.

On the other hand, there are those who do wish to strike fear into the public and trigger debate by presenting arguments to the effect that the world social order is going to collapse with Peak Oil. These arguments are equally biased, based upon data selected specifically to muddle, confuse or exaggerate issues.

The three parts of this paper will combine to form an argument of great and current relevance to the Canadian Forces. Through the logical progression from theory to

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[5]Simmons, *Twilight in the Desert*, 267-8.

practical example, all parts will serve to define a conclusion: the peak of oil production coupled with the forecast increase in world demand necessitates decisions today in order to ensure a Canadian Forces capable of executing future operations, both at home and overseas.

Part 1 – Oil's Decline

"The Stone Age didn't end for lack of stone, and the oil age will end long before the world runs out of oil." **–** Sheik Ahmed Zaki Yamani, Minister of Oil and Mineral Resources for Saudi Arabia, 1962 -1986[6]

This chapter addresses the origin of oil and the theory of Peak Oil. Using examples of how many of the world's oil fields have peaked or are due to peak, and knowing that OPEC has inflated its reserve numbers, experts have forecasted a date for Peak Oil. Peak Oil is not an energy crisis, but is a liquid fuels problem that will not be addressed by the many alternative fuels currently being proposed.

The world is running out of cheap oil. Prior to demonstrating that world oil productivity will start to decline in the near future, the biogenic versus abiogenic debate over petroleum creation must first be addressed. There has been much debate among geologists regarding the origin of oil. The Russo-Ukrainian Abiogenic Theory promises endless oil, as the theory proposes that oil is continuously made in the earth's crust from the high pressure and heat near the mantle. This is obviously a theory one would wish to prove true and, indeed, was seized upon by optimists in the oil debate and reported widely.[7] The theory has been supported by scientific laboratory experiments that have shown that hydrocarbon molecules such as methane, ethane, hexane, alkane and various propanes, butanes and pentanes with "…distributions characteristic of natural petroleum" were formed at pressures of 50 kbar and 1 500 degrees Celsius.[8] This experiment

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[6]Quoted in Peter Maass, "The Breaking Point," *New York Times Magazine* (21 August, 2005), 8, http://web.ebscohost.com/ehost/delivery?vid=6&hid=108&sid=7f5ffa4v-da8c-485e-999b.html; Internet; accessed 12 September 2009.

[7]An example is found in Lawrence Solomon, "Endless Oil," *The National Post*, 12 September, 2009, http://www.nationalpost.com/m/story.html?id=1987711&s; Internet; accessed 12 December 2009.

concluded that "…the genesis of natural petroleum must occur at depths not less than [approximately] 100 kilometers, well into the mantle of the Earth."[9] This led supporters of the Abiogenic Theory to deduce that the oil created deep inside the earth made its way through fissures in the earth's crust to the deposits that have become today's oilfields.[10]

The Biogenic Theory is more widely accepted but also the more pessimistic of the two theories as it means that oil is a limited resource.[11] This "fossil fuel" theory posits that oil is the product of dead organisms that have, over millions of years, been transformed to oil due to great pressure and heat. The intense global warming that occurred 100 million and 150 million years ago caused great algae blooms that atrophied the bodies of water in which they resided. The toxic water in turn killed the algae, which fell to the bottom of the lakes and seas to eventually be covered by silt and buried.[12] The dead organisms first transformed into a wax-like material called kerogen, then gradually formed into what are now the world's oil reservoirs.[13] The theory relies on evidence of

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[8]J Kenny, V. Kutcherov, N Bendeiani, and V. Alekseev, "The Evolution of Multicomponent Systems at High Pressure: VI. The Thermodynamic Stability of the Hydrogen-Carbon System: The Genesis of Hydrocarbons and the Origin of Petroleum," *Proceeding of the National Academy of Sciences*, 1. http://www.pnas.org/content/99/17/10976.full; Internet; accessed 13 December, 2009.

[9]*Ibid*., 1.

[10]Thomas Gold, "The Origin of Methane (and Oil) in the Crust of the Earth," *United States Geological Survey Professional Paper1570 (1993)*, 1. http://web.archive.org/web/20021015163818/www.people.cornell.edu/pages/tg21/usgs.html; Internet; accessed 13 December, 2009.

[11] In almost all sources, petroleum is called a "fossil fuel" or is described in a similar fashion to that above. The Biogenic Theory is supported by most scientists and petroleum experts and only on the rare occasion is it refuted by a very few such as Gold. Indeed Gold is the only scientist writing in English that was found to refute the Biogenic Theory.

[12]K Aleklett and C. Campbell, "The Peak and Decline of World Oil and Gas Production," *Raw Materials Report* Vol.18, no. 1 (2003), 3, www.peakoil.net/files/oilpeakmineralsenergy.pdf; Internet; accessed 18 January 2010.

biologic compounds that are found in oil called age-restricted biomarkers. An example of this is an organic compound called oleanane which is only produced by flowering plants (angiosperms).[14] Oleanane found in oil directly links a particular petroleum source to the late Cretaceous period.[15] The theory is supported by the fact that over ninety percent of all the oil reserves are trapped in the upper strata of the earth that are associated with the major periods of life, including the Jurassic and Cretaceous.[16] These two periods left much fossil evidence that illustrates that much of the world's oil is geologically young.

The Abiogenic Theory, was never widely accepted in the West and today has lost much favour in Russia and the Ukraine as is evidenced by the dearth of articles in the Russian journal *Petroleum Geology* dealing with the topic and its application in exploration.[17] If oil is indeed plentiful so deep below the surface, getting to it will be difficult and extremely costly, making it a true unconventional source. Due to issues of methane oxidation close to the earth's mantle and more knowledge of fluid dynamics and migration in the earth's crust, the movement of methane and other hydrocarbons given as foundations for the Abiogenic Theory have fallen into disfavour.[18] Further, the presence

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[13]Taylor, *The Abiotic Theory of Petroleum Formation: Theories of Deep Pools of Abiotic Oil shown to be Flawed*, 1. Some sources, such as this one, use "Abiotic," others "Abiogenic." Abiogenic is used throughout this paper.

[14]Paul Wilson, "Abiogenic Oil," *Sedimentary Basins and Petroleum Geology*, August 26, 2008, 1, http://www.basintectonics.blogspot.com/2008/08/abiogenic-oil.html; Internet; accessed 18 January 2010.

[15]*Ibid.*

[16]Geoffrey Glasby, "Abiogenic Origin of Hydrocarbons: An Historical Overview," *Resource Geology* Vol. 56, no. 1 (2006), 94.

[17]*Ibid*., 93.

[18]*Ibid*., 95.

of oil in shale, such as that in Venezuela, can only be proven through the biogenic hypothesis.

Shale is formed from sediments collected at the bottom of a body of water. Shale is of extremely low porosity and thus does not support the oil migration from the mantle required by the abiogenic paradigm.[19] Even the proofs by both Gold and the Soviet scientists of using the theory to successfully find oil in the Dnieper-Donets Basin and elsewhere have been shown to be false. As Glasby states about studies of the aforementioned basin, "…the U.S. Geological Survey has interpreted [the basin] entirely and convincingly within the framework of conventional petroleum geology, with no mention made of an abiogenic source of hydrocarbons."[20] The Abiogenic Theory was also tested practically in Sweden at great cost and was completely dismissed by the oil companies.[21] Indeed, industry has left the debate to theoretical science and is no longer using the Abiogenic Theory to forecast the potential locations of fields and, therefore, where to search for oil.[22]

A third and more recent theory that incorporates both the abiogenic and biogenic theories has recently been proposed. Glasby offers a theory that explains both the recent formation, in geological terms, of oil and the great amount of it that is found in the strata associated with the Jurassic and Middle Cretaceous periods.[23] As the earth's crust or lithosphere moved during these periods, large superplumes of hot magma were released,

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[19]Paul Wilson, "Abiogenic Oil," *Sedimentary Basins and Petroleum Geology,* 1.

[20]Glasby, *Abiogenic Origin of Hydrocarbons: An Historical Overview,* 95.

[21]Aleklett et al., *The Peak and Decline of World Oil and Gas Production,* 3.

[22]Glasby, *Abiogenic Origin of Hydrocarbons: An Historical Overview,* 95.

[23]*Ibid.,* 94.

causing intense global warming. There is ample geological record of this fact. This heated world had deeper oceans due to the lack of water trapped in ice (either in icecaps or glacially). A result of the superplume was vast deposits of carbons and other source materials for the formation of petroleum. These periods were also rich in life, and thus the remnants of carbon life-forms would also have been deposited with these abiotic carbons in the world's oceans.[24] This would help explain the significant quantities of petroleum in these two specific strata and why the oil has carbon traces that chemically fingerprint themselves as originating from living organisms.

The Glasby theory argues that petroleum is a limited resource. That oil is truly a limited resource is supported further by the peaking of oil field discovery in 1966.[25] Even if some oil is being produced in the mantle, it is not coming up fast enough to prevent oil wells from losing pressure and going "dry."

Of all the theories mentioned, the Biogenic Theory has the most support in the geological community. As positive as the Abiogenic Theory would be to the future of world oil supplies, the theory has too many critical flaws to be taken as a replacement to the reigning biogenic paradigm. Glasby's argument, although sound, does not change the principal issue that the Biogenic Theory proposes: oil is a limited resource and is thus prone to exhaustion.

When an oil field is discovered, oil recovery commences slowly and continues to increase until it reaches a maximum flow rate, called the "build up phase," followed by a

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[24]*Ibid.*, 94.

[25]Jeff Rubin, *Why Your World is About to Get a Whole Lot Smaller* (New York: Random House, 2009), 11.

peak or "plateau phase," and then gradually diminishes during the "decline phase."[26] This does not happen quickly for conventional wells; indeed, a well may take decades to peak. The peak will normally occur when half of the recoverable oil has been extracted and the peak times will vary from well to well depending on the size and pressure of the recoverable reservoir. Indeed, since it is impossible to determine exactly how much oil is recoverable from any given well, the peak can only be determined using estimates and then confirmed with hindsight. Only through examination of a well's output figures can the specific time of peaking be given. Peaking is thus not running out of oil, rather it is the point at which a well hits its most productive rate prior to easing off.[27]

An oil well is drilled, peaks, and then consistently provides less and less oil until it goes dry. This sequence is the same regardless of the location of a well. Deep ocean wells, defined here as unconventional, will peak earlier than their shallow water or terrestrial counterparts. This is due to the fact that technologies for this type of drilling were invented later and have thus incorporated many new technologies allowing for a more rapid extraction of the oil.[28] The bell curves that the production numbers trace are almost even on either side, although the bell may be taller or shorter. This was first

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[26]James Griffin, ed., *World Oil Outlook: 2009* (Vienna, Austria: OPEC Secretariat, 2009), 123.

[27]Robert Hirsch, *Testimony on Peak Oil Before the House Subcommittee on Energy and Air Quality*, (Washington, DC: House Subcommittee on Energy and Air Quality, December 7, 2005), 3, http://alternativeenergy.procon.org/sourcefiles/Hirsch_Peak_Testimony.pdf; Internet; accessed 14 October 2009.

[28]Rubin, *Why Your World is About to Get A Whole Lot Smaller*, 35.

recognized by M. King Hubbert and is known as the Hubbert Curve (depicted below):

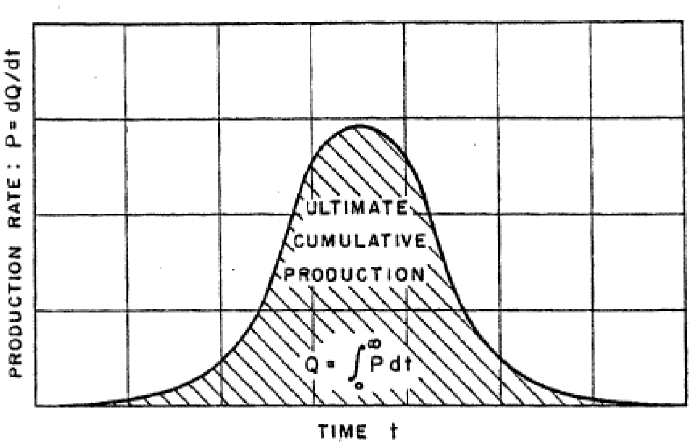

Fig 1.1 – Typical Oil Production Curve

Source: M. King Hubbert, *Nuclear Energy and The Fossil Fuels* (Houston, Texas: Shell Development Company, 1956).

Hubbert, a petroleum geologist active in the 1950s, had used equations to predict a well's production.[29] He then used his curve to predict entire fields and went on to predict an entire nation's peak date. In 1956, Hubbert, having carefully analysed his data, publicly announced at the American Petroleum Institute that the United States would peak in or around 1970 and would then continually produce less oil.[30] The graph he

[29]John M. Greer, *The Long Descent: A User's Guide to the End of the Industrial Age* (Gabriola Island, British Columbia: New Society Publishers, 2008), 2.

[30]Hubbert, *Nuclear Energy and the Fossil Fuels*, 24.

presented with his paper is shown below:

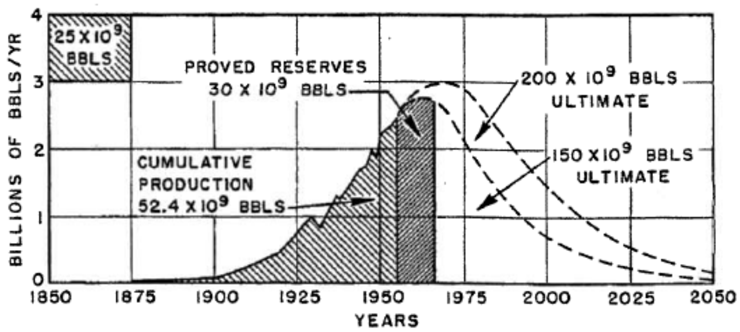

Fig 1.2 – Hubbert Peak Prediction for United States Production

Source: M. King Hubbert, *Nuclear Energy and The Fossil Fuels* (Houston, Texas: Shell Development Company, 1956).

Although refuted by the oil industry as being naïve and not taking into account the inevitable improvements in technology, the United States did indeed peak in December of 1970 when the Gulf of Mexico produced almost 10 million barrels a day, elevating Hubbert to the status of Peak Oil prognosticator.[31] Despite all the technological advancements in oil extraction, and even bringing to production the new oil fields in Alaska, the United States has never been able to regain this level of production. Indeed, the sharp decline in production came as a shock to the American oil industry.

The Hubbert Curve is now used extensively in almost all the literature to determine when the world's oil will peak. Essentially, all known wells are taken together; predictions for each well in each field are placed on a graph to show the expected date for the world's peak. This date is what is referred to as Peak Oil. As stated earlier, Peak Oil is not the date oil runs out; rather, it is the time at which the world's oil

[31]Simmons, *Twilight in the Desert,* 45.

production starts down the other side of the Hubbert Curve, showing ever increasing declines in world oil production.

Debunkers of Peak Oil Theory, such as Cambridge Energy Research Associates (CERA), attempt to refute the Hubbert Curve, as it is the lynchpin to the entire theory. CERA believes that the peak of world oil will not follow the curve observed for individual fields but will rather "…follow an undulating plateau for one or more decades before declining slowly…the slope of the decline being more gradual and not mirroring the rapid rate of increase."[32] Indeed, some sources attempt to avoid using the Hubbert Curve at all in order to look less biased.[33] The problem with the Hubbert Curve is its simplicity. Any lay person can look at the curve and make sense of it. Scholars argue that the curve is too simple, and thus not accurate, and believe that the curve fails to take into account such things as improvements in extraction technology and new well heads in a given field.[34] Resource Accounting is the most popular of the counter arguments to the Hubbert theory.

Resource Accounting, popular with economists and CERA, is based on a ratio of proven reserves (R) to production requirement to meet demand (P).[35] As demand increases, so does production and more of the reserves are drawn to meet this demand to

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[32]CERA, "Peak Oil Theory – 'World Running Out of Oil Soon' – Is Faulty; Could Distort Policy & Energy Debate," November 14, 2006, 2, http://www.cera.com/aspx/cda/public1/news/pressReleases/pressReleasesdetails.aspx; Internet; accessed 24 February 2010.

[33]As alluded to in David Greene, Janet Hopson and Jia Li, *Running Out of and into Oil: Analyzing Global Oil Depletion and Transitions Through 2050* (Oak Ridge, Tennessee: Oak Ridge National Laboratory, 2003), xi.

