ENERGY SUPPLY: ARE WE RUNNING OUT OF ENERGY?

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Contents

Summary

The world depends on fossil fuels (oil, natural gas, and coal) for most of its energy. The two principal concerns about these fuels are that they may be depleted before viable substitutes are available and that they are contributing to global warming through the emission of carbon into the atmosphere. While so-called "conventional" supplies of oil and natural gas that can be produced with existing technology at current prices may be relatively limited, technology is constantly shifting unconventional resources such as heavy oil into the conventional category. Vast, largely untapped, unconventional oil and natural gas resources exist in heavy oil, tar sands, oil shale, coalbed methane, low permeability gas reservoirs, gas shale and gas hydrates. Carbon emissions can be reduced by using natural gas instead of coal for some electrical generation. Natural gas produces approximately half of the carbon emissions of coal with oil midway between natural gas and coal. Nuclear power does not produce carbon emissions, but its use has been limited by concerns about safety and nuclear waste disposal. Hydroelectricity is an important energy source, but relatively few untapped sites exist in industrialized countries. Wind power electrical generation, which is becoming cost competitive with fossil fuels, is being installed in Europe to reduce carbon emissions. The cost of electricity from photovoltaic systems is also becoming more competitive. Just about anything that has kinetic energy (ocean tides, wind, water) or chemical energy

(municipal solid waste, biomass, fossil fuels) can be used as a source of energy. Whether or not the energy supply is utilized depends on accessibility, cost, and environmental impact.

1 Introduction

People in industrialized countries rely on an uninterrupted supply of energy. Disruptions of energy supply have major negative social and economic consequences. Prolonged power interruptions often lead to a declaration of a state of emergency. A steady supply of energy is required to maintain life as we know it in industrialized countries. In less developed countries, frequent energy disruptions in the form of scheduled or unscheduled electrical blackouts or transportation fuel shortages impede economic development. More reliable supplies of power and fuel are prerequisites for advancement in developing countries.

According to the United States Department of Energy, Energy Information Administration (EIA) total world energy consumption in 1996 was 375.5 Btu (4 x 10^5 J). The EIA predicts that world energy consumption will increase by 2 percent per year for the next 20 years, with reliance on fossil fuels (oil, natural gas, and coal) increasing from 85 percent to 88 percent of the total energy consumption. Since fossil fuels are non-renewable natural resources, the issue of resource exhaustion especially for oil has been hotly debated.

Society has begun to demand not just reliable energy supplies, but energy supplies that are perceived as safe and non-damaging to the environment. Concern about global warming may lead to a preference for energy supplies, which produce lower or no carbon emissions. Of the fossil fuels, coal emits the most carbon per unit of energy output, followed by oil, with natural gas producing the smallest amount. Even some sources of energy, which do not emit carbon are also viewed as posing threats to the environment. Although nuclear power has not been implicated in global warming, the risk of nuclear accidents and the hazards of nuclear waste disposal have led some countries to ban or seek to discontinue nuclear power generation. The construction of dams and flooding of habitats associated with hydroelectric power generation creates opposition to that energy source. Turbines used to generate wind power can pose threats to birds. Systems to harness tidal energy may be hazardous to some types of marine life. In the effort to provide the energy required to power civilization, a balance must be reached between availability, reliability, cost, and environmental impact of the different energy types.

2 Oil

In 1956 M. King Hubbert published a paper predicting that oil production from the lower 48 states in the United States would peak in the 1970s. Hubbert's prediction was based on an estimate of the ultimate recoverable oil reserves and the assumption that production rate would peak when half the ultimately recoverable oil had been produced and production rate would then decline in a symmetric negative-exponential form to zero. When United States production declined after 1970, Hubbert's methodology gained a considerable following. The sharp increases in oil prices associated with the

1973 Arab oil embargo, the 1978 Iranian revolution, and the 1980 Iran/Iraq war further enhanced the perception that oil was in short supply [Figure 1].

