Can Industrial Civilization SurviveThe Age of Oil?

By A. A. D. Clarke

The author is appreciative of the several suggestions and comments received from CACOR members John Walsh and J. Anthony Cassils following their review of an earlier draft of this paper.

There are increasing signs that the production of oil, cheap energy to power the industrial world and provide the feedstock for countless products, may be in serious trouble. In the United States, the country where the oil industry began, production is only half of what it was 35 years ago. Globally, of the 65 largest oil producing countries in the world, 46 are now in decline[(1)]. Eight additional countries are at or near peak production and a decline is expected soon. There is today a growing consensus that a world peak in oil production, to be followed by a long decline, may provide a challenge to civilization like no other since the beginning of the Industrial Revolution.

The arrival of a peak in global oil production has been discussed by petroleum engineers, geologists and university scientists for many years. In sharp contrast, the average citizen knows little about either the concept or consequences of peak oil. This situation may soon change. Comment and opinion on the decline of oil globally is now, for the first time, being expressed by a wide range of present and former leaders in government, finance, and even the oil corporations. It is only a matter of time before reduced energy supplies, and their greatly increased cost, will impact the lives of a steadily increasing number of private citizens.

To gain an adequate understanding of the meaning of peak oil it is necessary to consider the history of petroleum. Oil in the form of surface seepage has been known since ancient times. However, it was not until 1859/60 that the world's first oil wells were drilled in Pennsylvania and Ontario, only 146 years ago. The oil flow from these first and other early wells was limited. But 42 years later, in 1901 at Spindletop, Texas, and using a new rotary drilling technique, oil in large quantities literally exploded from the wellhead. The world's first oil well gusher almost immediately ushered in an age of cheap and plentiful energy, quite unlike anything the world had seen before. The age of oil had arrived!

Interestingly, only about 20 years earlier, in 1881, Nicholas Otto of Germany invented the internal combustion engine (ICE), to be followed very soon after with the first ICE powered automobile developed by Karl Benz. Unlike the steam engine invented by James Watt just over 100 years earlier, the ICE required a liquid fuel. As several writers have noted, the almost simultaneous advent of oil and the ICE automobile quickly changed the industrial landscape, at first in North America and Europe and later the world[(2)]. Internal combustion engine machines and cheap oil energy were made for each other, and the world would never be the same again, or so people at the time thought.

Oil: The Crucial Resource

Unlike all other finite resources, oil occupies a place not only unique in human history but is at present crucial to the continued survival, not to mention growth, of industrial civilization. As described above, the large scale use of oil began as the fuel for the rapid expansion of the automobile industry during the early 20th century. Today it is the energy source for over 90% of the world's transportation systems, i.e. road, rail, sea, and air transportation. There is no other low cost fuel available in the quantities required, or is likely to be available in the foreseeable future, that could replace oil as the source of energy to power the world's transportation systems.

In addition to its importance in transportation, oil is also essential to the production of food to a degree little understood by the general public. It was the large scale use of oil in industrial agriculture processes which made possible the Green Revolution in the 1960s. Essential oil dependent elements in the Green Revolution, and today's large agribusinesses, include the large scale use of agriculture machinery, the pumping of large quantities of water, the manufacture of oil based fertilizers, insecticides and herbicides, oil powered food harvesting and processing equipment, as well as the transport of food from farm gate to consumer. Few realize that a barrel of oil (42 gallons) contains the energy equivalent of 25,000 hours of human labour, equal to about 12 farm labourers working with shovel and hoe for one year. It has been calculated that about 80% of the cost of growing corn in the American mid west, as one example, is the cost of oil[(3)].

Oil also provides the petrochemical feedstock for countless industrial products, including plastic materials of all kinds, as well as a wide range of chemical, pharmaceutical and other consumer products. So widespread is the use of oil in industrial production that it is said that oil is too valuable to burn for transportation purposes.

Several writers, including Harrison Brown in **The Challenge of Man's Future** (1954), have said that petroleum is not only the cheapest and most convenient source of energy ever discovered by man, but it will be gone in about 150 years (5 generations) after it came into large scale use, a cheap energy source never again to become available for perhaps hundreds of million years. How will our descendants view our profligacy in the use of this one time only invaluable resource?

