# The World's Energy: Oil, Uranium, Nuclear power (An opinion article)

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## The World's Oil: Past, Present, and Future

The world relied on whale oil for hundreds of years, with various countries being the main suppliers. During the 19th century, whaling was a worldwide, major industry with its nucleus in Massachusetts, U.S.A. The result was a great decrease in the numbers of whales, and today, 7 of the 13 great whale species are still endangered. (As whales became scarce, elephant seals and even penguins were killed and boiled down for their oil content.) Whale oil production peaked about 1845, and was going downhill when, fortunately for the whales, the first successful oil well was drilled in 1859 in Pennsylvania, U.S.A. Soon the problem was to find uses for all this crude oil – what is it good for, besides lighting and lubrication? The internal combustion engine soon came to the rescue!

Today most oil is used for transportation. In the U.S., 2/3 of its use is for fuels for motor vehicles – cars, trucks, buses, and planes. The American lifestyle is twice as energy intensive as that of Europe and Japan, and 10 times that of the global average. With only 5 percent of the world's population, the U.S. uses 25 percent of the world's oil.

Petroleum (liquid crude oil and gaseous natural gas) was formed by the decay of microscopic organisms during the Phanerozoic Era. About 58 percent comes from Cenozoic rocks as old as 66 million years, 27 percent is from Mesozoic rocks 66 to 245 million years old, and 15 percent is from Paleozoic rocks 245 to 545 million years old. A fossil fuel is solar energy stored by organisms in ancient times, over hundreds of millions of years, and is a one-time gift. Therefore, oil, natural gas, and coal are NONRENEWABLE fossil fuels (Fig. 1).

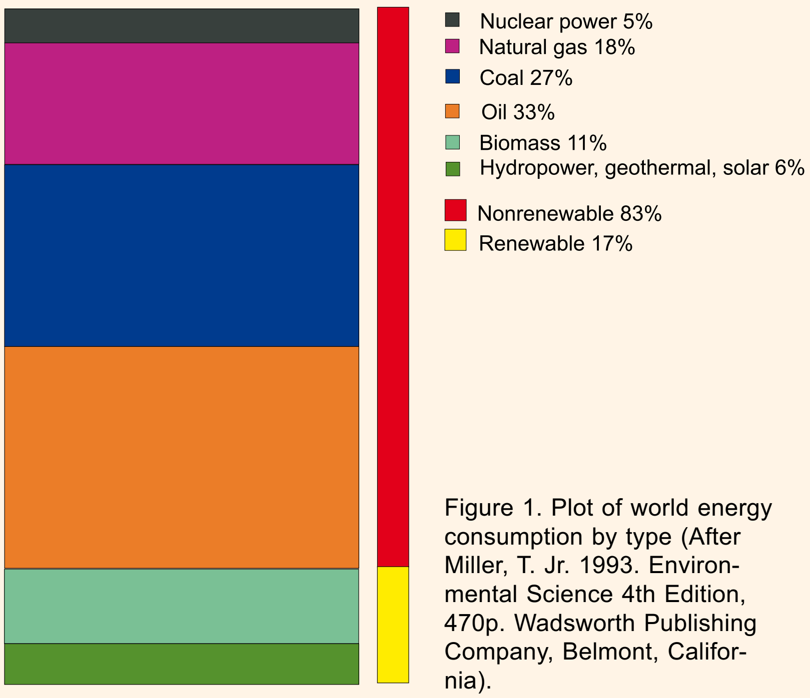


Figure 1. Plot of world energy consumption by type (After Miller, T. Jr. 1993. Environmental Science 4th Edition, 470p. Wadsworth Publishing Company, Belmont, California).

The requirements for an oil/gas field include: (1) source material of organic-rich black mud, (2) deep burial of

~ 2500 to 4000 m at high temperatures and pressures to "cook" the organics into oil, and deeper burial for natural gas, (3) a reservoir rock such as sandstone or limestone that is porous and permeable, (4) a migration pathway, and (5) a "trap" with an impermeable cap rock.

Oil, like water, is found in pore spaces of sedimentary rocks. Because of changes in the rock after deposition of the original sediment (diagenesis), not all of the pores remain connected. In general, only about 35 percent of the oil can be removed from a reservoir rock – secondary recovery techniques utilizing steam, water, and chemicals can increase this amount.