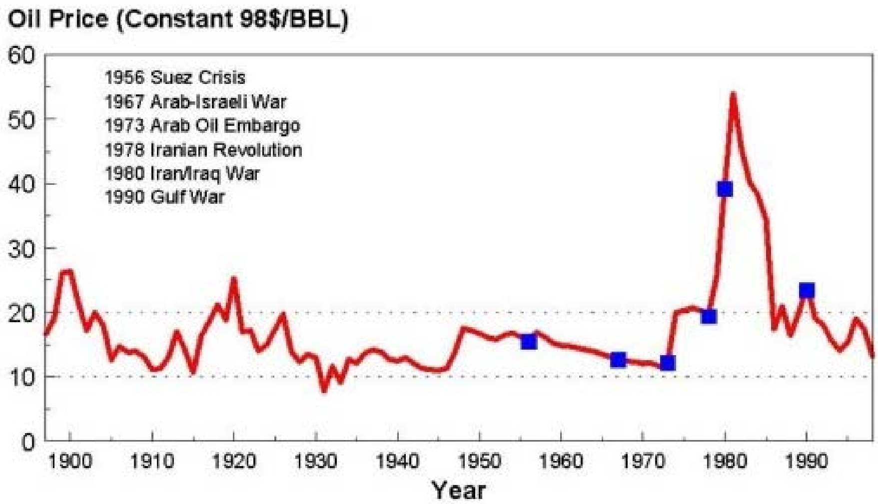

Figure 1: USA Average Wellhead Oil Price

Later, based on crude oil production rates through the end of 1977, Hubbert predicted that world oil production would peak about 1995. Laherrere has updated Hubbert's world oil peak prediction. As of 1999, he is predicting that oil production will peak within a decade. According to Laherrere's calculations, a billion barrel discovery delays the production peak by only ten days.

The Hubbert/Laherrere predictions are based on so-called "conventional oil." Laherrere defines "conventional reserves" as reserves that can be produced for $20 to $25 per barrel. "Optimistic" economists including people such as Julian Simon, counter gloomy predictions of scarcity. They note that predictions such as those of Hubbert and Laherrere are based on the supplies of the natural resource available at current prices with current technology, but that the most promising deposits will always be depleted first, so that predictions based on physical calculations of reserves exhaustion will always be pessimistic.

Small increases in price greatly increase the potential supplies that are economically available and experts tend to underestimate the impact of future technological advances. Thus, technology counterbalances depletion by reducing recovery costs of both conventional oil and substitutes. Indeed, under Laherrere's definition, resources are continually being transferred from the unconventional to conventional category as technology decreases production costs.

Supporters of Hubbert's gloomy forecast cite his successful prediction of the peak in oil production in the United States. In contrast, Simon's supporters point to a successful bet he made with natural resources doomsayers. Simon won a bet made in 1980 that five natural resources of his opponents' choice would be lower in cost in 1990. Increased scarcity of a raw material implies a higher price.

Opponents of Hubbert's predictions, including Porter, think that the peak in United States production was not strictly an indication of resource exhaustion. Porter points out that United States oil resources are, from a global perspective, relatively high cost and that the production decline in the United States was aggravated by restrictive federal policies, which blocked access to the most promising remaining areas.

Oil prices have not been set purely by supply and demand. There is a long history of price manipulation. For many years the Texas Railroad Commission regulated supply to keep oil price from collapsing. Since its formation in 1960, the Organization of Petroleum Exporting Countries (OPEC) has sought to keep oil prices high. The higher prices have enabled higher-cost non-OPEC suppliers to gain market share. When prices soared in the 1970's and early 1980's, OPEC's share dropped from 55 percent to 30 percent, and the Gulf states' share of world production plummeted from 38 percent to 18 percent. Almost all OPEC oil can be produced for less than \$10 per barrel. Persian Gulf production costs are less than \$2 per barrel. In the near future, unless OPEC exercises production restraint, there is risk of over supply of oil and very low prices.

Over one-fourth of the world's proven oil reserves are in Saudi Arabia, 261.5 x 10^9 barrels with up to 1 x 10^{12} barrels ultimately recoverable. Iraq has the second highest proven reserves, 112 x 10^9 barrels and 215 x 10^9 barrels probable and possible. Kuwait and Iran each have about 9 percent of the world's proven oil reserves.

Arguments about the scarcity of oil focus on the magnitude of the disruption and cost increase associated with the transition from conventional to non-conventional oil. However, the boundary between conventional and non-conventional oil resources is fuzzy.

Deep water resources are considered by some people to be non-conventional, but what classifies as deep water is a moving target. Rapid technological advances have quickly pushed the depth of production to over 1000 meters. Over 1 million barrels of oil per day are now produced from water depths over 200 meters. Not only has production become possible in deeper and deeper water, but the economic thresholds of field size and per well production rate have been reduced. Deep water production is a good example of a gradual transition of resources from the non-conventional to the conventional category.