[34]CERA, "Peak Oil Theory – 'World Running Out of Oil Soon' – Is Faulty; Could Distort Policy & Energy Debate," 4.

[35]*Ibid.*, 3-4.

maintain the R:P ratio. If proven reserves of conventional oil do not suffice, the unconventional reserves will be brought on line. This model, however, does not account for the fact that wells peak once fifty per cent of the recoverable oil is extracted. Resource Accounting provides that a field's production can be increased as long as there is oil and the requisite demand for it. Supporters of this theory believe that the Hubbert theory of peaking is too mechanistic and does not take into account the basic economic principles of supply and demand – the supply of oil will increase or decrease with world demand. Indeed, an OPEC official stated to this author that OPEC believes that there is ample supply to last "for centuries" and that some economists believe that if supply peaks first then "…the price would adjust the demand [regaining] the balance in the market again."[36]

The problem with Resource Accounting is that it ultimately ignores geology. Granted, the theory works for most consumables, but the issue is that oil is not a normal consumable. It is limited in supply and constrained by geology. Resource Accounting ignores completely the fact that wells may be overworked leading to their early demise and similarly ignores other geological constraints on production. This theory rests completely in the optimistic camp and, due to its disregard for the geological facts that surround oil extraction, is not supported in this paper.

Technology and the forecast improvements to it seem to be the panacea for many of the issues that surround the peaking of an oil field. Optimists, such as CERA, believe that peaking can be delayed by increasing the recovery from proven conventional

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[36]Mazyar Mazraati, OPEC Energy Models Analyst, email correspondence with the author, with permission, 27 January 2010, full text available upon request.

reserves in existing fields through improvements in extraction technology.[37] This was indeed the belief stated by a senior OPEC official in correspondence with the author.[38] Technology, made affordable by higher fuel prices, is seen, therefore, as the force to produce ever-increasing amounts of conventional oil.[39] This very argument was given in the 1950s by those refuting Hubbert's hypothesis that the United States would peak in 1970. Once the United States peaked, much was invested in technology to bring production back up to its high. Despite rapid increases in fuel costs and government subsidies in technology, nothing slowed the downward trend in production.[40] A curve illustrating that the United States' Lower 48 oil production was neither affected by increases in fuel costs nor by the improvements of oil field technology as shown below:

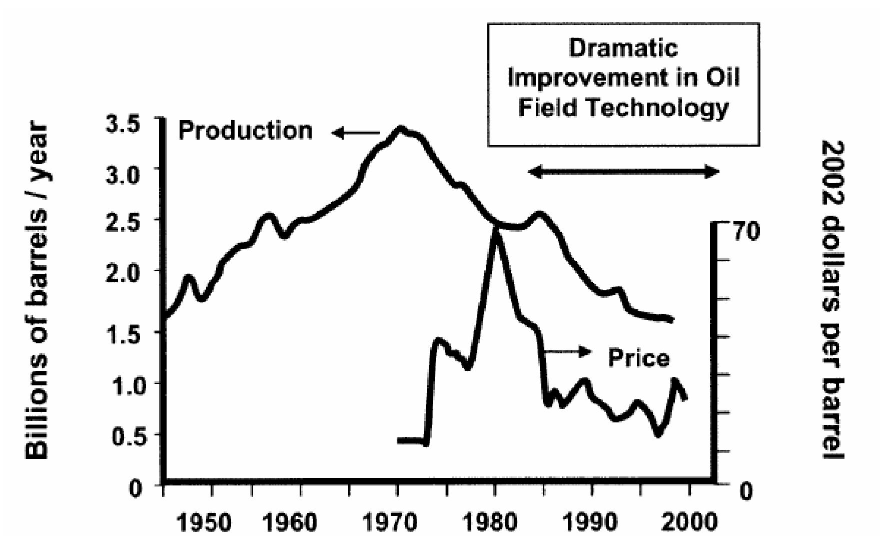

Fig 1.3 – Actual Peak Oil Production for United States' Lower 48

Source: Hirsch, *Testimony on Peak Oil Before the House Subcommittee on Energy and Air Quality*, 16.

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[37]Peter Jackson, *CERA Special Report: 2009* (Cambridge, Massachusetts: Cambridge Energy Research Associates, Inc), 10.

[38]*Ibid.*, 10.

[39]Hirsch, *Testimony on Peak Oil Before the House Subcommittee on Energy and Air Quality, 7.*

[40]Maass, *The Breaking Point*, 8.

Despite evidence such as that above, there still remains the myth that technological advancements will prevent, or significantly postpone, Peak Oil. Indeed, the Oil Minister for Saudi Arabia, Ali al-Naimi stated that he is "…quite bullish on technology as the key to our future….Technological innovation will allow us to find and extract more oil around the world."[41] However, this overly optimistic opinion is not a realistic assessment of the potential oil production of Saudi Arabia or of the world. In the end, technology does not get more oil out of the ground; it merely makes it easier to extract the oil that can be recovered.[42]

The fact remains that, despite efforts to the contrary, the Hubbert Curve has stood the test of time and has been used to accurately predict the peak of production in the United States in the 1970s and, in a more current context, the peaking of oil in Oman and the North Sea. These examples will be examined to further support the veracity of the Hubbert Curve.

Oman's experience provides an excellent example of what can happen when a state's oil policy is to produce as much oil as possible with no regard for the geological realities of oil extraction and illustrates what happens if only the Resource Accounting theory is applied to oil recovery strategy. Oil wells are all different and many factors need be considered to determine which secondary and tertiary recovery methods are most appropriate. There exists a perception that oil wells are like straws that suck lake-like reservoirs of oil out of the ground. Reservoirs are actually complex geological structures

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[41]Maass, *The Breaking Point*, 3 and reiterated by Mazyar Mazraati, OPEC Energy Models Analyst, in email correspondence with the author, with permission, 27 January 2010, full text available upon request.

[42]Rubin, *Why Your World is About to Get a Whole Lot Smaller*, 35.

in which droplets of oil are sandwiched between geological formations and, when initially tapped, forced to the well head by enormous gaseous pressures. The pressure can be so great as to cause geysers, but these are normally short lived, if they occur at all. Likely there will be a need to draw the oil out or to increase the pressure using water.[43] In the case of Oman, in 2001, 960 000 barrels of oil were being produced each day.[44] The state was interested in getting as much out of the reservoirs as possible and gave little regard to the issues of overworking the extraction; the result was damage to the reservoir. Although the most advanced technologies were employed in the extraction of the oil, Oman peaked and began to quickly decrease in production.[45] Today 785 000 barrels are produced each day, with the number decreasing annually, despite all technological efforts.[46]

The Ekofisk, Brent and Forties oil fields of the North Sea provide other examples of more current fields peaking despite technology's promise. These fields are also examples of how deepwater fields deplete much more rapidly than conventional fields. Indeed, they can deplete twice as rapidly.[47] Experience in these fields has shown that technology provides for a more rapid depletion of the resources than a sustainment of peak levels. Ekofisk, a Norwegian-owned field, was the first to start production in 1971. Five years later, it peaked at 280 000 barrels per day and immediately went into decline,

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[43]Maass, *The Breaking Point*, 5.

[44]*Ibid.*, 5.

[45]Peter Maas, *Crude World: The Violent Twilight of Oil* (New York: Alfred A Knopf, 2009), 17.

[46]*Ibid.*, 5.

[47]Rubin, *Why Your World is About to Get a Whole Lot Smaller*, 35.

producing only 69 000 barrels per day by 1987.[48] The Forties commenced production in 1975 and Brent followed two years later. Forties peaked in 1980 at 523 000 barrels per day and Brent followed in 1985 at 440 000 barrels per day.[49] By 2007, production had dropped by 43 per cent and, although major advanced Western states such as the United Kingdom and Norway were investing enormous amounts of money in technology to increase extraction rates, it was all to no avail.[50] Vigorous and costly (USD billions) water injection programmes were able to bring Ekofisk up to old production levels again but, once the sweep was completed, production dropped again to the point where production is expected to be below 50 000 barrels per day in 2010.[51] Deepwater fields give up their petroleum rapidly and, once they peak, they ease off just as quickly. The water injection programmes to sweep the last oil out of the reservoir caused another, lesser, peak in Brent but, once the sweep was complete, Brent trailed off again.

Nonetheless, as various oil fields come on line, peak, and then decline, the fields in Saudi Arabia have kept up with demand and kept the Western World's thirst for oil assuaged. With the examples of the Gulf of Mexico, Oman and the North Sea in mind, it is only logical to conclude that the great giant fields, such as Saudi Arabia's Ghawar, will also someday peak and decline. Most OPEC nations are now producing less than they were a decade or so ago.[52] Many may be assumed to have peaked. Saudi Arabia, ever silent about the state of their fields, continues to reassure the world that there is nothing

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[48]Simmons, *Twilight in the Desert*, 295.

[49]*Ibid.*, 296.

[50]Rubin, *Why Your World is About to Get a Whole Lot Smaller*, 35.

[51]Simmons, *Twilight in the Desert*, 295.

[52]Rubin, *Why Your World is About to Get a Whole Lot Smaller*, 79.

to fear. Ghawar, the world's most productive field, produces five million barrels a day. In total, Ghawar produces approximately one-third of the Saudi Arabian total of fifteen per cent of the world's production.[53] When production is just keeping up with demand, the health of Ghawar becomes even more important.

At about fifty years of age, Ghawar is getting old, even for a field that, on face value, seems so full of oil. Oil extracted from Ghawar is becoming increasingly adulterated with water as it comes from the ground. Saudi Arabia's state oil company, Aramco, is now employing secondary methods of extraction to extract the oil and maintain well pressure. This explains the increased water cut from their fields that is in some areas as high as 40 per cent.[54] The water mixed with oil is a result of Aramco pumping enormous quantities of water into the periphery of the oil field to increase well pressure and force the oil toward the well head. This technique is the same as that used at Brent and Forties when production was lagging. Although water sweeping is often initiated early, if the field is healthy and not near or past its peak, the high water cut would not exist. If the wells in the Ghawar field are having this technology employed, then it may be assumed that the Aramco engineers are concerned about pressure levels and are aiming to maintain the traditionally high productivity. This, we know from past experience, will not prevent the field's decline and may, in the end, lead to a sharp decline once technology is no longer of assistance.

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[53] Demand figures from Energy Information Administration, "International Energy Outlook 2009," Energy Information Administration, http://www.eia.doe.gov (accessed 19 October, 2009) using production figures from Simmons, *Twilight in the Desert*, 172 and Maass, *The Breaking Point*, 7.

[54]Simmons, *Twilight in the Desert*, 172.

In other Saudi fields, tertiary methods are now being employed in an attempt to get the last sums of oil from the ground.[55] Tertiary methods include the use of surfactants that allow more oil to be solubilised in water and thus extracted. Polymers are also added to the water being pumped into the wells for the sweep; these chemicals are expensive and the reason why tertiary methods are often not employed is simply because the costs outweigh the recovery values.[56]

The Ghawar field is not alone in Saudi Arabia. After examining petroleum engineer reports, Simmons determined that all the Saudi fields are, with great effort, being maintained at a constant production rate.[57] Saudi Arabia is hardly transparent, so it is by using engineering reports that this conclusion may be drawn. Saudi petroleum scientists believe that, due to its aging fields, a new field on the scale of Ghawar will have to be found for Saudi Arabia to maintain its production rates, meaning that 800 000 barrels per day of new oil must be produced to maintain state output rates.[58] Indeed, the world is consuming oil at such a rate that, in order to merely maintain current rates of 85 million barrels a day for the next twenty-two years, requires finding new fields equalling four Saudi Arabias.[59] If demand continues to increase at its current rate, then six such fields will have to be found. The fact that only one super giant field has been discovered since the 1960s, namely the Cantarell Field of Mexico found in 1975, is not promising.

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[55]*Ibid.*, 315.

[56]Christian Besson, *Resources to Reserves: Oil & Gas Technologies for the Energy Markets of the Future* (Paris, France: International Energy Association, 2005), 58.

[57]Simmons, *Twilight in the Desert,* 284.

[58]*Ibid.*, 282.

[59]Center for Naval Analysis, *Powering America's Defense: Energy and the Risks to National Security*, ed. Sherri Goodman (Alexandria, VA: Center for Naval Analysis, 2009), 18.

With all of the world's fields aging and many peaking, or having already peaked, one is led to conclude that the world may be approaching the apogee of its planetary Hubbert curve.

The fields described here are but samples. One could examine the only four super giant fields found in the last five decades to extrapolate what will happen in the Middle East. China's Daqing, Russia's Samotlor, Alaska's Prudhoe Bay and Mexico's Cantarell all had very high production rates in the millions of barrels per day and have all shown similar curves of peaking and then dropping off. All are now measured in the hundreds of thousands of barrels per day, even with sophisticated modern sweeping and drilling technologies. As with these four, the other super-giants will follow. It is an inevitability that must be acknowledged and faced.

There are thousands of oilfields in the world but, of these, only fourteen provide twenty per cent of the world's oil supply.[60] Further, oil is currently being extracted at three times the rate at which it is discovered.[61] The ensuing supply and demand problem is the crux of the issue of Peak Oil. When the world's great fields inevitably peak and decline, demand will not follow. Demand for oil will continue to increase, especially with the burgeoning economies outside of the Organisation for Economic Cooperation and Development (OECD), namely China and India. Indeed, the Energy Information Administration of the United States (EIA) forecasts those non-OECD nations will be

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[60]These fields are Ghawar (Saudi Arabia), Romashkino (Russia), Kirkuk (Iraq), Lagunilla (Venezuela), Burgan (Kuwait), Cantarell (Mexico), Daqing (China), Zakum (Abu Dhabi), Rumaila North (Iraq), Abqaiq (Saudi Arabia), Shaybah (Saudi Arabia), Prudhoe Bay (USA), Shengli (China), and Marlim (Brazil). Simmons, *Twilight in the Desert*, 374.

[61]Rubin, *Why Your World is About to Get A Whole Lot Smaller*, 11.

responsible for 73 per cent of the increases in fuel consumption.[62] The EIA's 2009 International Energy Outlook forecast that the "…world use of liquids and other petroleum grows from 85 million barrels per day in 2006 to…107 million barrels per day in 2030."[63] The EIA goes on to state that OPEC "…will maintain a share of approximately 40 per cent of total world liquids production through 2030 [which represents an increase by OPEC of] 8.3 million barrels [per day]."[64] Where these additional millions of barrels will come from in OPEC is not mentioned or, perhaps, not considered. It is founded on the belief that as demand increases, OPEC will provide. The 2004 EIA forecast stated that Saudi Arabia would produce 18.2 million barrels per day in 2020 and then 22.5 million barrels per day in 2025. This is simply not possible according to Sadad al-Husseini, the former Aramco senior executive for exploration and production.[65] Husseini points out the obvious when he states that with demand "…leaping by two million to three million [barrels per day] a year, and if you have to cover declines, that's another four to five million….That's like a whole new Saudi Arabia every couple of years….It's not sustainable."[66]

As the demand reaches the EIA's 107 million barrels per day mark in 2030, it is likely that there will not be enough conventional oil to meet the target. The EIA recognizes this and states that, by 2030, 13.4 million barrels per day will come from

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[62]Energy Information Administration, *International Energy Outlook 2009*, 1.

[63]*Ibid.*, 1.

[64]*Ibid.*, 1.

[65]Maass, *The Breaking Point*, 12.

[66]*Ibid*., 13.

unconventional sources and 5.9 million barrels per day will come from biofuels.[67] Both unconventional and biofuel solutions such as the tar sands and corn-based ethanol will increase fuel costs as will be shown later, as both extraction and production is far more costly than for conventional oil.