Oil Depletion

Unlike a renewable resource, the extraction and production of a finite resource generally follows what are now widely accepted "laws" of depletion. During the early period of production, the amount of the resource produced is limited. Over time, production increases and, although influenced by several variables, maximum production usually occurs when about half of the resource is extracted. Post peak production of a finite resource, because of steadily diminishing supply and production difficulties, is a mirror image in reverse of pre peak production increases, and usually follows a steady decline until all the cost effective portion of the resource is recovered(4). This process of gradual increasing production until production peaks, at which time about half the resource is extracted, then followed by a decreasing rate of production until all the recoverable resource is extracted, describes what is called a typical bell curve. Like oil, a similar bell curve can be used to describe the depletion of other finite resources, for example, uranium.

In the early 1950s an American petroleum engineer named Dr. Marion King Hubbert, employed with Shell Oil, attempted to apply the above bell curve pattern to the production of oil in the United States. Through the application of complex mathematical formulas which he developed, Hubbert predicted in 1956 that the peak production of oil in the lower 48 States would occur in 1970, to be followed by a steady decline in production until the recoverable US oil resource was exhausted. When 1970 arrived and oil production in the US was at an all time high, King Hubbert was ridiculed and his professional reputation was described as being in shambles. Several years later, however, it became apparent that the US production of oil in the lower 48 States did indeed peak in 1970/71, and Hubbert's 1956 prediction proved to be essentially correct. Today US oil production in the lower 48 States is only 50% of what it was 35 years earlier.

Efforts have been made to apply Hubbert's methods to calculate the date of world peak oil. Unfortunately, because many countries, particularly countries belonging to The Organization of Exporting Countries (OPEC), exercise extreme secrecy about their petroleum reserves and related matters, prediction of when the world peak will occur has been difficult. The decision of OPEC nations to independently and arbitrarily increase their "official" oil reserves — because their agreed cartel production quotas were in part tied to the stated reserves of each country — further exacerbated the difficulty. Nevertheless, using what data is available, and the best estimates that could be obtained of OPEC reserves, there is now a substantial body of opinion among geologists, petroleum engineers and other specialists that the world peak will occur not later than 2010.

While there is agreement among most authorities on the approximate date of world peak oil, a few organizations present a dissenting view, including the US Department of Energy (DOE) which suggests the peak will occur between 2021 to 2037. Unlike industry professionals and the authors of several recent studies(5), DOE and other optimists provide no detailed methodology to support their claims. The optimist school appears to accept at face value the questionable oil reserve claims of several OPEC countries, particularly Saudi Arabia which is considered to have the world's largest oil reserves. In a book by Matthew Simmons, published in July 2005, **Twilight in the Desert: The Coming Oil Shock and the World Economy,** Simmons reveals that five extremely mature fields that produce 90% of Saudi production are at the risk of unplanned production collapse(6). He explains that these fields are being over produced with the injection of sea water to maintain high production levels. Simmons' claims should not be dismissed. He has not only been a highly respected energy investment banker for many years, but was previously an advisor on energy security to President George W. Bush.

In addition to the Hubbert approach to calculating peak oil, there are other persuasive reasons to believe that the peak will occur sooner rather than later.

Several authorities on peak oil have observed that oil must first be discovered before it can be produced, and there is an unmistakable pattern of oil production reaching a peak about 40 years after peak discovery. For example, oil discovery peaked in the US in about 1930, and peak production occurred 40 years later in 1970. A similar lapse time between peak discovery and peak production has occurred in other countries. World oil discovery peaked in the 1960s. Therefore it would appear not unreasonable to expect the world peak to occur in the first decade of the 21st century, particularly considering that of the 65 largest producing countries in the world, 54 have now either reached peak or are at or near peak.

Still additional evidence that world peak oil is imminent is contained in a book by Dr. Kenneth S. Deffeyes, **Beyond Oil, The View from Hubbert's Peak,** released in May 2005. Deffeyes, a petroleum engineer and now Professor Emeritus at Princeton University, is also a former colleague of M King Hubbert at Shell Oil, and has been widely quoted in the media during recent weeks. In his newly released book he mentions several reasons internal to the oil industry which can only increase suspicions that the industry itself is aware that world peak oil is close, but for financial reasons is reticent about speaking openly on the subject.

Deffeyes oil industry reasons for believing world oil peak is imminent include:
a) No new oil refineries have been built in the US in 25 years. The question must be asked why have companies not increased their refinery capacity if oil is not about to become a diminishing resource?
b) Virtually no oil tankers are being built, undoubtedly for reasons similar to no new refinery construction.
c) According to Deffeyes, few students are studying oil related subjects at universities, e.g. geology, earth sciences, or earth resources. On this point Deffeyes quotes energy banker Matthew Simmons as saying there is "no freshman class."
d) But perhaps the straw in the wind that is most telling is that the oil industry has greatly reduced its funding for oil well exploration. When oil becomes increasingly scarce (it is believed that almost 90% of the planet's oil has now been discovered), exploration costs necessarily increase, and the major oil companies become increasingly less interested in drilling dry holes.