Heavy oil and tar sands are another category of non-conventional oil resource. Oils are graded on their density and viscosity. Oil may be considered heavy if its density is between 10°API and 20°API (specific gravity between 1 and 0.934) and extra heavy for less than 10°API (specific gravity greater than 1). The viscosity of tar sands is greater than 10,000 milliPascal-seconds at reservoir temperature. Different delimiters for heavy and extra-heavy oil are often used.

The volumes of heavy oil and tar sand resources around the world dwarf the quantity of conventional oil. The combined in-place heavy oil and tar resources of Canada, Russia, and Venezuela are about 5 x 10^{12} barrels (over a 100 year supply). In comparison, there are about 2 x 10^{12} barrels of oil in place in the Middle East of which 35 percent to 50 percent is recoverable with current technology. The EIA estimates ultimate conventional oil recovery at 4.7 x 10^{12} barrels, while the International Energy Agency (IEA) estimates ultimate conventional oil recovery at 2.7 x 10^{12} barrels. Laherrere's prediction of a peak in oil production in the next decade is based on the IEA estimate of ultimate conventional oil recovery. Just as deep water resources are gradually being brought onto production, heavy, and extra-heavy oil resources are slowly being developed. Steam injection, horizontal wells, use of light oil as a dilutant both downhole and for transportation, and emulsion technology are gradually making more and more heavy oil resources commercially viable.

Oil shale is another non-conventional source of oil. Oil shales are sedimentary rocks, which are rich in organic matter and can yield oil by pyrolysis at temperatures around 500°C. The richest oil shales in the United States are in the Green River Formation of Wyoming, Colorado, and Utah. Considering only the shales that could yield more than 45 liters of oil per ton, there are 1.5 x 10^{12} barrels of oil in place. Estimates of global oil shale resources are highly speculative. The EIA estimates 15 x 10^{12} barrels worldwide with more than one third of that total in the United States.

When oil prices soared in the late 1970s and early 1980s, several oil companies initiated pilot projects to produce oil from oil shale. However, when oil prices collapsed, these projects were discontinued. Since then, oil prices have been too low to revive interest. However, if oil becomes scarce and prices rise, oil shale represents a huge potential resource. One of the greatest potential sources of oil is enhanced oil recovery in existing oil fields. Conventional oil does not reside in giant underground lakes, but in tiny pore spaces within the rock. The size of these pore spaces, their percentage of the total rock volume, the degree to which they are filled with oil, and their inter-connectivity varies tremendously from oil field to oil field. Under current technical and economic conditions, on the average less than 35 percent of the oil in place is recovered. Recovery of over 50 percent has been achieved with existing technology in some reservoirs. If the worldwide average recovery were increased to 50 percent, over 750 x 10^{9} barrels would be added to reserves.

The definition of conventional oil is continuously evolving with advancing technology. While the easiest to find and produce oil may peak in the next ten to twenty years, huge volumes of extra-heavy oil, tar sands, and oil shales remain to be tapped. Future oil crises like the crises of the last thirty years are more likely to arise from politics and war than from global shortage of supply.

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Biographical Sketch

Eve Sprunt received her B.S. and M.S. from MIT and her Ph.D. from Stanford University. From 1978 through 2000 she worked for Mobil Oil spending the first 15 years in research, authoring 23 patents and 28 peer-reviewed technical publications, and subsequent years in Mobil's New Exploration and Producing Ventures. In 2000, she joined Chevron Corporation as a Senior Science and Technology Coordinator. From 1993 through 1996, she served as the Senior Technical Editor of the Society of Petroleum Engineers (SPE). As Senior Technical Editor, she supervised seven technical publications and wrote a monthly editorial column for SPE's Journal of Petroleum Technology (JPT). Since 1996, she has written a bimonthly column for JPT. She was a Distinguished Lecturer for SPE in 1998-1999. From 1991 through 1994, she served on the Board of Directors of SPE. From 1988 through 1990, she served as Executive Editor of SPE Formation Evaluation. She was SPE Program Committee Chairman in 1988. Eve founded the Society of Core Analysts (SCA) a chapter-at-large of the Society of Professional Well Log Analysts. She has served as President and as a distinguished lecturer for SCA. From 1989 to 1997, she served as Chairman of the American Petroleum Institute (API) Subcommittee on Core Analysis and edited the second edition of the API Recommended Practices for Core Analysis, RP40. Since 1983 Eve has been a member of MIT's Educational Council. She also serves on visiting committees at the Colorado School of Mines and MIT.