Peak Oil's veracity is even supported by OPEC.[68] The date of Peak Oil, however, is debated. The dates often vary based on assessments of future technology, proven reserves, future discoveries, unconventional oil, and biofuels that are expected to fill the void created by the decreased availability of conventional oil. Technology, unconventional oil and new discoveries are the three critical factors considered by the International Energy Association (IEA) to prevent oil supply shortages in the future. The removal of these three factors clearly reveals a peak as is seen in the graph below:

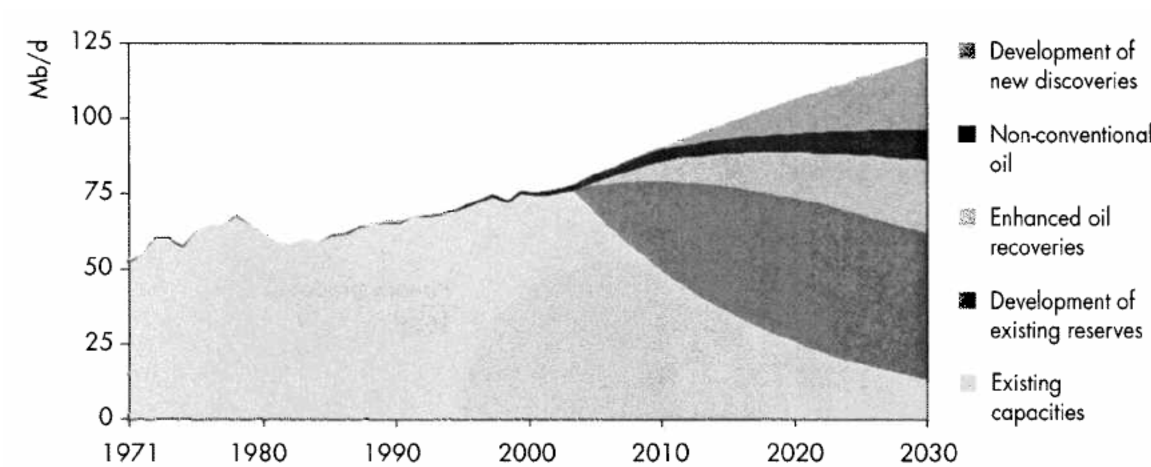

Figure 1.4 – IEA's Forecast: Technology, Unconventional Oil and New Discoveries to Prevent Peak Oil

Source: Besson, *Resources to Reserves: Oil & Gas Technologies for the Energy Markets of the Future,* 41.

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[67]Energy Information Administration, *International Energy Outlook 2009*, 3.

[68]From Mazyar Mazraati, OPEC Energy Models Analyst, email correspondence with the author, with permission, 27 January 2010, full text available upon request.

As outlined earlier, however, experience to date has shown that technology and new discoveries have historically failed to solve future supply issues.

Hubbert forecast in 1956 that world oil production would peak in 2000, although he admitted that new resource discoveries and changes in demand could change the date somewhat. Compare the "existing capacity" and "development of existing reserves" curves in Figure 1.4 above with Hubbert's prediction below:

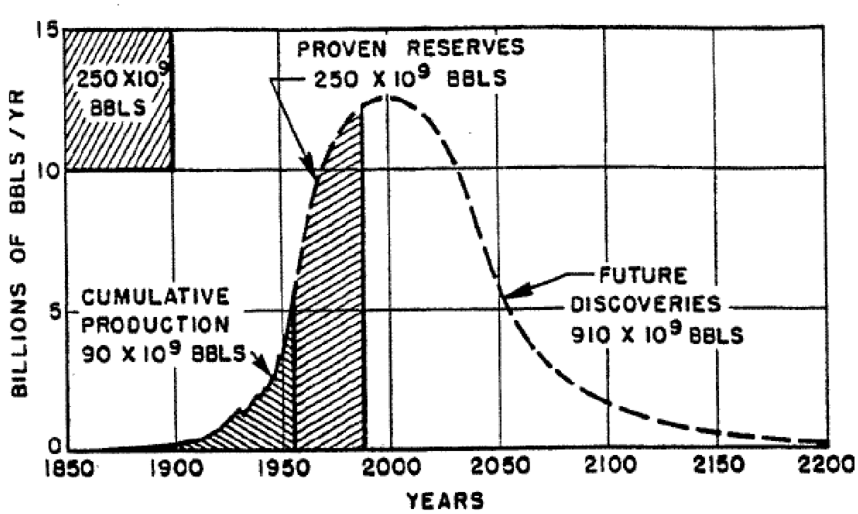

Figure 1.5 – Hubbert's World Peak Oil Prediction

Source: Hubbert, *Nuclear Energy and the Fossil Fuels*, 22.

The consistency of the two analyses, and the similarities of the two graphs made almost fifty years apart, are remarkable. Although the volumes are different due to the discoveries after Hubbert's publication, both graphs display a peak that occurs at approximately the same time if only existing oil reserves are considered.

The IEA, in its 2008 Energy Outlook, forecasted that oil would not peak before 2030 and was taken to task by an IEA "whistleblower" in a British newspaper, *The*

Guardian.[69] The unnamed IEA source claimed that the IEA, which is responsible for advising on energy policy to the OECD, was duplicitous in that it was reporting a peak in 2030 when oil was forecast to rise to 106 million barrels per day while many "…inside the organisation believe that maintaining supplies at even 90 – 95 million barrels a day would be impossible."[70] The reason for not disclosing the problem is reported as being that the IEA did not wish to cause "…panic in the financial markets."[71] If the IEA believes that maintaining 90-95 millions barrels per day will be impossible, then the true peaking will occur earlier, at around 2015, when the EIA forecasts that petroleum demand will have grown to 91 million barrels per day.[72]

Colin Campbell, perhaps one of the most pessimistic analysts of Peak Oil, in a letter to the editor of *The Guardian*, highlights the issue with the IEA's forecast. As someone who was consulted by the IEA, Campbell believes that the IEA's use of terms such as "unidentified unconventional" placed in the graph to coincidentally meet the 20 per cent increase in demand is a way to show shortage without alarming anyone.[73] Campbell believes oil will peak this year in 2010 and that conventional oil already peaked in 2005.[74] He goes on to explain that the deep water wells and the tar sands of

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[69]Wire Services, "IEA 'Whistleblower' Says Peak Oil Nearing," *Upstream: The International Oil & Gas Newspaper* (10 November 2009) [Newspaper on-line]; available from http://www.upstreamonline.com/live/articl198370.ece; accessed 18 January 2010.

[70]*Ibid.*

[71]*Ibid.*

[72]Energy Information Administration, *International Energy Outlook 2009*, 2.

[73]Colin Campbell, "Open Comment to the Editor of *The Guardian* on the article 'Key Oil Figures Distorted by US Pressure, Says Whistleblower'," http://www.peakoil.net/files/campbell_comments_20091110.pdf; Internet; accessed 18 January 2010.

[74]*Ibid.*

Canada, both "unconventional" by the definitions used in this paper, have been making up the shortfall, albeit at greater cost.[75]

The IEA has recently begun to move from the optimistic to the more pessimistic camp, marking a dramatic change in the Peak Oil debate. The IEA, never wanting to publicly forecast a date for Peak Oil, made headlines when Fatih Birol announced that "…the output of conventional oil will peak in 2020 if oil demand grows on a business as usual basis."[76] The IEA came to this conclusion after careful analysis of 800 oilfields that revealed that spare capacity was shrinking and, unless resources equivalent to four Saudi Arabias were found, the decline was inevitable.[77]

H.H. Rogner, a member of what is often called the "cornucopian" school of oil supply, is an optimist who does not support the Peak Oil Theory. In what he calls "aberrant conclusions," Rogner points out that pessimists have been claiming oil supply was not sustainable and would run out in two to four decades since the beginning of the twentieth century.[78] He states that there is enough oil to "…fuel the world economy through the twenty-first century, even in the case of drastic growth in global energy demand."[79] He argues that technology, new knowledge in the geosciences and economics have ensured that supply always met demand and will continue to do so.[80] Indeed he goes on to elaborate that economic theory argues that there is no such thing as

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[75]*Ibid.*

[76]The Economist, "The Peak-Oil Debate: 2020 Vision," *The Economist*, December 12, 2009, 82.

[77]*Ibid.*

[78]H. Rogner, "An Assessment of World Hydrocarbon Resources," *Annual Review of Energy and The Environment* 22 (1997), 219.

[79]*Ibid.*, 257.

[80]*Ibid*., 219.

a resource running out and that once one resource becomes too costly, others will take its place. Roger illustrates his belief that resources will continue to grow to meet demand by the fact that proven reserves have continued to increase with demand and that there has thus never been a shortfall.[81] Rogner relies on government and their agencies' reports of proven resource increases and does not have any suspicions regarding their "up-to-date estimates."[82] As will be illustrated later, these estimates may not be as reliable as he may want to believe.

Rogner, like many in the optimistic camp, also believes that the discussions on global warming and the subsequent legislated reductions in CO_2 emissions will lead to less consumption of oil.[83] The IEA holds the same opinion, believing that the agreement made in Copenhagen to not allow global temperatures to increase by more than 2^o Celsius will keep demand lower than forecast and push the peak date beyond 2020.[84] This would likely be true if all states reduced their consumption in a manner desired by the Copenhagen Conference. It is more probable, however, that since states such as China and India wish to maintain their vigorous economic growth supported by oil, the results from Copenhagen will be similar to the failed efforts after the Kyoto Conference.

In a paper written for the US Department of Energy, scientists took data from a variety of sources and, by using a risk analysis framework, forecasted when world conventional oil production would peak. Their model declined to use the Hubbert curve

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[81]*Ibid*., 222.

[82]*Ibid*., 219.

[83]*Ibid*., 222.

[84]The Economist, *The Peak-Oil Debate: 2020 Vision*, 82.

but used oil field reserve to production ratios.[85] The study concluded that "…the growth in world conventional oil production will slow substantially after 2020."[86] The study also forecast Peak Oil dates using United States Geological Survey (USGS) and Rogner's estimates of recoverable oil; the USGS estimates forecast a world oil production peak in 2039 while Rogner's forecast is 2037. Both the USGS and Rogner use very optimistic reserve growth rates and recovery rates that are outside historical norms.[87] They also include the recovery of "speculative resources" that are not included in more pessimistic forecasts such as Campbell's.[88] This use of optimistic speculation that results in the appearance of more recoverable resources leads to a peak date further to the right than it otherwise might be.

CERA, which has riled against Peak Oil prognosticators, has recently begun to admit that it has lost the debate. Jim Burkhard, CERA Global Oil Group Managing Director has acknowledged that "Peak Oil is here."[89] Although not admitting to geological factors having anything to do with the peak, it is obvious that there are fewer experts who deny that Peak Oil is about to occur. James Schlesinger, former United States Secretary of Energy stated that "…the peakists have won…you can declare

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[85]Greene, Hopson and Li, *Running Out of and into Oil: Analyzing Global Oil Depletion and Transition through 2050*, xi.

[86]*Ibid.*

[87]*Ibid.*

[88]*Ibid.*

[89]CERA, "Peak Oil Theory – 'World Running Out of Oil Soon' – Is Faulty; Could Distort Policy & Energy Debate," 1.

victory. You are no longer the beleaguered small minority….You are now mainstream."[90]

The proven conventional reserve numbers offered by OPEC are inflated, as criticized by both Campbell and Simmons. In what Campbell calls "spurious reserve revisions," he postulates that the various states in OPEC have increased their reserve estimates in order to claim greater shares or to maintain what they saw as their fair share of the quotas.[91] Due to OPEC secrecy, conventional reserves posted by OPEC members are provided without evidence. Increases in conventional reserves are taken on face value by such industrial giants as BP and factored into the reported world conventional resource figures reported by industry.[92] The largest increases occurred in the late 1980s. These new claims were reported without any associated great discoveries. Aleklett and Campbell state that Kuwait, in 1985, increased its reserves from 63.9 billion barrels to an even 90 billion and was followed by Venezuela in 1987 that doubled its reserves from 25 to 56.3 billion barrels. Venezuela had a good case, as it had large reserves of previously unreported heavy oil or bitumen. Also in 1987, Abu Dhabi, not to be outdone, went from 31 to 92.2. Meanwhile, Dubai increased its reserves from 1.4 to 4; Iran from 48.8 to 92.9; and Iraq from 47.1 to an even 100. Saudi Arabia, with 170 billion barrels of reserves, finally followed the others in 1989, increasing its reserves to 257.5.[93] These increases in proven reserves – that in total are measured in the hundreds of billions of

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[90] *Ibid.,* 1.

[91] Aleklett, K and Campbell, C., *The Peak and Decline of World Oil and Gas Production*, 7.

[92] Euan Mearns, "HIS Data Suggest Kuwaiti and Global Proved Oil Reserves Significantly Lower Than BP Estimates," *The Oil Drum: Europe*, November 17, 2006, 1, http://europe.theoildrum.com/story/2006/11/13/173619/51; Internet; accessed 25 February 2010

[93] Aleklett, K and Campbell, C., *The Peak and Decline of World Oil and Gas Production*, 7.

barrels – are taken at face value by many assessing the amount of oil remaining and when the peak in oil production will occur.

Kuwait now reports reserves of 101.5 billion barrels. Kenneth Chew, a Vice President of IHS Energy (owner of CERA), an historically optimistic voice with regard to Peak Oil, reported that Kuwait's proven and probable reserves are only 52 billion barrels. Chew also reported that world oil reserves, especially those posted by OPEC, are in all likelihood much lower than reported.[94] OPEC's claims lead to an overly optimistic outlook and, since the states in OPEC making these claims do not allow independent audits of their fields, there is no way of verifying the numbers. One is left to either trust the values given or to question them. In this case, it is likely that the OPEC reserves are highly inflated and this should be considered when looking at optimistic assessments of a Peak Oil date that is developed from them.[95] The reasons for OPEC's inflation of proven reserves may be due to an attempt to maintain export share: as one member inflates, the others are forced to as well. It may even be an attempt to make oil supply appear more stable than it actually is and thus maintain more consistent pricing to OPEC's advantage. Without truthful disclosure of reserve figures, many will cling to the belief that ample oil remains to supply world demand well into the future.

China is not a member of the OECD and thus not tied to the IEA. As a world power and economic giant, it is reliant on imported oil and believes that this dependence on imports may "…imperil the national strategic security since high dependency on oil

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[94]Euan Mearns, "HIS Data Suggest Kuwaiti and Global Proved Oil Reserves Significantly Lower Than BP Estimates," *The Oil Drum: Europe*, November 17, 2006, 1.

[95]See for example Euan Mearns, "HIS Data Suggest Kuwaiti and Global Proved Oil Reserves Significantly Lower Than BP Estimates," *The Oil Drum: Europe*, November 17, 2006; Simmons, *Twilight in the* Desert; and Jane Whaley, "Do OPEC Reserves Figures Matter?" *GEO ExPro*, April 9, 2007, http://www.geoexpro.com/news/do_opec_re/; Internet; accessed 14 April 2010.

importation is dangerous to a nation."[96] In a study by scientists from the China University of Petroleum, using figures from their own research and analysis of existing fields and analysis of proven reserves, world oil production will peak in 2012.[97]

Examining the projected Peak Oil forecasts provided in the various studies, one can reasonably conclude that oil production will peak between now and approximately 2020. A peak date of 2010 may be considered overly pessimistic. Discounting the most pessimistic and optimistic forecasts, the convergence of opinion tends to be around the year 2020. This year will be used as the date for Peak Oil in this paper.

The inability to maintain supply with the increases in demand may be called an "energy crisis." This conjures up memories of OPEC shutting off the taps in the 1970s or of refineries damaged in hurricanes and thus unable to provide for demand resulting in rapid price increases at the gas pump. The difference with Peak Oil is that there is no tap to turn on and no refinery to start up. With Peak Oil, there is simply less oil than there was a year before and the promise of even less the year after. As the Chevron Oil advertisement says: "One thing is clear, the era of easy oil is over."[98] It is not that there is no oil; it is that there is less of it to go around, causing prices to continue rising. With the increases in price, the often dirtier and harder to obtain petroleum will be recovered. As interest in environmental stewardship increases, the costs of recovering this

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[96]Pang Xiongqi and others, *The Challenge and Countermeasures Brought by the Shortage of Oil and Gas in China* (Beijing, China: Chin University of Petroleum, 2005); http://www.cge.uevora.pt/aspo2005/abscom/Abstract_Lisbon_Pang.pdf; Internet; accessed 12 January 2010.

[97]*Ibid.*

[98]Chevron, "One Thing is Clear, the Era of Easy Oil is Over," http://www.chevron.com/Document/Pdf/RealIssuesAdTrillionBarrels.pdf; Internet; accessed 10 February 2010.

unconventional oil will increase, as is evidenced by the public outrage over birds dying in toxic ponds in Canada's tar sands or even the proposed conventional drilling in Alaska's nature reserve.[99] The energy-extravagant lifestyles of voters will be in conflict with the outrage felt by those same people over the environmental degradation that will inevitably accompany unconventional extraction.