Geologic structures in which oil is trapped – anticlines, faulted rocks, and salt domes – commonly have a surface expression and thus can be rather easily located by geologists. However, the "easy oil" has all been found, and stratigraphic traps without a surface expression must be located by more expensive geophysical methods, both on land and offshore.

Oil discoveries in the U.S. peaked in 1940, production peaked in 1970, and today U.S. oil production is one-half of what it was in 1970. The U.S. had reserves of 25 b. bbls in 1992 and used 6.2 b. bbls. that year – thus it had a 4-year supply in 1992. A decade later in 2002, reserves were down to 22.4 b. bbls. and the rate of use was 7.19 b. bbls. – thus it had a 3-year supply. (Note the trend!) Therefore, IMPORTED OIL now totals about 60 percent of U.S. consumption (1 bbl or barrel equals 42 U.S. gallons or 159 liters.).

Worldwide, the rate of oil discovery peaked in 1960. The rate of consumption first exceeded the rate of discovery in about 1980. Since then, we have been using oil more rapidly than we have been discovering it. Some statistics indicate that the world is consuming 2 bbls. of oil for every bbl. of newly discovered oil.

Most countries of the world import oil. World oil consumption in 2005 was 29.2 billion bbls., and is estimated to be > 50 b. bbls. by 2035. China and India, with their large populations and booming economies, will especially increase demand.

Where is the world's oil? About 2/3 is in the Middle East, a dangerous neighborhood that includes 6 of the 13 OPEC nations (Organization of Oil Exporting Countries). Saudi Arabia has the greatest reserves and Iraq is second. There are about 50 000 oil fields in the world, but more than half of the world's oil is in the 40 largest fields. The largest is Saudi Arabia's Gharwar field (87 b. bbls.), and the second largest if Kuwait's Burgan field with 70 b. bbls. For comparison, the largest field in the 48 states was the East Texas field with only 5 b. bbls., and Prudhoe Bay, Alaska, contained 12 b. bbls.

## Peak Oil

How much total oil is there? We have discovered 1900 b. bbls., and have used 850 b. bbls. It has been estimated by some that we may discover another 650 b. but others estimate that the world's total oil is about 2000 b. bbls. (i.e., 2 trillion bbls.). Based on the most optimistic of these figures, we have about 1700 b. bbls. of reserves and potential reserves. However, reserve figures are difficult to verify, and several major companies, including Shell, recently decreased their reserve figures. OPECs figures are especially difficult to verify. Most of the world's oil will be produced in a 100-year period that is now known as "Hubbert's peak".

King Hubbert, a Shell Oil Company geologist, predicted back in the 1950s that U.S. oil production would peak in the 1970s. His predictions were roundly criticized by most oil geologists. But he was right – U.S. oil peaked in 1970. Using Hubbert's methods, several studies indicate that the world's oil production will peak between 2004 and 2008. Kenneth Deffeyes, author of Hubbert's Peak_(2001)_and_Beyond Oil_(2005), has stated that we peaked on November 24, 2005. Some have said non-OPEC oil will peak in 2015 and OPEC oil in 2025. David Goodstein in his book entitled Out of Gas (2004) asked, "Which comes first, Hubbert's peak or the collapse of the Saudi regime? Both would have the same effect, and both seem inevitable." Matthew Simmons has written Twilight in the Desert, which is about Saudi oil. Goldstein also emphasized the R/P ratio, the ratio of reserves to production, and stated that this ratio is 40 years for oil and 60 years for natural gas – then we "run out". Many major oil producing areas are in decline – Alaska's North

Slope, Canada's Western Basin, the North Sea, Mexico, and Saudi Arabia. There is a Saudi saying: "My father rode a camel. I drive a car. My son flies a jet plane, His son will ride a camel." Several excellent books relating to the end of the world's oil have been written in the last two years. There is no doubt at all that oil supply is a major problem.

## What we can do to increase energy supplies – alternatives?

The world had an energy crisis in the 1970s. Alternative energy was studied during President Jimmy Carter's administration: the U.S. spent $1 b on alternative energy research in 1980. This amount was drastically decreased under the succeeding administrations, as oil once again became cheap. The result? We have lost 25 years and $25 b of research time and money that would have placed us in a much better position today. What can we do now, after the fact?