Non Conventional Oil

The above discussion relates to conventional oil; it does not include various forms of non conventional oil including liquified natural gas (NGL), tar sands and heavy oil, oil shale, and other potential sources which can be converted to liquids. A brief analysis of the most promising sources of non conventional oil, liquified natural gas and the Alberta tar sands, follows.

Natural Gas

The world did not reach a peak in natural gas discovery until some 15 years after oil, and it can therefore be expected that its production will not peak until a similar number of years after oil.

The US and Canada[7], however, exceeded peak production of natural gas several years ago. Because of the greatly increased demand for natural gas in North America during recent years, particularly for electrical power generation and residential heating, the North American market is experiencing serious difficulties. An additional factor contributing to the natural gas shortage is the requirement for large quantities of natural gas in the production of oil from Northern Alberta's tar sands (see below). In an effort to alleviate the situation, plans are now being implemented to greatly increase the import of liquified natural gas (NGL) from overseas sources in specially designed tankers, as well as augment supply from non-conventional sources such as coal bed methane.

Tar Sands and Heavy Oil

Tar sands and heavy oil is found in some 30 countries but only two, Alberta in Canada and an area north of the Orinoco River in Venezuela, contain very major deposits, possibly potentially more oil than is available in all the world's conventional oil wells. During our discussion of conventional oil it was explained that only some 50% of the "potential" underground reserve is economically recoverable and will ever appear in production figures; similarly, tar sands production will also be limited to a fraction of potential resources. For reasons explained below, these major deposits are unlikely to have a significant impact in either delaying peak oil, or mitigating the inevitable decline in oil production following peak.

In 2003 Canada decided to include the Alberta tar sands reserves in its estimate of "proven" oil. reserves, and thereby increase its reserves from a previous 5 billion to 180 billion barrels, placing Canada second only to Saudi Arabia's reserves of 256 billion barrels. At present approximately one million barrels per day (mbd) is being produced through two extraction methods: mining with a production potential of 32 billion barrels and "in situ" production with a much larger potential of 140+ billion barrels.

The prospect of Canada ever realizing its enormous tar sands oil potential is unlikely because of the following constraints:
1) The present largely mining process involves massive engineering infrastructure, and a large number of trained workers. The enormous size of the operation requires an investment of up to $5 billion, thus discouraging all but the largest operators. (In 2003 two companies delayed indefinitely their plans for new tar sand mines).
2) The prospects for the potentially much larger "in situ" production process are limited by technological uncertainties and the need for massive quantities of natural gas, a resource increasing in cost and already in short supply in North America. Large quantities of water are also consumed.
3) Tar sands oil production creates enormous quantities of carbon dioxide and other pollutants. There is serious doubt Canada can increase tar sands production without violating its adherence to the Kyoto Protocol.

Nevertheless, the above constraints notwithstanding, it is possible that the present level of production of 1 mbd can be increased to 3 mbd by about 2015. After allowing for Canada's domestic requirements in 2015, as well as probable Canadian net production of conventional oil(8), possibly 2 mbd would be available for export, an amount not appreciably greater than present oil exports. The tar sands are therefore unlikely to influence the arrival of peak oil, and may have only a minimal impact in responding to the world's 2015 oil requirements.

Post Peak Production

While the date of peak oil is understandably a subject of considerable interest, the exact date of its occurrence is far less consequential than the rate at which supply decreases following peak. Should the decline in production following peak oil be sharp (some writers use the analogy of "falling off a cliff"), and energy demand growth continues at its level of recent years, the industrial world may well face an economic discontinuity of unprecedented proportions, undermining the very fabric of society and human well-being.

One scenario of how events may unfold projects a reduction in oil supply to 74% of a 2006 peak of 85 mbd by 2020, or an average annual rate of decline in supply of 2.1%. Should world demand for oil, or equivalent energy, continue to increase at a rate similar to what has been experienced in recent years, i.e. an annual growth of about 2%, the shortfall gap of 4.1% following peak oil will mean a shortage increasing at the rate of 3.5 mbd annually, a situation which undoubtedly will send oil prices through the roof.