As Robert Hirsch, the Senior Energy Program Advisor for the Science Applications International Corporation (SAIC) stated to House Subcommittee on Energy and Air Quality in 2005, it is not an energy crisis but a "liquid fuels problem."[100] Petroleum derived fuels are liquids such as diesel, gasoline, kerosene and aviation fuel. These are also the fuels that propel modern vehicles, ships and aircraft. A whole infrastructure has been developed to supply this fuel to the end user. Crude oil is taken from the wells to the refinery from where the finished products are distributed through a supply chain to the various distribution points. There is no easy alternative to the fuels and to rebuild a whole infrastructure is difficult to fathom. Therefore, the most likely result is that the world will continue to rely on the ever increasingly expensive liquid fuels to propel their vehicles.

Unlike the energy crises of the past, this one will mark the beginning of a revolution in transportation. The move from the horse and sail to coal and steam marked an evolution in transportation technology, as did the move to petroleum-derived liquids. However, what makes this liquid fuels problem so potentially catastrophic to our infrastructure is that there are no ready alternative fuels to fill the void.

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[99] ANWR.org, "ANWR Oil – Politics and Logistics," http://anwr.org/Background/ANWR-Oil---Politics-and-logisitcs.php; Internet; accessed 10 February 2010.

[100] Hirsch, *Testimony on Peak Oil Before the House Subcommittee on Energy and Air Quality*, 11.

A counter argument may be made that alternative fuels exist that can replace our current fuels. Electricity, wind and solar generated power may be seen as partial solutions to the liquid fuels problem of Peak Oil. Although useful in assisting with the electric power grid, solar and wind energy will not fill the vehicular demand void caused by Peak Oil. Nuclear and coal generators are also useful for supplying the power grid but, once again, they are of little use in propelling vehicles, except for ships, which at least have the size to be nuclear powered. Electric vehicles may solve some problems but, with challenges with power and range, they are still very much in the future. This leaves first and second generation biofuels, some that can even be mixed with petroleum-based fuels and that are able to use the existing distribution infrastructure. The greatest hope is that ethanol, derived from such plants as corn and soy, will meet the fuel demand void for vehicles that oil will no longer fill.

Ethanol is an example of a common first generation biofuel, a fuel manufactured from sugar, grains or seeds of food crops.[101] Ethanol is not a new fuel. What may be considered "new" is the fact that it is even considered as an affordable replacement to gasoline. Henry Ford used pure ethanol fuel in his first automobile and in 1905 a vehicle was designed to run on a gasoline/ethanol mix.[102] Ethanol is considered an environmentally-friendly way to both keep vehicles on the road while reducing greenhouse gases. Some vehicle engines are now designed to burn fuel comprised of 85% ethanol, generating a greatly increased demand for it.

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[101]Griffin, *World Oil Outlook: 2009*, 47.

[102]Rubin, *Why Your World is About to Get A Whole Lot Smaller*, 99.

Ethanol is widely perceived to be the principal actor in the solution to the inevitable shortage in liquid fuels. Technology improvements such as genetic engineering seem to promise more productive crops for ethanol production. Plants and even animals might be genetically engineered to produce the right type and quantity of chemicals needed in the future bio-based economy.[103] In a 2006 United States Senate Committee on Foreign Relations hearing on American Energy Security and Oil Dependence, the American faith in an ethanol solution was clearly stated: "…the Commission believes that cellulosic ethanol holds the most potential for displacing a significant fraction of transportation oil demand within the next twenty to thirty years."[104] There is a belief that ethanol will fill the void created by dwindling oil production and will be a viable solution to the liquid fuels problem.

The popular belief that ethanol can replace our current and future liquid fuel needs is, unfortunately, a myth. Although widely perceived as a solution, there have been many studies that show that the world will use up its arable land quickly in producing fuel rather than food.[105] One-third of the United States' corn crop is already being used

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[103]Robert E Armstrong, "From Petro to Agro: Seed of a New Economy," *Defense Horizons* 20 (October 2002): 2; http://www.ndu.edu/inss/DefHor/DH20/DH_20.pdf; Internet; accessed 24 September 2009.

[104]Jason Grumet, *United States Senate Committee on Foreign Relations: Hearing on Energy Security and Oil Dependence* (Washington, DC: United States Senate Committee of Foreign Relations, Bipartisan Policy Center, 16 May 2006); http://bipartisanpolicy.org/library/testimony/united-states-senate-committee-foreign-relations-hearing-on-energy-security-and-oil-dependence.html; Internet; accessed 14 October 2009.

[105] These include BP Global, "Reserve Numbers in this Review," *Statistical Review 2009,* http://www.bp.com/sectiongenericarticle.do?categoryID=9024043&contentID=7045243; Internet; accessed 25 February 2010 and Woods Institute, "The Impacts of Large-Scale Biofuel use on Land use and Conservation," http://woods.stanford.edu/docs/biofuels/biofuels6a.pdf; Internet; accessed 10 February 2010.

to produce 6 billion gallons of ethanol.[106] The American goal is 35 billion gallons which would essentially remove corn from the feed lots and from people's tables, and may even use up arable land currently being used for other crops. This figure is still far from the United States National Research Council's 1999 report that 50% of American liquid fuel needs could be met by a domestic bio-based economy.[107] For the same reason that corn and the complex sugars it contains is so useful for making ethanol, it is likewise valued by feed lots in the production of inexpensive meats demanded by today's consumer. With corn out of the factory farm, not only will food become more expensive because of increased transportation costs but also because the cost of feeding the animals will have increased.

Since 95% of the ethanol in North America comes from corn, the cost of growing corn is worthy of examination. Corn is grown in tightly packed rows and relies upon great quantities of synthetic fertilizer and pesticides to keep it healthy. These fertilizers, in the form of ammonia, are derived from petroleum-based fuels. Indeed, 40% of the fertilizer used in the United States is used to grow corn.[108] The large factory farms rely upon large diesel driven vehicles to tend and harvest the crop. Then there is the transportation and grinding and distilling of the corn to make the ethanol. In the end, the energy input per acre of corn farm is equal to three to four tons of TNT; in other words, ethanol delivers almost the same amount of energy as it takes petroleum based energy to produce it.[109]

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[106]Rubin, *Why Your World is About to Get A Whole Lot Smaller*, 100.

[107]Armstrong, *From Petro to Agro: Seeds of a New Economy*, 2.

[108] Rubin, *Why Your World is About to Get A Whole Lot Smaller*, 100.

Further exacerbating the issues surrounding ethanol is that it is not transportable through pipelines as it is corrosive and causes gasket and seal deterioration, further increasing its costs for transportation.[110] This increased cost would make ethanol exceedingly expensive if the source material was not kept artificially inexpensive due to farm subsidies from the various state governments.[111] Ethanol's production also has a negative environmental impact as it reduces biodiversity due to mono-cropping, uses great amounts of water and, due to the increased use of cellulosic products (the stalks as well as the seeds) in its manufacture, the plants are no longer tilled back into the soil causing increased nutrient leaching.[112]

Biobutanol and microalgae both hold great promise as second generation biofuels. Biobutanol, which uses the same source materials as ethanol, employs bacteria rather than yeast in its manufacture. The biobutanol is not as corrosive as ethanol and can thus be transported in pipelines. Otherwise, however, biobutanol suffers from all the other negative points that ethanol does. Like ethanol, biobutanol also turns into a solid in cold temperatures, making it useless – at least with current technology – in aircraft that fly at high altitudes and in military vehicles that need to operate in Arctic-like conditions.[113]

Fuel made from microalgae, a true second generation fuel, takes the fat compounds from algae and renders it into fuel. This fuel does not take anything out of

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[109]*Ibid.*, 101, and BP Global, "Reserve Numbers in this Review," *Statistical Review 2009,* 1.

[110]T. Crowley et al, *Transforming the Way DoD Looks at Energy: An Approach to Establishing Energy Strategy* (Washington, DC: LMI Government Consulting, 2007), E-4.

[111]Griffin, *World Oil Outlook: 2009*, 48.

[112]*Ibid.*, 48.

[113]T. Crowley et al, *Transforming the Way DoD Looks at Energy: An Approach to Establishing Energy Strategy* (Washington, DC: LMI Government Consulting, 2007), E-4.

the world's food production and is considered a replacement for diesel.[114] Unfortunately, it, like other advanced biofuels, is still very much in the experimental phase by such reputable agencies as the US Department of Energy's National Renewable Energy Laboratory, the US Department of Defense Advanced Research Projects Agency and BP.[115] This alternative fuel is certainly not expected to be available by the 2020 time frame.[116]

Another source of synthetic fuel is coal from which liquids are created using a method called Fischer-Tropsch. The Fischer-Tropsch method, widely used by the Germans in the Second World War, is the partial oxidation of coal which creates a gas that is then used with a catalyst to produce a chain of hydrocarbons resembling oil. A benefit of this fuel is that the synthetic fuel acts much like the fuel it is designed to replace. It may be used in vehicles and aircraft and has an environmental benefit of having fewer emissions when burned than do traditional fuels.[117]

The method of production, however, does have a negative side; it uses enormous amounts of costly energy and has only recently become cost effective since the value of the synthetic fuel is so high.[118] Environmentally, it is seen as widely negative as its production creates enormous amounts of greenhouse gases. The company that manufactures synthetic fuel in South Africa, SARSOL, is recognized as being Africa's

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[114]*Ibid.*

[115]Griffin, *World Oil Outlook: 2009,* 48.

[116]*Ibid.*

[117]T. Crowley et al, *Transforming the Way DoD Looks at Energy: An Approach to Establishing Energy Strategy* (Washington, DC: LMI Government Consulting, 2007), E-4.

[118]Grumet, *United States Senate Committee on Foreign Relations: Hearing on Energy Security and Dependence,* 4.

greatest producer of CO_2, if not the single greatest contributor of greenhouse gases in the world.[119] Without carbon sequestering, the fuel is now illegal in the United States due to its perceived negative effect on global warming if it came into wide use.[120] Only through yet to be proven carbon sequestering technology might it become permitted in the United States.[121] Further, this synthetic fuel does not contain the required properties to lubricate and otherwise not damage existing gas turbine engines that are used both in ships and aircraft; thus, this potential fuel still requires improvement in chemical composition prior to being considered as a replacement to oil. Coal, too, is a limited resource and is currently used for electricity generation; with any increase in demand comes an increase in cost. Thus Fischer-Tropsch synthetic fuels do not resolve the cost issues associated with fuel production and would likely cause price increases in other energy sectors.

Many of the same cost issues surround the hydrogenation of bitumen to make it resemble crude oil. The extraction of bitumen, such as that taken from the Canadian tar sands, is costly and has an intensely negative environmental impact. Vast open pits have been excavated in the now denuded wilderness of Northeastern Alberta to extract what is considered a marginal source of oil. The only reason that it is remotely affordable to extract is due to high oil prices caused by a decreasing supply of more conventional sources.[122] The hydrogenation process of the bitumen uses a lot of energy. To make a

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[119]T. Crowley et al, *Transforming the Way DoD Looks at Energy: An Approach to Establishing Energy Strategy* (Washington, DC: LMI Government Consulting, 2007), E-4.

[120]William Mathews, "Synthetic Future: USAF Pushes Ahed with Fuel Production despite Price Drop," *Defense News* (2 March 2009): 1; http://www.defensenews.com/story.php?i=3969089; Internet; accessed 12 January 2010.

[121]*Ibid.*

[122]Rubin, *Why Your World is About to Get A Whole Lot Smaller*, 46.

single barrel of synthetic crude from the tar sands takes approximately 1, 400 cubic feet of natural gas. This poor energy rate of return is what the production of all conventional oil replacements has in common; the cost of production threatens to outweigh the energy value of the product. This energy return for energy invested is often used in literature with the acronym EROEI.[123] EROEI is defined as "…the ratio of the amount of usable energy acquired from a particular resource to the amount of energy expended to obtain that energy resource."[124]

A look at the EROEI ratios for the fuels discussed above when compared to oil reveals the shortcomings of the alternative liquid fuels. A hunter gatherer has an EROEI of approximately 10:1.[125] Thus using the low 10:1 ratio as a benchmark, a good EROEI is easily explained as anything better than this ratio. Oil, in its truly easily accessible days, had an EROEI of greater than 100:1, but by the late 1990s it had dropped to a respectable 32:1 and declined to 19:1 by 2005.[126] As oil becomes harder to find and more expensive to extract, it is estimated that it will reach the hunter-gatherer ratio of 10:1 this year.[127]

Not all ethanol and biodiesels are equal and it is the material used in their creation and even the location in which those substances are grown that affects the EROEI ratios. Corn ethanol, for example, has an EROEI of 1.8:1 if co-product crediting for the waste

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[123] EROEI or sometimes EROI (energy return on investment) is often used in fuel comparisons by the Carbon Institute, to which Heinberg belongs, as well as in distinguished magazines such as *Science*.

[124] Richard Heinberg, *Searching for a Miracle: Net Energy Limits & The Fate of Industrial Society* (Sebastapol, CA: Post Carbon Institute, 2009), 10.

[125] *Ibid.*, 25. The EROEI figures used in this paper are those deemed credible and have been chosen so as to present the most valid ratios. Those ratios that were extreme outliers were not used.

[126] *Ibid.*, 24-25.

[127] *Ibid.*

product used as animal feed is included as an energy saving value and to less than 1:1 if it is not.[128] Brazil produces the only economically competitive ethanol with a ratio of 8-10:1 using sugar cane, whereas the same process in the United States gives a value of merely 1:1 or less due to the poorer sugar cane growing conditions.[129] Biodiesel from soybeans give 1.93-3.5:1 while biodiesel from palm oil offers a favourable ratio of 9:1.[130] For synthetic fuels, Fischer-Tropsch has an EROEI of 0.5-8.2:1,[131] tar sands offer 5.2-5.8:1 and oil shale 1.5-4.1:1.[132] None of these alternative fuels offer an EROEI of greater than 10:1. Accordingly, except at high financial and environmental cost, they have very limited potential to fill the void when conventional oil, with a much greater EROEI, peaks.

Ahmed Zaki Yamani was correct when he stated that the oil age would end long before the world runs out of oil. The oil age will end when oil becomes so costly that it can no longer fuel our growth and industrialization. There will always be pockets of oil left in the world, but the cost of its extraction will necessitate a shift away from petroleum-derived fuels to something else. The problem is that there is not yet an identified energy source that can take the place of petroleum. Peak Oil will happen within a decade and the world is ill-prepared. As we start slipping down the opposite side of the global Hubbert curve, it is incumbent upon governments to make decisions on

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[128]*Ibid.*, 49 and Culter J. Cleveland, Robert Constanza, Charles Hall, and Robert Kaufmann, "Energy and the U.S. Economy: A Biophysical Perspective." *Science*, *New Series*, l 225, no. 4665 (Aug 31, 1984), 894.

[129]Heinberg, *Searching For a Miracle: Net Energy Limits & The Fate of Industrial Society*, 49 and Cleveland et al, "Energy and the U.S. Economy: A Biophysical Perspective," 894.

[130]Heinberg, *Searching For a Miracle: Net Energy Limits & The Fate of Industrial Society*, 49.

[131]Cleveland et al, "Energy and the U.S. Economy: A Biophysical Perspective," 894.

[132]Heinberg, *Searching For a Miracle: Net Energy Limits & The Fate of Industrial Society*, 52.

how fuel may be conserved until an adequate replacement is found, and, in due course, what this "adequate replacement" might be.

Part 2 – The View from the Peak

"The reason we are asking for a global energy revolution is to prepare everybody for difficult days and difficult times." – Fatih Birol, Chief Economist for the IEA[133]

This chapter will describe how oil is fundamental to the continued growth of an industrialised economy. In order to prevent economic difficulty, industrialised states will continue to compete for the limited oil remaining, as demonstrated by current foreign policies. Lastly, this chapter will argue that fuel usage, and its increase with each generation of new equipment, is a capability deficiency. With Peak Oil approaching, decisions need to be taken *now* to ensure the future viability of the Canadian Forces.

Fatih Birol, in his November 2008 interview with *The Guardian*, was referring to the difficulties that states relying heavily on energy will face in the near future unless they make the necessary changes to reduce their rates of consumption. He went on to say that states should ensure that they "…make policies ranging from the efficiency policies to research and development to get new technologies in place in a timely manner."[134] These states, with their heavily industrialized economies, as well as those states that aspire to become similarly industrialised, need to be cognisant of how, and how rapidly, they consume oil. The importance of energy security to maintain economic growth thus becomes a pressing issue. When demand begins to outstrip supply around 2020, the major industrialised states will begin to face problems that could have serious economic and societal ramifications. Birol, in acknowledging that 2020 was a likely date for Peak Oil, stated the problem succinctly when asked by the interviewer what would happen if

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[133]George Monbiot, "Interview with Fatih Birol," *The Guardian* (video); http://www.guardian.co.uk/environment/video/2008/dec/15/fatih-birol-george-monbiot; Internet; accessed 12 February 2010.