Can we find more oil? Surely more exploration will result in more oil being discovered, and this would postpone somewhat the day of reckoning. President Bush and the Republican congress want to drill in ANWR, the Arctic National Wildlife Refuge in Alaska. The U.S. Geological Survey estimates the amount of oil there at somewhere between 4.3 and 11.8 b. bbls. So, the question obviously is whether opening the refuge to exploration is worth the risk of harming the fragile ecosystem, one of the last pristine regions in the U.S., for a limited supply of oil. Interestingly, several major oil companies have recently stated they are NOT interested in ANWR.

Petroleum companies are exploring in deepwater basins situated just beyond the continental shelves. The best-explored example is the Gulf of Mexico, where potential is estimated at 25 b. bbls. Similar exploration is going on off the west coast of Africa and the east coast of South America.

Can we make gas by the gasification of coal? Surely, for it was done successfully by Germany during WWII and is being done today, for example, in South Africa. The world has much coal, especially in the U.S. and China. However, the 200-year supply at the present rate of use would not last nearly that long if it were used to manufacture coal gas. The manufacture of coal gas requires combination with hydrogen from natural gas, which is also limited.

What about the "tar sands" of northern Alberta, with reserves estimated at 315 b. bbls., and which have moved Canada into the number two position in petroleum reserves? Natural gas and extensive mining are required for it's processing.

Oil shale is abundant, especially in the tri-state area of Wyoming, Colorado, and Utah, and high-grade reserves are estimated at 400 b. bbls. Extensive mining and environmental disturbance would be required.

Ethanol can be produced, for example, from corn or soybeans. However, we might ask whether we should be doing this so that we can fuel motor vehicles when hundreds of millions of people are starving or don't have enough to eat? And, it takes much energy to produce ethanol.

Wind power is becoming more important, but will likely never be a dominant energy source because of global wind patterns.

Hydroelectric power is about at its maximum, as all of the major rivers have been dammed. However, small hydroelectric plants on small streams have been proposed as potentially being an important source of power. Tidal and wave energy have further potential.

The sun is a fantastic source of energy. The solar energy falling on the U.S. is equal to 10 000 times the amount of electric power that the U.S. consumes. To put it another way, the earth's surface receives something like 173 000 billion times more energy from the sun than people generate by all present methods. For various reasons, mainly technological, we utilize only a tiny fraction of that energy.

Methane hydrate, methane gas in crystalline ice structures, has been found in areas of permafrost and in sediments of the continental slopes beneath more than 300 meters of water; these are two environments of low temperature and high pressure. The technology to utilize this potentially very large resource has not been developed, and it may never be feasible.

## Global warming

The earth's surface has warmed about 0.8 °C over the past century. Global warming is a FACT, but it must be asked whether the temperature rise is a natural one, unrelated to human activity. Surely over Earth's long history, temperature changes caused greenhouse times and icehouse times, for there have been episodes of glaciation as far back as 2.3 billion years and perhaps as far back as 3.0 billion years. A major factor in these past temperature changes may have been the carbon cycle – how much carbon was buried versus how much was in the atmosphere.

Data indicate that the use of coal, oil, and gas since the beginning of the Industrial Revolution in the late 1700s has resulted in the increase of $CO_2$ in the atmosphere from 275 ppm to about 370 ppm, an increase of 34 percent. The synchronous increases in the atmospheric $CO_2$ content and the surface temperature, especially over the past 50 to 100 years, strongly suggest that we humans are responsible. The Intergovernmental Panel on Climate Change, comprised of 600 scientists, has carefully studied the situation. In 1990, the panel stated that there was a reasonable doubt as to the cause. In 1996, the panel stated that there was a discernible definite human influence. In 2001, the panel stated that most warming of the past 50 years was due to human activity, and that human-created greenhouse gases could raise the global temperature by 5.8°C (10.4°F) by the year 2100 (Fig. 2).

Figure 2: A polar bear on arctic seasonal ice. If the sea-ice disappears, the 26 000 polar bears that feed on seals on that ice will also disappear. Photo by author.

The Kyoto Treaty, drafted in 1997, is designed to decrease $CO_2$ output. A total of 126 nations (including Russia) have ratified it, but the U.S., which produces 36 percent of the greenhouse gases, refuses to do so.

## Nuclear power: do we have a choice?

Einstein gave us the equation for nuclear power, $E = mc^2$. The amount of energy produced by a nuclear reaction is equal to the amount of transformed mass times the velocity of light squared. Whereas the involved mass is small, the speed of light is a large number and the quantity of energy produced is huge.