Alternatives to Oil

Before examining the alternatives to what appears to be a rapidly approaching energy crisis, it is well to note that the world had ample warning of the need to act. But because of inertia and false hopes it repeatedly failed to respond to warnings contained in several scientific studies, including The Club of Rome's book **The Limits to Growth** published in 1972. Very recently, in an address to the US House of Representatives, Republican Congressman Roscoe Bartlett said: *"So its very probable that the world is peaking in oil about now. .... The world in general, and the US in particular, has pretty much blown 25 years of time that we had, but no longer have, for preparation for the necessary transition."*

Instead of preparing for the inevitable transition, nations have focused on how best to control and exploit existing petroleum resources, a policy approach which has only made matters worse by hastening the day of peak production, followed by a rapidly increasing gap between demand and supply.

Energy Productivity

While the day is late, a first and immediate energy policy should be to greatly improve energy productivity. Much has already been achieved in increasing energy efficiency, particularly in Europe and Japan where living standards are similar to the US and Canada but only about half as much energy is used per person. Among the reasons: energy usage standards and building codes are more stringent. The taxation system encourages improved productivity. And gasoline sells for a more heavily taxed US$5.00 to $6.00 a gallon, not the subsidized US$2.50, or its close equivalent in Canada. This differential between the US and other industrial countries helps explain why per capita oil consumption in the US exceeds all other industrial countries, as well as the fact that less than 5% of the world's people use 25% of the world's oil.

The Nuclear Option

Experience has demonstrated that nuclear energy has two major disadvantages compared to other energy sources. It is expensive, a fact which may explain why no nuclear reactors have been built in the US for over 30 years. A large share of nuclear energy's costs (includes insurance, security, nuclear waste disposal, decommissioning, etc) are hidden. Nuclear reactors also pose serious security risks.

Nuclear reactors of course make electricity, not oil; expensive electricity is not a substitute for the two most important advantages of oil: its use in transportation systems and agriculture.

Wind and Solar Energy

Wind energy is now experiencing an exceedingly rapid growth rate and is expected to provide 20% or more of the electricity needs in several countries in a very few years. It has many advantages and, compared to other sources of energy, it is becoming increasingly cost effective.

Electricity produced by photovoltaics is at present expensive but there appears to be good prospects of technical breakthroughs at an early date which may greatly improve the efficiency of photovoltaic technology. Meanwhile, photovoltaic solar is being used increasingly for home roof installations, particularly in Japan and Germany. Like the nuclear option discussed above, both wind and solar produce electricity, a doubtful substitute for the many advantages of oil.

Biomass

The production of the bio fuels ethanol and methanol from plant organic sources may well provide a partial solution to the search for a transportation fuel to replace oil, particularly when the price of oil increases well above its present level. Brazil, a large country with limited oil resources, has been using sugar cane based ethanol with considerable success for several years.

The production of a bio fuel from plant sources must pay close attention to energy inputs into the growing of the biomass and its conversion to fuel. As Kenneth Deffeyes and others have explained, the production of ethanol from corn is a net energy loser; only the farmer who grows the corn is a winner, and then only if his production is heavily subsidized by the government.

The Promise of Hydrogen

The promise of creating a hydrogen/fuel cell economy as the successor to the present oil/ICE economy has received extensive publicity during recent years. Even the President of the US, George W. Bush, has spoken on the need for the replacement of oil by hydrogen for transportation and other energy needs. Unfortunately, and despite the considerable expenditure of research funds, progress during recent years toward developing a hydrogen/fuel cell economy in the US or elsewhere has been minimal. There are several problems which have yet to be solved, quite apart from continuing technical difficulties and the cost of manufacturing fuel cells(9).

It is important to keep in mind that hydrogen is a carrier of energy, not a source of energy. Most hydrogen today is obtained from natural gas, clearly not a satisfactory source for several reasons. A better long term approach is to produce hydrogen by electrolyzing water. While this method may have promise, and could as one example be a means to store surplus wind energy, major problems relating to the efficiency of the process remain to be solved.

The conversion of electricity into hydrogen for its use as a fuel for transportation purposes involves three important steps:
a) The production of hydrogen by electrolyzing water;
b) The storage of the compressed or liquid hydrogen in specially designed tanks; and
c) Fuel cell conversion of the stored hydrogen back into electricity to power an automobile or other vehicle.

While the above sequence is entirely feasible, conversion efficiencies present a serious problem. As explained by Deffeyes: *"The hydrogen economy has a built-in surcharge. You get back about 40% of what you put in."* Deffeyes also states that further research may improve efficiency. It is certainly to be hoped that science will find a way to improve the conversion efficiency problem if for no other reason than, apart from possibly biomass, there may be few other options in the short term to replace the existing oil/ICE transportation systems of the world.