[134]*Ibid.*

the global energy revolution called for did not take place and responded that "…we will have much more difficult days."[135] He further conceded that there would be a large transfer of wealth from OECD states to the few oil producing states that may "…have many implications on the energy sector and beyond."[136] The negative effects of such a large transfer of wealth and the ramifications on complex industrialized states are illustrated in the work of Joseph Tainter discussed below.

Oil, like any principal resource used to maintain and grow ever increasingly complex societies, is required to ensure the standard of living to which modern societies have become accustomed. In his study of how societies fail, anthropologist and archaeologist Joseph Tainter explains that modern societies, like societies past, rely on energy as a major input to sustain them.[137] Oil and its predecessor coal have provided energy that has been used to replace human labour to the point that societies have been able to grow unbounded in their complexity. Tainter states that "…in the days before fossil fuel subsidies, increasing the complexity of a society usually meant the majority of its population had to work harder."[138] Tainter notes that over the past twelve millennia of

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[135]*Ibid.*

[136]*Ibid.*

[137]Joseph Tainter, *New Studies in Archaeology: The Collapse of Complex Societies* (Cambridge, UK: Cambridge University Press, 2003), 92. Tainter one of the most commonly quoted founders of Collapse Theory (referred to in Diamond, etc) and provides a typical view of collapse. His theory is similar to those supported in other works on collapse, of which there are many. Collapse Theory is unable to be covered in the depth it perhaps deserves due to the limitations of this paper, but for a good assortment of material in addition to Tainter's, read: Jared Diamond, *Collapse: How Societies Choose to Fail or Succeed* (New York: Penguin Books, 2005); Stephen Leeb, *The Coming Economic Collapse: How You Can Thrive When Oil Costs $200 a Barrel* (New York: Warner Business Books, 2007); and Carolyn Baker, *Sacred Demise: Walking the Spiritual Path of Industrial Civilization's Collapse* (Bloomington, IN: iUniverse, 2009).

[138]Joseph Tainter, "Complexity, Problem Solving, and Sustainable Societies," in *Getting Down to Earth: Practical Applications of Ecological Economics*, ed. Robert Costanga et al (Washington, DC: Island Press, 1996), 3, http://dieoff.org/page134.htm; Internet; accessed 15 February 2010.

human history, human societies have grown increasingly complex as they increase productivity, and this complexity provides societies with the advantage of improved problem solving.[139] Our development from that of small foraging and agrarian communities to highly advanced populous societies with many levels of social strata and sub-groups is the result of surpluses of food and free time in which humanity is allowed to think and invent.[140]

Increasing leisure time and improving the standard of living involves the greater consumption of resources. As each generation desires its children to have a so-called "better life," improvements in technology and innovation are fed by the principal resource of today, oil. Oil has provided a lifestyle for the industrialised states that is now desired by the emerging economies and is considered a measure of success by the burgeoning middle class in populous states such as China and India. These states, with their aspirations to secure an improved standard of living, are consuming more oil. Oil consumption, therefore, will continue to grow in order to permit the increasing complexity desired by the world as people continue to yearn for those things that offer leisure and a break from labour. There is, however, there is a downside to the complexity purchased with cheap oil.

Human history is littered with examples of once complex and highly advanced societies that collapsed. These include the Lowland Classic Maya and the more familiar Western Roman Empire.[141] They are representative of what Tainter refers to as the

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[139]*Ibid.*, 2-3.

[140]*Ibid.*, 3.

[141]Tainter, *New Studies in Archaeology: The Collapse of Complex Societies*, 12.

"fairly common process" of the collapse of complex societies.[142] The collapse of societies has followed a very predictable route. Societies first adopt simple and relatively inexpensive solutions to problems, such as farming rather than foraging, to only be replaced by more advanced methods and then manufacture. Increasing amounts of resources deliver lesser returns in improvements as simple ideas are exhausted and more complex solutions are sought.[143] When a resource shortage emerges and societies become disenchanted with leaders that are no longer able to maintain the standard of living to which they have become accustomed, societies begin to collapse. The route toward collapse is hastened by losses in revenue; military and the enforcers of society's rules and regulations become ineffective due to their own disenfranchisement or lack of leadership and the societal structure breaks down. The result, according to Tainter, is often a reversion to a more regionalized social grouping and often a drastic drop in population due to regional conflicts and malnutrition.[144]

The hypothesis argued by Tainter is supported by Richard Heinberg who believes that Peak Oil is the point at which the modern globalized society will commence its decline.[145] The states reliant on readily available and affordable petroleum will suffer first, but the entire globalized economy will suffer. Heinberg postulates that Peak Oil will be the first of the "peaks" we will see and will be closely followed by others. "Peak

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[142]*Ibid.*, 5.

[143]Tainter, *Complexity, Problem Solving, and Sustainable Societies*, 4.

[144]Tainter, *New Studies in Archaeology: The Collapse of Complex Societies*, 20.

[145]Richard Heinberg, "Life After Growth" (lecture hosted by Post Carbon Toronto, Trinity St Paul's United Church, Toronto, Ontario, March 22, 2010), with permission.

Food" may be next, as the production and shipping costs of currently inexpensive foods rise due to increased oil costs.[146]

The fundamental issue surrounding both Heinberg's and Tainter's collapse analysis is energy. A state, or indeed world, facing a shortage of a fundamental resource such as oil has basically two choices. The first is what Fatih Birol was alluding to when he said we are facing "difficult times." A state, when faced with diminishing resources, must decide which capital will be maintained with the forecast resources and attempt to maintain its capital as is, neither increasing or decreasing once specific cuts are made. This requires difficult decisions as it will mean an end to what has become the norm for states accustomed to constant growth. Capital replacement on a one for one basis rather than growth will be maintained at or slightly below resource replenishment. This will make states more frugal with their oil resources and new fuels will increase in importance with the aim of replacing oil when a suitable replacement is available. This rather utopian belief that society will embrace costly energy-conserving technology and act prior to a drastic shortage in oil is simply not supported by human history.[147]

The second option is pessimistic. This option is for states to continue to maintain their growth and to secure resources at any cost. As the depletion of resources, in this case oil, continues, states will attempt to use means such as military force to maintain their resource flow. In the case of oil, dirtier methods of extraction such as Fischer-Tropsch, shale oil and tar sands will be exploited. Only when society feels "…long and

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[146]*Ibid.*

[147]Tainter, *Complexity, Problem Solving, and Sustainable Scoieties,* 14.

protracted hardship" will the need for change be accepted.[148] If change is not accepted and no new resource inputs are found, oil gives out leading to what has been described as catabolic collapse: when most of a society's capital is turned to waste due to the lack of any resource input.[149]

Catabolic collapse is the extreme and a yet to be discovered alternative fuel discovery would mitigate the dire hypothesis proposed by Tainter. Although societies such as the Western Roman Empire suffered catabolic collapse,[150] a state that recognizes that there is a problem and aims to address it will likely to first attempt to convince the population of the need for change and then implement policies that ensure a form of rationing. This will be especially difficult in consolidated democracies whose populations are geared to short-term political and economic satisfaction. Nonetheless, collapse may still ensue as states dissolve, but populations may be spared the devastation of a catabolic collapse. The collapse analysis described here, in short, is entirely predicated on the single factor of energy and how it is used. States that ignore resource shortages or attempt to monopolise them and continue with rapid growth, are the most likely to suffer a severe collapse.

Competition for resources will inevitably occur, and conflicts may ensue as states realize that their standards of living and maintenance of their industrialized growth hinge on the diminishing resources. No two states are more aware of this than the current great superpower, the United States, and the superpower in waiting, China. The United States

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[148]*Ibid*.

[149]Greer, *The Long Descent: A User's Guide to the End of the Industrial Age*, 233.

[150]*Ibid*., 234.

currently consumes twenty-five per cent of the global supply of oil while it possesses a mere three per cent of the world's proven reserves.[151] China also is becoming more reliant on imported oil to fuel its growth. China's oil production is in decline and its domestic oil reserves are unable to meet the demands of the growing economy.[152] The competition between the United States and China for the remaining oil resources is recognized, although many believe that a direct armed conflict between the two is less likely due to the associated risks and the economic reliance the two states have upon each other.[153]

The problem with humanity in general, and thus with those who elect governments is, according to Heinberg, a tendency toward short sighted thinking and policy making which is thus an issue for OECD states.[154] Anger over high oil costs or shortages will motivate leaders to secure the resource for the populous and to postpone Birol's "difficult days." In the case of China, which is an authoritarian state with strong capitalist policies, the ability to make policies that look far into the future may serve the state well to prevent collapse. China is a "command and control economy" that is already embracing technology to help prevent the consequences of oil shortages.[155] China is also

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[151]Securing America's Future Energy, *Oil Shockwave: Oil Crisis Executive Simulation* (Washington, DC: Securing America's Future Energy, 2007); http://www.oilshockwave.com/pdf/OS_2007_Report_042808.pdf; Internet; accessed 16 October 2009.

[152]Xiongqi et al, *The Challenge and Countermeasures Brought by the Shortage of Oil and Gas in China*, 3.

[153]Daniel Yergin, "It's Still the One," *Foreign Policy* (September/October 2009): 1; http://www.foreignpolicy.com/articles; Internet; accessed 19 November 2009.

[154]Heinberg, "Life After Growth" (lecture, March 22, 2010), with permission.

[155]China Daily, "China's Energy Needs Secure, Expert Assures," http://www.chinadaily.com.cn/bizchina/2009-05/22/content_7928825.htm; Internet; accessed 23 February 2010.

able to invest greatly in oil stockpiles to ensure it does not suffer due to projected wide fluctuations in oil prices, something easily done by a state with large amounts of hard currency and a state-run oil industry.[156] Democracies may thus be more likely to be drawn into conflict as they attempt to secure the needed resources to keep their voting populations content.

States will inevitably have to make do with fewer resources and will have to come to terms with shortages. An American simulation called Oil Shockwave was conducted by former senior military and government officials of the United States in late 2007. The aim of the simulation was to examine the "…economic and national security implications of America's formidable and growing dependence on oil."[157] Using realistic challenges that could be faced in the near future, the exercise provided a fundamental warning about a modern industrialized state's reliance on oil as the principal resource feeding its economy's capital growth.

The findings of Oil Shockwave are as applicable to Canada and the rest of the world as they are to the United States. Although Canada is a net exporter of energy, Canada is not the owner of those resources and thus the state is not going to be isolated from a global oil shortage. Having the United States as its largest trading partner, Canada's future is inextricably linked to that of the United States. Indeed, difficulties encountered by the United States and the other most industrialized states will have a great impact upon the world's globalized economy. One conclusion drawn from Oil

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[156] Duncan Marvin, "China Moves to Secure its Energy Future," *Financial Post* (February 18, 2009); http://www.financialpost.com/story.html; Internet; accessed 23 February 2010.

[157] Securing America's Future Energy, *Oil Shockwave: Oil Crisis Executive Simulation*, 4.

Shockwave was that a 1.2 per cent disruption in global oil supplies resulted in a 75 per cent increase in oil prices over four months.[158] The higher oil prices, if the disruption is not corrected, will result in a recession with a shedding of millions of jobs and high inflation.[159] This shortage would not be restricted to the American economy; states such as China, that rely on cheap and available oil to ship their products would find the markets for their goods shrinking as costs increase. States everywhere would suffer inflation and the possible destabilizing effects that long-term inflation can create.

The effects of a 1.2 per cent disruption in oil supplies will wreak havoc upon the world's economies and the exercise clearly illustrates how close supply is to demand. Essentially, the world has very little room for any disruption in the supply chain and, as oil becomes more scarce, states will do all that is in their power to ensure this supply chain is not disrupted. This compels states such as the United States to "…make difficult tradeoffs between their optimal policy choices and ones that will maintain the steady flow of oil."[160]

American foreign policy, although it would prefer to be always on the side of human rights and democracy, is unable to do so as it relies on oil-exporting states that largely do not have democratic systems or follow human rights norms and covenants. The United States' close ties with Saudi Arabia is a case in point. Even Hugo Chavez, a vocal critic of the United States, still exports oil to the hungry super power. With 71 per cent of the world's oil in undemocratic or quasi-democratic states with unflattering

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[158]*Ibid.*

[159]*Ibid.*

[160]*Ibid.*

human rights records,[161] all the United States can do is attempt to say the right things without offending while maintaining its resource imports.

Like the United States, China is investing heavily in other states in an attempt to secure oil supplies ahead of competitors. It is in these supplier states that a clash may occur between the two greatest consumers of oil. China ceased exporting oil in 1993 and is expected to import 13.1 million barrels per day by 2030.[162] China is attempting to secure a share of the world's remaining oil reserves as the Chinese state run PetroChina continues to purchase or invest in oil projects around the world. In Canada, in what Canada's Industry Minister Tony Clement called a "net benefit to Canada," China has purchased two oil sands projects in Alberta.[163] Gaining control of 60 per cent of Athabaska Oil Sands Corporation ensures China has a firm foot hold in Canada's 175 billion barrels of reserves – the world's second largest oil reserve and the largest unconventional.[164] China is also investing in such conflict-torn areas as Angola, the Republic of Congo, Equatorial Guinea, Sudan, Chad, Nigeria, Algeria and Gabon.[165] PetroChina's investment in the oil reserves of many of these states is sought after and welcomed for the aid and additional infrastructure that accompanies Chinese investment. Moreover, the Chinese policy of "non-interference in internal affairs" and a belief in that states are "masters of their own affairs" means China does not tie investment and aid with

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[161] Stephanie Hanson, *Council on Foreign Relations Backgrounder: China, Africa, and Oil* (Washington, DC: Council on Foreign Relations, 2008), 2; http://www.cfr.org/publication/9557; Internet; accessed 26 January 2009.

[162] *Ibid.*

[163] British Broadcasting Corporation, "China's PetroChina Invests in Canada Oil Sands," BBC; http://news.bbc.co.uk/2/hi/8434603.stm; Internet; accessed 26 January 2010.

[164] *Ibid.*

[165] Hanson, *Council on Foreign Relations Backgrounder: China, Africa, and Oil*, 2.

discussions on human rights and democracy.[166] China believes that to interfere in domestic affairs is a violation of the rights of a sovereign state.

Thus, China and the United States are both vying for their share of the oil in Africa and the Middle East. On the downward slope of the world's Hubbert Curve, where even a brief disruption to supply can spell problems for major economies, the stability of the exporting states is of vital concern. As exemplified by Sudan, if a state is unhappy with American politics, intervention, or the conditionality associated with Western donors, it may choose to sell oil to China and accept Chinese investment. In this respect, the "Washington Consensus" has been replaced by the "Beijing Consensus."[167] On the other side, the United States may be able to use its economic or military power to reduce supplies to China in order to keep a greater share for themselves. In either case, the state which suffers will look upon this as a risk to its national security and may be forced to act, increasing the risk of regional conflicts. Likewise for the Middle East, states such as Saudi Arabia, which have become accustomed to a standard of living paid for by oil may, once their resources peak and decline, find it difficult to maintain the benefits their people have historically enjoyed. Indeed, since enormous amounts of oil are used in desalination, the supply of water will decrease as a greater share of the dwindling domestic production is committed to the maintenance of export levels, resulting in an unhappy population. This is a risk in many of the Middle Eastern states

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[166]Ministry of Foreign Affairs of the Peoples' Republic of China, *China's position on Establishing A New international Political and Economic Order*, 1, http://www.fmprc.gov.cn/eng/wjdt/wjzc/t24883.htm; Internet; accessed 23 March 2010.

[167]Ellen Lammers, "How Will the Beijing Consensus Benefit Africa?" *The Broker Online* (March 22, 2007), 1; http://www.thebrokeronline.eu/en/articles/How-will-the-Beijing-Consensus-benefit-Africa; Internet; accessed 23 March 2010.

that rely on desalination for their water. The comforts that cheap oil has brought to the region will end and the public tolerance for the current dictators may wane.