There are two types of nuclear reactions – fusion and fission. With nuclear fusion, nuclei of the light element hydrogen are fused or combined to form nuclei of heavier elements, thereby releasing a great amount of energy. That is the principle of the hydrogen bomb. We have not yet succeeded in controlling the produced energy, but research with magnetic fields is in progress. Nuclear fission (splitting of nuclei) is used in nuclear power plants.

There are 440 nuclear power plants in 31 countries. Since the early 1980s, there has been much opposition to nuclear power for two main reasons: the dangers of accidents such as Chernobyl and the long-term storage of radioactive nuclear wastes. More recently, there is a growing realization that nuclear power, despite its problems, is the only tried and proven energy alternative to the use of fossil fuels. The reasons for "going nuclear" include the following: (1) the impending oil and gas shortage, (2) environmental protection – nuclear power does not foul the atmosphere, (3) lower fuel costs compared to oil, gas, and coal.

During nuclear fission, uranium nuclei are bombarded with neutrons, thereby splitting the nuclei into nuclei of lighter elements and releasing great amounts of energy. There are two isotopes of uranium – uranium 235 and uranium 238. The former makes up only 0.72 percent of uranium. Only uranium 235 is fissionable, so it is enriched up to 4 percent in the uranium fuel of nuclear reactors in order to facilitate the required nuclear chain reaction. Some atoms of uranium 238 absorb a neutron and become plutonium 239, which is also fissionable and produces energy. After a few years, most of the uranium 235 has been split, and the depleted fuel consists of 94 percent uranium 238, 5 percent of lighter elements formed during the fission process (e.g. cesium 137 and strontium

90), and 1 percent of the dangerous long-lived elements including plutonium and americum. This "spent fuel", which still contains 95 percent of its original energy, is removed as nuclear waste and stored.

In a fast-neutron reactor (the fast breeder reactor), this "spent fuel" could be used as fuel. This would increase the energy supply by roughly 100 times, and alleviate the waste storage problem. Because chemically pure plutonium that can be used for making atomic bombs can be produced in the fast breeders, the breeder reactor did not become commercial. However, advanced technology is presumably such that pure plutonium is not produced, thereby minimizing the nuclear weapon problem. Such experimental reactors have been built. For a recent update, see Smarter Use of Nuclear Waste by W.H. Hannum, G.E. Marsh, and G.S. Stanford, Scientific American, December, 2005.

The French say, "We have no oil, we have no gas, we have no coal, we have no choice". Doesn't this also apply to the Finns?

## Uranium deposits

Is there a shortage of uranium? The price of uranium ore has been low for the last 20 years and weapons uranium has been utilized in power plants, so exploration essentially ceased. Now that the price is rising, exploration for uranium has increased dramatically. And with a higher price, lower-grade deposits will become economic, so there might well be no shortage of uranium ore. The first major cycle of uranium exploration lasted from about 1970 to 1985 and the second major cycle started in 2003.

World uranium production was about 35 000 tons in 2005. A reactor that produces 1 m KW/year, the size of most reactors in the U.S., will use about 24 tons of uranium enriched to 4 percent uranium 235. (For comparison, a coal-fired electric plant will use about 4 ½ million tons of coal per year.)

The average crustal abundance of uranium is about 2 ppm. Primary uranium is most abundant in felsic igneous rocks, which contain more than 3.5 ppm, with rare "fertile" granites containing as much as 5000 ppm. Mineable uranium deposits are the result of the concentration of uranium by various natural processes.

Figure 3. Quartz-pebble conglomerate.

There are many types of uranium deposits, 14 according to one classification. However, only 4 types contain most of the world's uranium: Quartz-pebble conglomerate-type, unconformity-type, breccia-type, and sandstone-type. The first three are restricted to Precambrian rocks, and the latter is mainly Mesozoic-Cenozoic in age.

## Quartz-pebble Conglomerate-type Deposits

The two main quartz-pebble conglomerate-type deposits (Fig.3) are the Witwatersrand Basin of South Africa, where uranium has been produced in 26 of the gold mines as a by-product, and the Blind River-Elliot Lake area of Ontario, Canada. Mines in the latter area have been closed. This type contains pyrite as well as microscopic grains of uraninite ($UO_2$), and is commonly interpreted as having been deposited by stream action prior to the presence of an oxygen atmosphere.