Discontinuity Ahead?

The above discussion indicates that world oil production will peak before 2010, if it has not already arrived. While several alternatives to oil exist, and there have been warnings of an impending crisis for many years, nations have failed to act. Alternative energy systems have not received much needed research and development support. Now it may be too late to prevent a breakdown in the global economy, with an associated financial and political collapse. It appears probable that we will be faced with a situation unprecedented in history.

There are three elements of our present situation, each described below, which may be central to the storm ahead.

1) Capacity Overshoot
The world's oil based economic system, particularly with reference to transportation, agriculture and medicine, has made possible a six-fold increase in world population since the dawn of the age of oil, a number probably well in excess of what an alternative energy system may be able to support.
2) Global Consequences
In earlier times, the consequences of a civilization in peril, and facing possible collapse, were limited to its immediate geographic area. Today's industrial civilization is global in scope. If our future is endangered, all humankind will be impacted. This time we are all occupying a single lifeboat.
3) Political Division
Global society has very recently become a single functioning geographic, economic and financial world system, its imperfections notwithstanding. Measured from a political, social and religious perspective, humankind has many parts and is divided. It is clearly deficient in political and legal institutions possessing the capacity to solve global problems with fairness and equity.

The Shape of Discontinuity

The above three elements of the impending discontinuity require that we now address two exceedingly important questions that now loom before the community of nations, questions that we are clearly reluctant to face, but are unquestionably unavoidable.

Question 1: Distribution of a Declining Resource
When the availability of oil, a vital resource for economic growth for over a century, enters the period of its long decline, will the rate of oil depletion be managed with equity and fairness to the best advantage of the world community of nations? Or will the nations of the world enter a period of competition (perhaps violent) to individually obtain a maximum share, each seeking to advance its national self interest with little or no regard for other nations?

Question 2: The End of an Economy Based Upon Growth
When the availability of oil enters the period of its long decline, and should an adequate alternative energy system prove not feasible (at least in the short term), it is inevitable that the present political/economic system based upon growth will prove unworkable and collapse(10). What will be the form and shape of a new political/economic order that, if humankind is to have a future, must emerge in response to a contracting world economy leading ultimately to a "steady state" world community?

Possible answers to **Question 1** have been advanced during recent months. One set of proposals(11) contains the following provisions:
a) No country shall produce oil at above its current Depletion Rate, such being defined as annual production as a percentage of the estimated amount left to produce;
b) Each importing country shall reduce its imports to match the current World Depletion Rate; and
c) Detailed provisions shall be agreed with respect to the definition of categories of oil, exemptions and qualifications, and scientific procedures for the estimation of future discovery and production.

Notes

(1) Refer report by Dr. Colin Campbell to the ASPO Conference in Lisbon, Portugal, May 19-20, 2005.
(2) For additional information on significant events in the history of oil, refer page 5 of this issue of Proceedings.
(3) Refer page 6 of Beyond Oil, The View from Hubbert's Peak by Dr. Kenneth Deffeyes.
(4) Only about 50% of the original oil in underground wells is economically recoverable.
(5) Several books have been written on the subject of peak oil during the past year and most are in substantial agreement that peak oil is imminent.
(6) Without any known justification, in 1990 Saudi Arabia announced a massive increase in its reserves from 170 billion barrels to 256 billion barrels. Although Saudi Arabia has produced some 50 billion barrels since 1990, the 256 billion barrel reserves figure remains unchanged.
(7) Unlike the US, Canadian production of natural gas may have only recently peaked, or is expected to peak soon. Because of the high level of market integration, the US and Canada are treated as a single market in this instance.
(8) Eastern Canada still imports oil from foreign sources.
(9) Fuel cell technical difficulties and manufacturing costs are discussed by Paul Roberts in **The End of Oil, On the Edge of a Perilous New World** (2004), and other authors. Roberts makes particular reference to fuel cell engineering obstacles such as reliability, hydrogen storage issues, and material costs (especially platinum catalysts). On page 319 he states: "a self-sustaining fuel cell car industry is, at best, at least two decades away.
(10) For an in-depth examination of the economic consequences of declining oil production, refer to **Power Down – Options and Actions for a Post-carbon World,** by Richard Heinberg, as well as several articles by Colin Campbell, among other authors.
(11) The above proposals are contained in **"The Uppsala Protocol"** proposed by the Uppsala Hydrocarbon Study Group, Uppsala University, Sweden.