Remaining reliance on oil imports as supply increasingly falls short of demand will create greater global instability. In the American report, "Powering America's Defense: Energy and the Risks to National Security," it was determined that "…the market for fossil fuels will be shaped by finite supplies and increasing demand. Continuing our heavy reliance [on oil] is a security risk." [168] This has been recognized for over thirty years. The risk of another state impeding the ready American importation of oil from the Middle East was made clear in the 1980 State of the Union Address by President Jimmy Carter. The address was made at a time when there was a belief that the Soviet Union might attempt to gain control of the Middle East through the invasion of Afghanistan. In his address, Carter stated that any Soviet attempt to exert control in this region of American influence "…will be regarded as an assault on the vital interests of the United States and…will be repelled by any means necessary, including military force."[169] This offers some insight into American foreign policy in the region, evident by American invasion of Iraq and the First Gulf War. The American reliance on oil "…has severely distorted and crippled [their] foreign policy options abroad."[170] If taken in the context of China attempting to gain control of the Gulf Region or any other region that the United States considers in its national interest, the risk of military involvement is evidently high.

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[168]Griffin, *World Oil Outlook: 2009,* vii.

[169]J. Carter, "State of the Union Address, 1980," *Jimmy Carter Library,* 2; http://www.jimmycarterlibrary.go/documents/speeches/su80jec.phtml; Internet; accessed 26 January 2010.

[170]Jeffrey Eggers, "The Fuel Gauge of National Security," *Armed Forces Journal* (May 2005)*;* http://afji.com/2008/05/3434573; Internet; accessed 14 October 2009.

The regions of interest to the United States include Africa, the Middle East and Canada. Indeed, much of American energy policy is now looking firmly north at the potentially abundant supplies from Canada's tar sands. The risk of conflict in the former two is currently much higher than in Canada due to Canada allowing outside investment and the limited state controls placed on those who invest in Canada's natural resources. Current federal government policies permit both China and the United States to invest in Canada's free market, but neither state will be allowed to gain total control. Today, the greater risk, therefore, is of regional conflicts elsewhere. This may not remain so as supplies become less available and more difficult to attain and it is logical to assume that Canada's tar sands will become more important facets of other states' foreign policies. Canada may be forced to make decisions that side with one state over another that may lead to conflict in the political and economic realms and may even lead to foreign military incursions. A well equipped and capable armed force to conduct the military interventions that will be required to safeguard oil supplies is thus a necessity. The cost is great. The American cost in 2003 of ensuring the free flow of oil from the Persian Gulf was USD $44.4 billion, and in the time of conflict this will be multiplied many fold.[171]

The current fuel usage of a modern military should be considered as a capability deficiency. Nowhere is this better exemplified than in the United States. As Canada uses much of the same equipment, proportional to our size, it is worth analysing American fuel usage as it will, due to our reliance on American military technology and equipment,

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[171]Paul Boyce, "Army Announces Historic Electric Vehicle Release," http://www.army.mil/newsreleases/2009/01/12/15707-army-announces-historic-electric-vehicle-release; Internet; accessed 26 January 2010.

be relative. During the Second World War, each soldier consumed approximately 4.5 litres of fuel per day. By the First Gulf War in 1990, this had increased to 18 litres. By 2006 in Afghanistan, the American military was consuming almost 73 litres per soldier per day.[172]

The American Department of Defense (DoD) is the largest single consumer of oil in the world.[173] The American military has become so reliant on oil that fuel now constitutes 70 per cent of the supply weight in support of the United States Army in battle.[174] In 2008, the DoD consumed on average 350 000 barrels of oil per day of which 75 per cent went to fuelling vehicles.[175] This heavy reliance on a fuel heavy supply chain has led some, including United States Marine Lieutenant General James Mattis, to publicly state that armed forces must become less reliant on fuel.[176]

The long and threatened fuel convoys that require armed resources to protect them pose a weak point in logistics support to modern Western militaries.[177] The effective sustainment of the operators and fighters in the forward areas is a critical function of any military operation planning and execution. A certain absurdity of the protection of these large fuel convoys is the fact that, in a study of a Marine Expeditionary Unit in Iraq in

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[172]Mathews, *Synthetic Future: USAF Pushes Ahead with Fuel Production Despite Price Drop*, 2.

[173]Sohbet Karbuz, "U.S. Military Energy Consumption," 3, http://www.karbuz.blogspot.com; Internet; accessed 6 April 2009.

[174]Bryan Bender, "Pentagon Study Says Oil Reliance Strains Military: Urges Development of Alternative Fuels," *The Boston Globe* (May 1, 2007); http://www.boston.com/news/nation/Washington/articles/2007/05/01; Internet; accessed 14 October 2009.

[175]Karbuz, "The US Military Consumption in 2008," 3.

[176]NRAC Future Fuels Study Panel, "Breaking the Tether of Fuel," *Marine Corps Gazette* 90, no. 8 (2006), 49-53.

[177]Center for Naval Analyses, *Powering America's Defense: Energy and the Risks to National Security*, 9.

2003, only 10 per cent of the fuel consumed by ground vehicles went to the deliverers of lethal force such as tanks and other armoured vehicles. The remainder was used by large trucks and logistics vehicles delivering the supplies and conducting the force protection.[178] A model of efficiency it is not.

An excellent example of how fuel costs can become a capability deficiency is by examining a modern warship. A ship built today using the common engine layout of two gas turbine engines and a cruise engine can burn, at maximum speed, approximately 56 barrels of oil per hour. At the current USD $75 per barrel of crude, diesel costs USD $92 a barrel without any taxes and only including average transportation and refining costs.[179] This gives a cost per hour of USD $5152. If the price of fuel doubles, as is conservatively estimated by the EIA, the resulting impact on budgets is obvious.[180] As the markets become increasingly volatile, the risks of erroneously planning fuel consumption in the budget may become problematic. An example of this occurred in 2007 when, as reported by the Canadian Broadcasting Corporation, the East Coast Canadian Fleet was tied up and not deploying HMCS Halifax due to the increase in fuel costs and the inability of Maritime Command to anticipate the demands on the fuel budget in the fourth quarter.[181]

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[178]*Ibid.*, 9.

[179]Transportation Business Associates, "Crude Oil Versus Diesel Prices," http://www.tbabz.com/CrudeOilDieselPrice.htm; Internet; accessed 27 January 2010.

[180]Energy Information Administration, *International Energy Outlook: 2009*, 2.

[181]CBC News, "'Navy Patrol Can Go Ahead,' O'Connor Says," http://www.cbc.ca/canada/nova-scotia/story/01/17/navy-tieup.html; Internet; accessed 26 February 2010.

It can be deduced, therefore, that as militaries become more technologically advanced with larger and more complicated vehicles, the rate of fuel consumption, if left unchecked, will only increase. This increase in fuel demand, coupled with a general global demand that suffers from a lack of supply, will negatively influence military budgets due to soaring costs of operation. The jet fuel that costs so much now will only get more expensive and there is no suitable replacement envisaged, despite trials with biofuels and other synthetics.[182]

The current fuel usage and its increase over time should be a concern to the Government of Canada. Canadian major capital purchases of ships, ground vehicles and aircraft should be made with a full knowledge of the length of time these vehicles will be in use and their resultant costs of operation over their life spans when the economic effects of Peak Oil come to fruition. This capability deficiency should be addressed with each new vehicle purchase and should be factored into the lifetime operations cost of proposed new purchases.

As major capital equipment replacement can take a very long time, decisions rendered now in the options analysis and definition phases of a project will have considerable effect decades into the future. The nature and composition of the military of the future will be greatly affected by the future supply and cost of fuel. Militaries such as Canada's tend to purchase military vehicles and then retain them for long periods of time. Indeed, Canada operates ships that are almost forty years old and flies fighter airplanes

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[182]Richard Fullerton, "The Future: Oil, America, and the Air Force," http://airpower.maxwell.af.mil/airchronicles/apj/apj05/win05/fullerton.html; Internet; accessed 24 September 2009.

that were purchased in 1980.[183] Clearly, vehicles purchased today should logically be expected to remain in the inventory for approximately thirty years. With Peak Oil expected to occur around 2020, procurement of energy efficient vehicles must be considered *now*.

An example of how long it takes to purchase a major piece of equipment in Canada under current guidelines is seen with the Arctic Offshore Patrol Ship. This ship, a desired item by the current government, has not been slowed down for any reason as sufficient funds have been allocated and personnel are working hard on the project. Despite this, the project has been mired in staff work and various levels of approval boards for more than three years and still has not begun to cut steel. The ship is expected to be delivered in 2014, seven years after its official announcement, which is considered excellent by the project staff when a programme staffs are accustomed to twelve to eighteen years to complete a project.[184] Operational deployment of the Arctic Offshore Patrol Ship (AOPS) will likely take more time after delivery due to the acceptance trials. All this time is for a ship that is largely civilian specified and that will not to be classified as a combatant.

The length of time it takes to purchase a major warship, such as the required replacement for the Halifax Class Frigates and the older destroyers, is amply demonstrated by the many projects that have been commenced and recommenced over the past decade. None of these have yet been able to move into definition, although the

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[183]Allan Ng, "The CF 18 Hornet Fighter," *Canadian American Strategic Review*, http://www.casr.ca/id-cf18-4.htm; Internet; accessed 27 January 2010.

[184]Henrick Ouellet, email communication with author, 9 February 2010, full text available upon request. It is not known how fuel efficient the ship will be as it has range and speed specifications that may be met in any manner by the builder.

current Canadian Surface Combatant Project does appear promising. This ship will not likely begin construction until 2020, although funds have already been committed through the Canada First Defence Strategy. This ship, that could arrive just as the world's oil supply peaks, could be obsolete before delivery if fuel consumption decisions are not taken early that would ensure its viability for a thirty to forty year lifespan.

The issues surrounding Peak Oil and the resultant increase in fuel costs need not be as dire as some of the pessimists who support catabolic collapse theory would have us believe. There is much that can be done and has been done by other states to ensure proper preparations are taken to mitigate issues such as those that the Canadian Forces will face. It is only through the preparation for "difficult days" and "difficult times," as Fatih Birol cautioned, that the Government of Canada will ensure its forces are ready for the challenges of the future.

Part 3 – Preparing for the Post-Peak World

***"...with respect to the long-term question of our vulnerability to oil dependence….we now really need to not just turn this into a conversation, but turn it into a serious plan and execute against that plan."* –** Robert E. Rubin, Former United States Secretary of the Treasury.[185]

Many oil producing states are fragile due to reliance on a single resource and will likely be the seat of future conflicts which will necessitate military intervention by Western states including Canada. Fuel inefficiency has resulted in problems in the recent past and, to prevent future problems, fuel efficiency solutions are necessary. Some potential solutions will be suggested. Although Canada has yet to place fuel efficiency at parity with other high level requirements, it will need to do so in order to preclude untimely obsolescence.

Just as the dwindling supply of oil poses a risk to national security, fuel renders military operations vulnerable, a situation that will only intensify with Peak Oil. Not only are Canada and other Western economies dependent on imported oil but, as has been shown in the previous chapter, oil dependency is increasingly hindering foreign policy decisions as Western states take care not to estrange oil producing regimes. The states that produce the majority of the oil imported by the West tend to be wracked with territorial disputes and violence incited by special interest groups.[186] States that rely on resources such as oil as their primary source of revenue also have the highest levels of conflict.[187] These disputes are exacerbated by the fact that many of these states are

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[185]Quoted in Yergin, *It's Still the One*, 1.

[186]Le Billon, Phillippe and El Khatib, Fouad, "From Free Oil to 'Freedom Oil?' Terrorism, War and US Geopolitics in the Persian Gulf," http://www.geog.ubc.ca; Internet; accessed 2 January 2010.

[187]Paul Collier, "Greed and Grievance in Civil War," http://www.csae.ox.uk/workingpapers.pdfs/2002-01text.pdf; Internet; accessed 2 January 2010. Collier's

authoritarian and spend great sums of money on military armament that results in less oil revenue being distributed to an often disenfranchised population.[188]

Military operations in areas from which oil is exported will become a paradigm of our times as future conflicts will tend to involve states that are exporters of oil. As the supply of oil dwindles, these regional conflicts will become increasingly relevant to Western interests, thus escalating the risk of a clash between great powers as proposed in Part Two of this paper. Even if Western states do not intervene directly, the interruption of the existing supply or removal of any spare capacity will create economic fallout in oil dependent states.[189]

If, as appears likely, conflicts will not disappear in the future, Canada, as an ally and active partner with many Western States such as the United States and NATO, will be engaged in foreign deployments. What these deployments will look like is entirely speculative but, suffice it to say, the conflicts will involve modern equipment that, as it is sent great distances, will come with a high financial burden and the risks posed by a long supply chain. In this respect, Afghanistan may be a harbinger of things to come.

The increased cost of oil, compounded by the fuel inefficiencies of military equipment, will result in a greater percentage of Canada's military budget being allocated to fuel and will make sustained operations more costly. A four percent shortfall in the

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work is an example of the voluminous work on what is often termed the "resource curse." For more see also Richard Auty, *Sustaining Development in Mineral Economies: The Resource Curse Thesis* (New York: Routledge, 2001); Macartan Humphreys, Jeffrey Sachs and Joseph Stiglitz (eds), *Escaping the Resource Curse* (New York: Columbia University Press, 2007); and Michael Ross, *Timber Booms and Institutional Breakdown in Southeast Asia* (New York: Cambridge University Press, 2001).

[188]Le Billon and El Khatib, *From Free Oil to 'Freedom Oil?' Terrorism, War and US Geopolitics in the Persian Gulf,* 6.

[189]National Academy of Sciences, *Improving the Efficiency of Engines for Large Nonfighter Aircraft: Committee on Analysis of Air Force Engine Efficiency Improvement Options for Large Non-Fighter Aircraft*, http://www.nap.edu/catalog/11837.html; Internet; accessed 27 January 2007.

global oil supply will cause the cost per barrel to increase to near USD $200.[190] The Government of Canada must act now in order to alleviate the impact of this forecasted increase in operating costs on future operations. If Canada and other oil dependent states do not take timely action it may "…be too late to avoid considerable discomfort or worse."[191]

The weapons and support systems employed by the navy, army and air force are high energy users and thus require constant and planned deliveries of fuel.[192] The more oil needed at the front drives more oil in the supply chain that, in turn, requires more oil for the conduct of force protection. This spiral can only be slowed by reducing the use of fuel by the front line users. Ninety per cent of the oil used by a Marine Expeditionary Unit was for logistics and the force protection of a logistics column that used seventy percent of its carrying capacity transporting fuel.[193] Even a small reduction, therefore, of the fuel usage by front line users would have a significant effect upon the supply chain and force protection requirements.

The limitations on the freedom of action that devolve upon a commander dependent on oil were exemplified during the First Gulf War in 1991. General Paul Kern, the commander of the Second Brigade of the 24th Infantry Division in that war, was responsible for racing across the desert to surprise Iraqi formations from behind. He was

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[190]Hirsch, *Testimony on Peak Oil before the House Subcommittee on Energy and Air Quality*, 12.

[191]*Ibid.*, 14.

[192]Center for Naval Analyses, *Powering America's Defense: Energy and the Risks to National Security*, 45.

[193]*Ibid.*, 9.

less concerned about the elite Iraqi units he would face than "running out of fuel."[194] The tanks that Kern commanded were so inefficient that, in order to ensure they never went below a half tank of fuel and were thus always prepared for contact with the enemy, they had to stop every two and a half hours to refuel. The supply chain feeding the attack was such a weakness, Kern noted, that the logistics demands "…drive tactical planning. They determine how you fight. More efficiency can give you more options. That's what you want as a commander."[195]

Fighting insurgencies requires greater tactical manoeuvre than seen in the First Gulf War as the enemy is everywhere and one never is sure when contact will be made. For a commander to retain flexibility as to how and when a battle will be fought will be constrained not only by the enemy but also by his fuel supply, potentially leaving the commander with reduced options for an optimal tactical solution. With greater fuel efficiency, the restrictions of the supply chain will be reduced, allowing more flexibility in the fight.

Many states who stand to suffer greatly from Peak Oil have already determined to make themselves less susceptible to the detrimental effects of a liquid fuels shortage. The European Union intends to reduce its dependence on oil by twenty per cent by 2020.[196] The research on alternative fuels for the world's largest consumer, the United States, will only serve to benefit those who wish to become more fuel independent.

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[194]*Ibid.*, 14.

[195]*Ibid.*, 14.