## Unconformity-type Deposits

The two main regions of unconformity-type uranium deposits (Fig.4) are in the Alligator Rivers region of northern Australia and the Lake Athabasca region of northern Saskatchewan, Canada.

In Australia, the fluvial Kombolgie Formation (1500 – 1700 Ma?) unconformably overlies older Paleoproterozoic (1850 Ma) basement rocks. Where the Kombolgie has been eroded away, the uncon-

Figure 4. Unconformity-type.

Figure 5. Sandstone-type.

formity-related deposits have been exposed. The four big deposits, all proximal to the escarpment of Kombolgie Formation that forms the western edge of the Arnhem Land Plateau and Aboriginal Reserve, are Nabarlek (already mined), Ranger (now being mined), Jabiluka (being prepared for mining) and Koongaara.

In Saskatchewan, the fluvial Athabasca Sandstone (1700 Ma?) unconformably overlies Paleoproterozoic basement rocks (1850 Ma?). The first deposits were located where the Athabasca Sandstone had been eroded away, exposing the unconformity and the deposits. Projection of graphite-bearing bedrock beneath the sandstone has resulted in the location of several other deposits, some overlain by as much as 1400 m of sandstone. The dozen or so deposits are small but rich, with $UO_2$ contents of some exceeding 12 percent. The Cluff Lake deposit is an impact structure in the western interior portion of the Athabasca basin. That deposit, and the others more recently located beneath the sandstone, suggest that additional deposits may exist. Estimated reserves are about 800 000 tons. Recent exploration in the Thelon basin to the northeast of the Athabasca region has already led to one new deposit.

## Breccia-type Deposits

Olympic Dam in southern Australia is the only known major deposit of this type. It is a hematite-rich breccia in an anorogenic granite. It is a Cu-U-Fe-REE deposit of 20 percent iron, 1.1 percent copper, and 0.04 % U; only the latter two elements are recovered. It is the largest uranium ore body in the world, containing 3810 m. tons, and making up about 2/3 of Australia's U reserves.

## Sandstone-type Deposits

This type of deposit (Fig.5), Phanerozoic in age, is the product of groundwater that moved through sandstone and deposited its dissolved uranium as uraninite or coffinite where the oxidizing waters encountered reducing conditions. These "roll-front" deposits are commonly C-shaped in cross section, and can be tens of meters thick with width and length measured in km. The grade is low, measured in tenths of a percent.

## Conclusions

Because the world has not developed alternative energy in any quantity to date, we MUST have oil to keep fueling the world's economies. Therefore, we have military conflict in the Middle East. The word OIL is synonymous with the word GEOPOLITICS. Because of oil, every nation is facing major problems that include national security, the economy, the balance of trade, and the environment. We must DECARBONIZE for several reasons. The world may HAVE to go nuclear to sustain our great energy demands. Nuclear power can also provide the great amounts of energy necessary for dissociating water, thereby providing hydrogen for the hydrogen fuel cell for vehicles.

Are we concerned? We should be looking into the future, "which isn't what it used to be!" David

Goldstein dedicated his 2004 book, Out of Gas, as follows:"To our children and grandchildren who will not inherit the riches that we inherited." What are we leaving our descendents? They will look back at our time and shake their heads in disbelief – "They used up the oil for transportation in millions and millions of motor vehicles, and did not save it for petrochemicals!" We are practicing unsustainable consumption on a limited planet. Abraham Lincoln said, "You cannot escape the responsibility of tomorrow by evading it today."

**ENERGY SOLUTIONS?**

1. DRILLING FOR MORE OIL?
2. CONSERVATION?
3. ALTERNATIVE ENERGY, INCLUDING NUCLEAR?
4. ALL OF THE ABOVE? YES!!

The amount of oil in tar sands and oil shale, as noted above, appears to be very large, 315 b. bbls. and 400 bbls., respectively. And we read about new oil discoveries, such as a 4 b. bbl. discovery in Kazakhstan! Just divide any such numbers by 7 to see how long that oil, regardless of the quantity, would last the U.S. today. (How long will ANWR oil last the U.S.?) Divide the size of a new discovery by 30 to see how long it will last the world at today's rate of use. Divide by 50 to see how long it would last the world in 2025. The answers are shockingly small numbers, and show that we MUST have alternative plans in place, and SOON! And it is cheaper to conserve than to find and produce new oil.

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