[196]Griffin, *World Oil Outlook: 2009*, 36.

The American military is investing heavily in research into fuels that can be used in existing equipment, otherwise known as legacy systems. As the leader in this field and the manufacturer of much of the equipment the Canadian Forces uses, what is achieved by the Americans could be capitalized on by Canada. The promise of synthetic fuels such as those using the Fischer-Tropsch method and other unconventional sources such as heavy oil and bitumen are being seized upon as a potential panacea by American policy makers as possible methods to ensure a fuel supply to the military. In the *Energy Policy Act of 2005* that was passed to "…ensure jobs for our future with secure, affordable and reliable energy," the strategy of increasing American energy independence was emphasised.[197] The *Energy Policy Act* directed the military to devise a plan to use fuel manufactured in the United States and produced partially or entirely from coal, shale oil and tar sands.[198] This fuel, however, must be manufactured in such a fashion that it does not increase the amount pollution produced.[199] The American military seized upon this and experimented with synthetic fuels derived using the Fischer-Tropsch method to fuel its aircraft.

A successful test of a 50-50 blend of synthetic fuel was recently conducted in a B-52 bomber, proving the fuel's viability.[200] This test provided no new information as these fuels had been widely used by Germany during the Second World War.[201] Currently, the

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[197]United States of America Public Law, "Energy Policy Act of 2005 – 109-58: 2398 (a)," http://www.epa.gov/oust/fedlaws/publ_109_058.pdf; Internet; accessed 2 February 2010.

[198]*Ibid.*, 2398a(a).

[199]*Ibid.*, 2398a(a).

[200]Crowley et al., *Transforming the Way DoD Looks at Energy: An Approach to Establishing Energy Strategy*, E-1.

issue with production of the Fischer-Tropsch fuel is with the environmentally important problem of carbon capture. With increased global environmental awareness, the debate is still open on such highly polluting production methods as Fischer-Tropsch, as well as on the pollution generated with exploitation of the tar sands and in drilling in such environmentally sensitive regions as the Arctic National Wildlife Refuge in Alaska.[202] In the event of a conflict or another national emergency, such as running out of oil, Fischer-Tropsch fuel would likely still be employed despite any ability to properly sequester the CO_2 during its manufacture. Likewise, the exploitation of resources with other large environmental price tags would also probably take place.

As indicated in the discussion of Fischer-Tropsch synthetic fuel above, fuel efficiency, as a capability deficiency is being addressed by the American military through heavy investment in research and development.[203] Some "success" has been identified by

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[201]C. Taylor, J. Baltrus and R. Gormley, "R & D Facts: Fischer-Tropsch Fuels," http://www.netl.doe.gov/publications/factsheets/rd/R&D089.pdf; Internet; accessed 12 January 2010.

[202]ANWR.org, "ANWR Oil – Politics and Logistics," http://www.anwr.org/Background/ANWR-Oil---Politics-and-Logistics.php; Internet; accessed 10 February 2010.

[203]It is difficult to obtain verifiable empirical data providing how much is being spent per annum on this research. Research is funded by various departments and at many levels of the military through both military and civilian research laboratories.

reducing fuel usage in buildings (illustrated in the graph below):

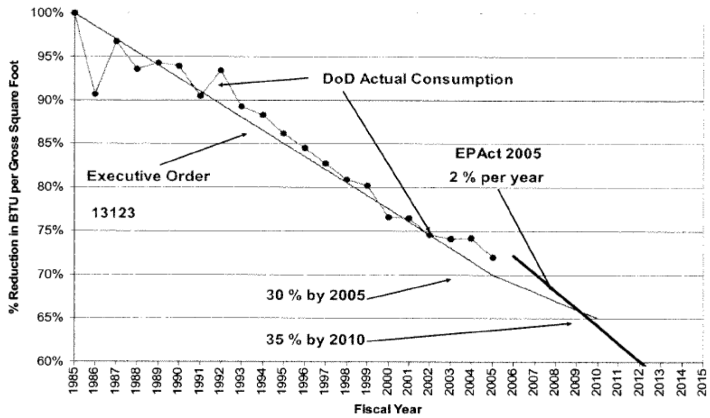

Fig 3.1 – American Military Fuel Consumption Reduction

Source: Crowley et al, *Transforming the Way DoD Looks at Energy: An Approach to Establishing Energy Strategy*, E-1.

Figure 3.1 depicts the success of energy saving programs for existing infrastructure. Although much of this was accomplished through fuel saving initiatives, what cannot be discounted is the fact that much of the reduction came from the closure of military bases, privatization of buildings or outsourcing other energy consuming activities to contractors.[204] While some of these activities may result in real reductions of fuel use, some merely change the accounting structure and do nothing to reduce fuel consumption.

In order to further reduce the costs of operating non-combat vehicles, the American military is investing heavily in hybrid vehicles and American companies are currently developing prototypes of electric hybrid vehicles for use by the military.[205] An example is the purchase and trial of electric vehicles, including the possibility of a one

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[204]Karbuz, *The US Military Consumption in 2008*, 2.

[205]IT.TMCNET.com, "U.S. Army's TARDEC to Showcase Alternate Energy Vehicle Technology at 2010 North American International Auto Show," http://it.tmcnet.com/news/2010/01/07/4564492.htm; Internet; accessed 2 January 2010.

ton cargo capacity truck, from Bright Automotive in Indiana.[206] The electric drive vehicles will use electricity stored in a vehicle battery using energy produced from non oil sources.

As promising as the savings may be from consolidating buildings and saving fuel costs by switching to hybrid drives for non-combat vehicles, it is through actual increases in fuel efficiency of combat vehicles that real reductions to the vulnerability of deployed troops and the safeguarding of freedom of action for commanders in the field will be realized. The American military is aiming to improve fuel efficiency and, as has been discussed earlier, the fuel efficiency of combat vehicles is foremost in the minds of senior American military officers. This approach may not yet be wholly recognised by procurement decision makers in Canada. If a vehicle consumes so much fuel that it becomes difficult to operate in theatre, it will require replacement by a vehicle that is sustainable using less fuel dependent supply lines. As will be discussed below, fuel efficiency will in the future be of equal or more importance than weaponry and speed.

In the face of Peak Oil, the Canadian Forces needs to place the priority of fuel efficiency at a level equal to, or perhaps greater than, the maximum speed of the vehicle or even the types of weapon systems carried. That this is not the case, yet, is evident in both current major capital projects for land and maritime procurement. In correspondence with the author, the Department of Public Works and Government Services Canada representative attached to the LAV III Upgrade Project stated that fuel economy has been a consideration and given a level of priority with the contractor in that

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[206]Emma Ritch, "Bright Automotive Scores Military Contract," http://cleantech.com/news/5207/bright-automotive-scores-military-contract.htm; Internet; accessed 2 January 2010.

Project.[207] Despite this, speed and endurance are still considered more important than fuel efficiency, as are agility and mobility. Indeed, rather than increasing range through fuel efficiency, larger fuel tanks may be the method of addressing the issue.[208] It is thus clear that, in this project, the ranking of priorities places many other vehicle characteristics ahead of fuel efficiency.

The same solution is evident off-shore in the example of the American Abrams tank purchased by Australia. This fast and highly mobile vehicle is praised for its excellent crew protection; however, it consumes fuel at rates that can be as poor as 200 metres a litre, necessitating a 2 200 litre fuel tank. The Abrams tank was defended in the Australian media after purchase of the vehicle to replace aging Leopard Is, as the fuel capacity of the Abrams allows the vehicle to have a range similar to that of the Leopard. Additionally, Australia purchased eight large refuelling trucks in an effort to ensure that the tanks would not run out of fuel in operations.[209] Australia thus intentionally increased the size of its required supply chain and, therefore, the force protection that supply chain will need, making the Australian Army that much less energy efficient and therefore more vulnerable to attack. It was indeed a short sighted purchase once the cascading effects of Peak Oil are considered.

A priority ranking structure similar to that of the LAV III Upgrade Project is also being used for maritime projects. The Project Manager for the Canadian Surface

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[207]Hugo Lalonde, email correspondence with the author, with permission, 29 January 2010, full text available upon request.

[208]*Ibid.*

[209]Mark Dodd, "Army's $500m Abrams Tanks in the Wars," *The Australian,* September 23, 2006, http://www.theaustralian.com.au/news/nation/armys0500m-tanks-in-the-wars/story-e6frg6nf-1111112255764; Internet; accessed 10 February 2010.

Combatant Project informed the author that, currently, naval staff both inside and outside major capital projects wrestle with what are termed Key User Requirements, that is, requirements that must be met and are prioritized from the most required to the least.[210] As yet, these requirements have not been stipulated for a project destined to recapitalize the Canadian Fleet. It is the aim to have the Statement of Requirements document rank the requirements so as to clearly stipulate what may be dropped if costs become too high.[211] The Canadian Surface Combatant Project Manager, in his knowledge that fuel economy will be important in the future, confirms that the Americans are doing much research that will benefit Canadian naval projects. He states that Canada will "…get to benefit from the sunk cost of non-recurring engineering that others are doing to improve fuel efficiency in various systems."[212] It is therefore clear that fuel economy is known to be crucially important by the Canadian Navy but the degree to which it is and what capability would be displaced by fuel economy remains very much in debate at both the operational and strategic levels. According to Heinberg, the political level in the United States is also unaware of the importance of fuel economy. Heinberg notes that in military planning, the government's unstated assumptions of readily available fuel and resources, as well as continued increases in technology may be fallacies that must be addressed.[213]

One of the systems that has been identified by ship designers as requiring improvement in efficiency is propulsion gas turbine engines in medium sized surface

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[210] Patrick Finn, email correspondence with the author, with permission, 1 February 2010, full text available upon request.

[211] *Ibid.*

[212] *Ibid*.

[213] Heinberg, "Life After Growth" (lecture, March 22, 2010), with permission.

ships. In modern warships, gas turbine engines that have been developed from those used in aircraft have become ubiquitous in the world's modern naval fleets, despite their fuel inefficiencies.[214] Canada, like many Western states, uses the 1960s designed LM2500 gas turbine in its ships.[215] This aging power plant could be replaced in the short term with an engine such as the WR-21 gas turbine that has compressor inter-cooling and exhaust heat recuperation systems that reduce marine diesel consumption by sixty per cent at the lower speeds to seventeen per cent at maximum speed.[216] This engine was designed to replace the LM2500 in that, although it has slightly more horsepower, it is able to fit in the same footprint as the older engine. It is thus evident that new technologies currently exist to replace legacy systems in current ships and to dramatically reduce fuel consumption. As Canada's current fleet is only now reaching midlife, it will remain in service for twenty or more years. As fuel supply will become increasingly costly in this timeframe, the ability to replace legacy engines with more fuel efficient replacements will become more important.

Improvements in ship design that allow for increased fuel efficiency in the way of retrofit include bulbous bows and stern flaps. Bulbous bows, common on commercial ships for many years, have become more popular in naval designs and have found wide acceptance in many recently launched warships.[217] The Unites States Navy has

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[214]Steven Ashley, "Fuel-Saving Warship Drives," *The American Society of Mechanical Engineers: Mechanical Engineering Power* (August 1998), 1, http://www.memagazine.org/backissues/membersonly/aug98/features/fuelsav.htm; Internet; accessed 26 February 2010.

[215]*Ibid.*, 3.

[216]*Ibid.*, 4.

concluded that the addition of a bulbous bow on a destroyer could reduce fuel consumption by 3.9 per cent, a saving of 2 400 barrels per year per ship.[218] In addition, if a stern flap is affixed to the ship in the form of a small plate that lengthens the bottom of the hull, a further 6 to 7.5 per cent savings in fuel may be realised.[219] Stern flaps, being relatively inexpensive, have been included in the Canadian Halifax Class mid-life refit in order to increase fuel efficiency.[220] The technologies described here, however, are suitable for retrofitting current inefficient vessels and, although useful in future designs, they will not in and of themselves generate the levels of improved fuel efficiency required in naval platforms in the post Peak Oil era.

Regardless of the efficiencies realised with new gas turbines, whether in tanks or ships, the eventual necessity to use engines such as incredibly efficient high speed diesels will become more the norm in a future of constrained fuel resources. Diesel generators may be used to create electricity to propel a ship with an electric rather than mechanical drive system. The great amounts of electricity produced by this type of ship will allow for sophisticated sensor and weapon suites that increasingly have greater power loads while concurrently providing greater fuel efficiency than gas turbines.[221] This form of propulsion is gaining favour in many navies.[222]

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[217]Ronald O'Rourke, *Navy Ship Propulsion Technologies: Options for Reducing Oil Use – Background for Congress* (Washington, DC: Congressional Research Service, 2006), CRS-5.

[218]*Ibid.*

[219]*Ibid.*

[220]Yves Perron, "Frigate Life Extension and the Halifax Class Modernisation Overview," http://www.forces.gc.ca/aete/documents/FELEX_Industry_Day_Brief-eng.pdf; Internet; accessed 26 February 2010.

[221]Committee for the Role of Experimentation in Building Future Naval Forces, "Technology for Future Naval Forces: Electronic Power and Propulsion," *The Role of Experimentation in Building Future*

Another possible future contribution to maritime fuel efficiency would be to favour smaller vessels over the larger. To facilitate deployments of vessels in the post Peak Oil world, vessels will have to be highly fuel efficient and less reliant on large quantities of fuel. Smaller, lighter ships propelled with efficient electric or diesel engines may, in the interests of fuel efficiency, not have the high speeds currently available to the turbine driven vessels of today. Lighter ships may constrain armament options, but the overall result may be a fleet with more options available in its operational and tactical employment as it will be less dependent on its supply chain.

The future will demand increasing efficiencies both with legacy equipment that will continue to be operated post peak and with equipment yet to be acquired. These efficiencies will be required for a future wracked by conflict over resources and the insecurity of oil producing states. To safeguard their economies, states must make decisions now on their defence capital acquisitions to ensure the viability of their forces in a future of dwindling oil supplies. Synthetic fuel will help rectify some supply issues in the future as will some infrastructure changes that may provide some early opportunities to save energy. In the short term, technological updates and refits to legacy equipment may ease consumption rates and reduce budgetary pressures. In the longer term, however, an advanced weapon system will prove next to useless if it cannot be deployed effectively due to the fuel inefficiency of the platform. Indeed, long term solutions, initiated now by force development staffs, will ensure the viability of our military forces in the tumultuous world of tomorrow.

Naval Forces (Washington, DC: National Academies Press, 2004), 1, http://www.nap.edu.html/tech_21st/t8.htm; Internet; accessed 2 January 2010.

[222]*Ibid.*

Conclusion

The peak of oil production, coupled with the forecast increase in world demand, necessitates decisions *today* in order to ensure the viability of Canadian Forces operations *tomorrow*. Peak Oil poses both risks and opportunities to governments and to the people they govern. The end of the oil age is approaching rapidly and, although oil will remain in the ground, its scarcity and resultant cost will be such that industrialized states such as Canada need to prepare now. A review of the theories behind Peak Oil demonstrates that the demand for oil will outstrip production rates in about 2020 and that a constant rate of oil production will not be maintained beyond 2020, giving a sense of urgency to the preparations states must make. A suitable liquid fuel replacement for oil has yet to be discovered, nor are any reliably envisaged in the foreseeable future. Ethanol and biodiesel, regardless of their source materials, simply do not offer the EROEI required to compete with oil. Despite this, synthetic fuels may help alleviate initial critical shortages in the short term, although their high cost and limited supply will not solve all supply issues.

Collapse theory and apocalyptic predictions aside, it is clear that with oil remaining the principal resource in maintaining the economies of both existing and emerging industrialized nations, the risk of conflict is increased as supplies dwindle. The potential for conflict and Canada's potential involvement in those conflicts proves the requirement for a capable armed force in the future. These conflicts will have to be fought using equipment that has been designed to be sustained in a fuel-strapped world and, thus, fuel consumption must be considered early by those responsible for military procurement. The weighting of the fuel efficiency requirement must be adequate to safeguard the equipment against early and untimely obsolescence. In the mere ten years before Peak Oil, governments such as Canada's need to act quickly and make the critical decisions now that will ensure the fuel efficiency of legacy and future equipment.

Reliance upon limited fuel resources drives logistical requirements that, in turn, impact a commander's freedom of action. The conflicts of tomorrow will be similar to those conducted today in that they will occur in distant lands which will, in turn, necessitate long fuel dependent supply lines. Militaries can and must make a difference in their fuel consumption rates. There are technological changes that can be made today to naval, army and air force legacy equipments that will save fuel in the near term; more significant technological improvements and, perhaps, design limitations on capability will reduce fuel consumption rates in the longer term. Decisions on prioritizing capability requirements, especially rating fuel efficiency against other key requirements including protection, weight, speed, and armament, are always difficult but, to ensure the viability of Canada's military in the future, these issues must be addressed and the decisions implemented now.

The future need not be regarded as bleak but as urgent. Facing the challenges of Peak Oil now will offer opportunity. As the oil age draws to a close, and the difficult days and times forecasted by the IEA dawn, it is clear that forward looking governments, with the interests of their people foremost in their considerations, will be in a position to develop strategies that can be executed now to safeguard the state in the future. These strategies will include the military. The Canadian Forces, properly prepared with equipment designed to meet the challenge of Peak Oil, will continue to protect our interests in the future.

Bibliography

Aleklett, K. and Campbell, C. “The Peak and Decline of World Oil and Gas Production. ” *Raw Materials Report* 18, no. 1 (2003). www.peakoil.net/files/oilpeakmineralsenergy.pdf; Internet; accessed 18 January 2010.

ANWR.org. “ANWR Oil - Politics and Logistics. ”www.anwr.org/Background/ANWR-Oil---Politics-and-logistics.php, Internet; accessed 10 February 2010.

Armstrong, Robert E. “From Petro to Agro: Seeds of a New Economy.” *Defense Horizons* 20, (October 2002): 1-1-8. http://www.ndu.edu/inss/DefHor/DH20/DH_20.pdf; Internet; accessed 24 September 2009.

Ashley, Steven. “Fuel-Saving Warship Drives.” *The American Society of Mechanical Engineers: Mechanical Engineering Power* (August 1998). http://www.memagazine.org/backissues/membersonly/aug98/features/fuelsav/fuelsav.htm; Internet; accessed 26 February 2010.

British Broadcasting Corporation. “China’s PetroChina Invests in Canada Oil Sands,” BBC; http://news.bbc.co.uk/2/hi/8434603.stm; Internet; accessed 26 January 2010

BP Global. “Reserve Numbers in this Review,” *Statistical Review 2009*, http://www.bp.com/sectiongenericarticle.do?categoryID=9024043&contentID=7045243; Internet; accessed 25 February 2010.

Bender, Bryan. “Pentagon Study Says Oil Reliance Strains Military: Urges Development of Alternative Fuels.” *The Boston Globe*, 1 May 2007, 2007, sec. National News, www.boston.com/news/nation/washington/articles/2007/05/01/; Internet; accessed 14 October 2009.

Besson, Christian. *Resources to Reserves: Oil & Gas Technologies for the Energy Markets of the Future*. Paris, France: International Energy Association, 2005.

Boyce, Paul. “Army Announces Historic Electric Vehicle Release.” www.army.mil. www.army.mil/-newsreleases/2009/01/12/15707-army-announces-historic-electric-vehicle-release; Internet; accessed 26 January 2010.

Campbell, Colin. “Open Comment to the Editor of the Guardian on the Article 'Key Oil Figures were Distorted by US Pressure, Says Whistleblower'.” www.peakoil.net/files/campbell_comments_20091110.pdf; Internet; accessed 18 January 2010.

Carter, J. "State of the Union Address 1980." Jimmy Carter Library. www.jimmycarterlibrary.gov/documents/speeches/su80jec.phtml; Internet; accessed 26 January 2010.

CBC News. "Navy Patrol Can Go Ahead, O'Connor Says." http://www.cbc.ca/canada/nova-scotia/story/2007/01/17/navy-tieup.html; Internet; accessed 26 February 2010.

Center for Naval Analyses. *Powering America's Defense: Energy and the Risks to National Security*, edited by Sherri Goodman. Alexandria, VA: Center for Naval Analyses, 2009.

CERA. "Peak Oil Theory – 'World Running Out of Oil Soon' – Is Faulty; Could Distort Policy & Energy Debate," (November 14, 2006), http://www.cera.com/aspx/cda/public1/news/pressReleases/pressReleasesdetails.aspx; Internet; accessed 24 February 2010.

Chevron. "One Thing is Clear, the Era of Easy Oil is Over." http://www.chevron.com/Documents/Pdf/RealIssuesAdTrillionBarrels.pdf; Internet; accessed 10 February 2010.

China Daily. "China's Energy Needs Secure, Expert Assures." http://www.chinadaily.com.cn/bizchina/2009-05/22/content_7928825.htm; Internet; accessed 23 February 2010.

Collier, Paul. "Greed and Grievance in Civil War." World Bank. http://www.csae.ox.uk/workingpapers.pdfs/2002-01text.pdf; Internet; accessed 2 January 2010.

Committee for the Role of Experimentation in Building Future Naval Forces, "Technology for Future Naval Forces: Electronic Power and Propulsion," *The Role of Experimentation in Building Future Naval Forces* (Washington, DC: National Academies Press, 2004); http://www.nap.edu.html/tech_21st/t8.htm; Internet; accessed 2 January 2010.

Crowley, T., T. Corrie, D. Diamond, S. Funk, W. Hansen, A. Stenhoff, and D. and Swift. *Transforming the Way DoD Looks at Energy: An Approach to Establishing Energy Strategy*. Washington, DC: LMI Government Consulting, 2007.

Dodd, Mark. "Army's $500m Abrams Tanks is the Wars." *The Australian,* 23 September 2006, sec. The Nation, www.theaustralian.com.au/news/nation/armys-500m-tanks-in-the-wars/story-e6frg6nf-1111112255764; Internet; accessed 10 February 2010.

Eggers, Jeffrey. "The Fuel Gauge of National Security." *Armed Forces Journal* (May 2008, : 14 October 2009, www.afji.com/2008/05/3434573; Internet; accessed 14 October 2009.

Energy Information Administration. "International Energy Outlook 2009." Energy Information Administration. www.eia.doe.gov/oiaf/ieo/highlights.html; Internet; accessed 19 October 2009.

Finn, Patrick. Email correspondence with the author, with permission, 1 February 2010, full text available upon request.

Fullerton, Richard. "The Future: Oil, America, and the Air Force." Airpower. www.airpower.maxwell.af.mil/airchronicles/apj/apj05/win05/fullerton.html; Internet; accessed 24 September 2009.

Glasby, Geoffrey. "Abiogenic Origin of Hydrocarbons: An Historical Overview." *Resource Geology* 56, no. 1 (2006): 85-98.

Gold, Thomas. *The Origin of Methane (and Oil) in the Crust of the Earth*. United States: United States Geological Survey Professional Paper 1570, 1993.

Government of Canada. "Welcome to the NCR Handbook." http://www.cfsuo.forces.gc.ca/wnc-mbr/index-eng.asp; Internet; accessed 2 February 2010.

Greene, David, Janet Hopson, and Jia Li. *Running Out of and into Oil: Analyzing Global Oil Depletion and Transition through 2050*. Oak Ridge, Tennessee: Oak Ridge National Laboratory, 2003.

Greer, John M. *The Long Descent: A User's Guide to the End of the Industrial Age*. Gabriola Island, British Columbia: New Society Publishers, 2008.

Griffin, James, ed. *World Oil Outlook: 2009*. Vienna, Austria: OPEC Secretariat, 2009.

Grumet, Jason. *United States Senate Committee on Foreign Relations: Hearing on Energy Security and Oil Dependence*. Washington, DC: United States Senate Committee of Foreign Relations, Bipartisan Policy Center, 16 May 2006, http://bipartisanpolicy.org/library/testimony/united-states-senate-committee-foreign-relations-hearing-on-energy-security-and-oil-dependence.html; Internet; accessed 14 October 2009.

Hanson, Stephanie. *Council on Foreign Relations Backgrounder: China, Africa, and Oil*. Washington, DC: Council on Foreign Relations, 2008.

Heinberg, Richard. *Searching for a Miracle: Net Energy Limits & The Fate of Industrial Society* (Sebastapol, CA: Post Carbon Institute, 2009), 10.

Heinberg, Richard. "Life After Growth" (lecture hosted by Post Carbon Toronto, Trinity St Paul's United Church, Toronto, ON, March 22, 2010), with permission.

House Subcommittee on Energy and Air Quality. *Testimony on Peak Oil before the House Subcommittee on Energy and Air Quality*. Wednesday, December 7, 2005.

Hubbert, M. King. *Nuclear Energy and the Fossil Fuels*. Houston, Texas: Shell Development Company, 1956.

IT.TMCNET.com, "U.S. Army's TARDEC to Showcase Alternate Energy Vehicle Technology at 2010 North American International Auto Show," http://it.tmcnet.com/news/2010/01/07/4564492.htm; Internet; accessed 2 January 2010

Karbuz, Sohbet. "U.S. Military Energy Consumption." http://www.karbuz.blogspot.com; Internet; accessed 6 April 2009.

Kenny, J., Kutcherov, V., Bendeiani, N., and Alekseev, V. "The Evolution of Multicomponent Systems at High Pressures: VI. the Thermodynamic Stability of the Hydrogen-Carbon System: The Genesis of Hydrocarbons and the Origin of Petroleum." Proceedings of the National Academy of Sciences. http://www.pnas.org/content/99/17/10976.full; Internet; accessed 13 December 2009.

Lalonde, Hugo. Email correspondence with the author, with permission, 29 January 2010, full text available upon request.

Le Billon, Phillippe and El Khatib, Fouad. "From Free Oil to "Freedom Oil"? Terrorism, War and US Geopolitics in the Persian Gulf." Department of Geography, University of British Columbia. http://www.geog.ubc.ca; Internet; accessed 2 January 2010.

Maass, Peter. "The Breaking Point." *New York Times Magazine* (21 August 2005), http://web.ebscohost.com/ehost/delivery?vid=6&hid=108&sid=7f5ffa4v-da8c-485e-999b.html; Internet; accessed 12 September 2009.

Maas, Peter. *Crude World: The Violent Twilight of Oil*. New York: Alfred A Knopf, 2009.

Marvin, Duncan. "China Moves to Secure its Energy Future." *Financial Post* (18 February 2009), http://www.financialpost.com/story.html; Internet; accessed 23 February 2010.

Mathews, William. "Synthetic Future: USAF Pushes Ahead with Fuel Production Despite Price Drop." *Defense News,* (2 March 2009), http://www.defensenews.com/story.php?i=3969089; Internet; accessed 12 January 2010.

Mazraati, Mazyar. Email correspondence with the author, with permission, 27 January 2010, full text available upon request.

Euan Mearns, “HIS Data Suggest Kuwaiti and Global Proved Oil Reserves Significantly Lower Than BP Estimates,” *The Oil Drum: Europe* (November 17, 2006), http://europe.theoildrum.com/story/2006/11/13/173619/51, Internet; accessed 25 February 2010.

Ministry of Foreign Affairs of the Peoples’ Republic of China, *China’s position on Establishing A New international Political and Economic Order*. http://www.fmprc.gov.cn/eng/wjdt/wjzc/t24883.htm; Internet; accessed 23 March 2010.

Monbiot, George. “Interview with Fatih Birol.” *The Guardian.* http://www.guardian.co.uk/environment/video/2008/dec/15/faith-birol-george-monbiot; Internet; accessed 12 February 2010.

National Academy of Sciences*. Improving the Efficiency of Engines for Large Nonfighter Aircraft: Committee on Analysis of Air Force Engine Efficiency Improvement Options for Large Non-Fighter Aircraft*: National Academies Press, 2007, http://www.nap.edu/catalog/11837.html; Internet; accessed 27 January 2010.

Ng, Allan. “The CF 18 Hornet Fighter.” Canadian American Strategic Review. http://www.casr.ca/id-cf181-4.htm; Internet; accessed 27 January 2010).

NRAC Future Fuels Study Pannel. “Breaking the Tether of Fuel.” *Marine Corps Gazette* 90, no. 8 (2006): 49-53.

O'Rourke, Ronald*. Navy Ship Propulsion Technologies: Options for Reducing Oil use - Background for Congress*. Washington, DC: Congressional Research Service, 2006.

Ouellet, Henrick. email correspondence with the author, with permission, 9 February 2010, full text available upon request.

Perron, Yves. “Frigate Life Extension and the Halifax Class Modernisation Overview.” Government of Canada. http://www.forces.gc.ca/aete/documents/FELEX_Industry_Day_Brief-eng.pdf; Internet; accessed 26 February 2010.

Ritch, Emma. “Bright Automotive Scores Military Contract.” Cleantech Group. http://cleantech.com/news/5207/bright-automotive-scores-military-contract.htm; Internet; accessed 2 January 2010.

Rogner, H. “An Assessment of World Hydrocarbon Resources.” *Annual Review of Energy and the Environment* 22, (1997): 217-262.

Rubin, Jeff. *Why Your World is about to Get A Whole Lot Smaller*. New York: Random House, 2009.

Securing America's Future Energy. *Oil Shockwave: Oil Crisis Executive Simulation*. Washington, DC: Securing America's Future Energy, 2007; www.oilshockwave.com/pdf/OS_2007_Report_042808.pdf; Internet; accessed 16 October 2009.

Simmons, Mathew R. *Twilight in the Desert*. Hoboken, New Jersey: John Wiley & Sons, Inc, 2005.

Solomon, Lawrence. “Endless Oil.” *National Post* (12 September 2009); http://www.nationalpost.com/m/story.html?id=1987711&s; Internet; accessed 12 December 2009.

Tainter, Joseph. “Complexity, Problem Solving, and Sustainable Societies.” In *Getting Down to Earth: Practical Applications of Ecological Economics*, edited by Robert et al Costanga. Washington, D.C.: Island Press, 1996; http://dieoff.org/page134.htm; Internet; accessed 15 February 2010.

Tainter, Joseph. *New Studies in Archaeology: The Collapse of Complex Societies*. Cambridge, UK: Cambridge University Press, 2003.

Taylor, C., Baltrus, J. and Gormley, R. “R & D Facts: Fischer-Tropsch Fuels.” U.S. Department of Energy; http://www.netl.doe.gov/publications/factsheets/rd/R&D089.pdf; Internet; accessed 12 January 2010).

Taylor, Rupert. “The Abiotic Theory Fo Petroleum Formation: Theories Fo Deep Pools of Abiotic Oil shown to be Flawed;” http://geologyecology.suite101.com/article.cfm/the_origin_of_oil_a_mystery; Internet; accessed 12 December 2009.

The Economist. “The Peak-Oil Debate: 2020 Vision.” *The Economist,* 12 December 2009, 2009. 82.

Transportation Business Associates. “Crude Oil Versus Diesel Prices.” Transportation Business Associates; http://www.tbabz.com/CrudeOilDieselPrice.htm; Internet; accessed 27 January 2010.

United States of America Public Law. “Energy Policy Act of 2005 – 109-58: 2398 (a),” http://www.epa.gov/oust/fedlaws/publ_109_058.pdf; Internet; accessed 2 February 2010.

Whaley Jane. “Do OPEC Reserves Figures Matter?” *GEO ExPro*, 9 April 2007, http://www.geoexpro.com/news/do_opec_re/; Internet; accessed 14 April 2010.

Wilson, Paul. “Abiogenic Oil,” *Sedimentary Basins and Petroleum Geology*, August 26, 2008; http://www.basintectonics.blogspot.com/2008/08/abiogenic-oil.html; Internet; accessed 18 January 2010.

Wire Services. “IEA "Whistleblower" Says Peak Oil Nearing.” *Upstream: The International Oil & Gas Newspaper*, 10 November 2009; www.upstreamonline.com/live/article198370.ece; Internet; accessed 18 January 2010.

Woods Institute. “The Impacts of Large-Scale Biofuel use on Land use and Conservation.” Woods Institute; http://woods.stanford.edu/docs/biofuels/biofuels6a.pdf; Internet; accessed 10 February 2010).

Xiongqi, Pang, Meng Qingyang, natori Mariko, Zhang Jun, and Feng and Lianyong. *The Challenge and Countermeasures Brought by the Shortage of Oil and Gas in China*. Beijing, China: China University of Petroleum, 2005; www.cge.uevora.pt/aspo2005/abscom/Abstract_Lisbon_Pang.pdf; Internet; accessed 12 January 2010.

Yergin, Daniel. “It's Still the One.” *Foreign Policy* Sept./Oct., (2009): 19 November 2009; www.foreignpolicy.com/articles; Internet; accessed 19 November 2009.