ENERGY RESOURCES ASSESSMENT

Anthony D. Owen
The University of New South Wales, Sydney, Australia

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Summary

This article presents an assessment of the world's commercial energy resource base. Energy resources are generally categorized as either renewable or exhaustible (or non-renewable). The latter category currently dominates the commercial energy market, meeting approximately 80 percent of global energy demand. Although current resources of fossil fuels are relatively large, and certainly sufficient to provide for the world's requirements throughout the current century, concern about the environmental effects of energy use based upon fossil fuel technologies has highlighted the role that renewable energy technologies can play in the future. Uranium, a nuclear fuel, is also in ample supply, but it too suffers from (different) environmental concerns. The potential for renewable technologies is (at least in theory) unlimited. However there are many technological, as well as cost, constraints to their widespread adoption.

1. Introduction

Natural Resources are defined as the living and non-living endowments of the earth that are exploited by man as sources of food, raw materials, and energy. Thus natural resources exist in the environment as stocks from which economic activity draws flows of inputs. A major distinction is drawn in natural resource economics between *renewable* (i.e. non-agricultural animals and plants) and *non-renewable* or exhaustible (i.e. minerals) natural resources.

Given appropriate harvesting techniques, all renewable resources should be sustainable without manipulating the population's reproductive systems (hence the exclusion of agricultural products). The economics of commercial ocean fisheries dominates this topic area. However, it is relatively easy to make a renewable resource disappear if the rate of harvest persistently exceeds the rate of natural growth of the resource (the Dodo was a renewable resource). This could also happen if the resource population falls below some critical level.

Although all non-renewable resources are exhaustible, some are recyclable thus extending the effective total life of the resource. Others, mainly non-nuclear energy minerals, are not. Combustion is a physically irreversible process.

The statement that the world's natural resources are currently being overused with reference to future generations is a relatively common subjective opinion. To consider this premise, essentially we need to address two questions:

- Are the use rates observed as the outcomes of the operations of markets as they actually exist those required for efficiency in intertemporal allocation?
- From among the many available efficient intertemporal allocations, which should we now choose having regard to the interests of future generations?

With regard to the first question, whilst in reality there is clearly a significant departure from "ideal" market conditions, it is more difficult to assess how actual outcomes may deviate from those under efficiency requirements. Market distortions can lead to departures from the efficiency outcome in both positive and negative directions. Consequently the direction of the net impact is not certain. Thus where the firms exploiting natural resource stocks are not price takers, the competitive outcome will involve less current use than the efficiency standard requires. Conversely, where there are external costs attached to resource extraction and/or use, or where private property rights in resource stocks are absent (such as open-access fisheries), the competitive outcome will involve current over-use with respect to the efficiency standard.

2. World Energy Reserves and Resources: Summary

Table 1 gives year-end 1998 reserves of the world's major energy minerals, 1998 production levels of each mineral, and the corresponding reserves to production ratio.

	Units	Reserves	Production	R/P Ratio
Crude Oil	Billion barrels	1052.9	25.8	40.8
Natural Gas	Trillion cubic meters	146.4	2.3	64.5
Black Coal	Billion tons	509.5	3.7	139.4
Brown Coal	Billion tons	474.7	0.9	527.4
Uranium	Thousand tons U	2535.0	33.9	74.8

Sources: Crude oil and natural gas from *BP Statistical Review of World Energy*.
Black and brown coal from *Coal Information 1998*, OECD, Paris.
Uranium from *Uranium: Resources. Production and Demand, 1998,* OECD, Paris, and the Uranium Institute.

Table 1.World Non-Renewable Energy Reserves, Year-end 1998

The latter figure gives the level of forward production available from reserves at current rates of the mineral's exploitation. It is clear from the reserves to production ratios that world reserves of all energy minerals are currently in relative abundance. However, for oil in particular, an asymmetric distribution of reserves across the globe has been an ongoing concern for security of supply for OECD countries over the past half century.

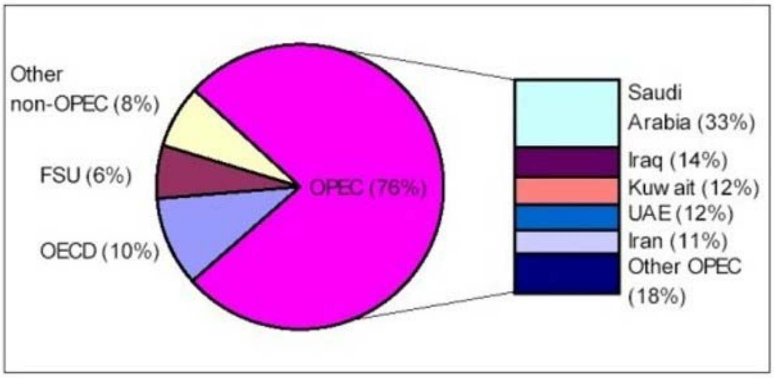
3. Oil

3.1 Oil reserves

Oil reserves comprise oil that has been discovered but which remains in place. All discoveries are initially appraised for their size in terms of oil *in situ*. Based on probabalistic estimates derived from a large number of parameters there will subsequently be an initial declaration of recoverable oil which geological and engineering information indicates can, with a reasonable degree of certainty, be recovered in the future under existing economic and operating conditions. These constitute the so-called "proven reserves" of the field at that particular time. All fields will also be declared as having additional volumes of "probable" and "possible" reserves, with over 50 percent and under 50 percent probability respectively of being recoverable, from the estimated total volume of oil-in-place in the reservoir.

The production process itself, however, produces a continuing flow of information that enables regular re-evaluations of the recoverable reserves of a field to be made. Though some fields' reserves are downgraded, as a result of production experience, upward evaluation of reserves over time is more usual. This process often leads to a situation in which the declarations of the proven reserves of oil in a field trend upwards over time, in spite of the ongoing extraction of oil in the production process. Although this process must ultimately reach the limit of the field's physical size, this too may be re-evaluated upwards as extensions to the boundaries are exploited. Naturally the economic environment will also play a critical role in such processes, with rising profitability stimulating interest in enhancement of a field's recoverable reserves.

Figure 1 shows the distribution of the world's oil reserves across major economic "blocks."



Source: *BP Statistical Review of World Energy*

Figure 1. Distribution of World Oil Reserves

The Organization of Petroleum Exporting Countries (OPEC) dominates here, accounting for 76 percent of the total reserve base. The only significant non-OPEC reserves are located in Mexico, the USA, the Former Soviet Union (FSU), and China. However, within OPEC an asymmetry also exists, with Saudi Arabia dominating the reserve base.

The veracity of the data contained in Figure 1 has been in question for many years, with claims that OPEC has exaggerated its oil reserve estimates in order to slow down investment in alternative energy. This claim is based upon the premise that, if oil reserves appear to be plentiful, then the prospect of relatively low oil prices over the foreseeable future may discourage capital flows into alternative, more environmentally benign, technologies such as the hydrogen fuel cell car. Correspondingly, it has also been claimed that OECD countries may be inflating non-OPEC reserves in order to keep downward pressure on OPEC-determined price ceilings.

At current rates of production and discovery, oil reserves are sufficient to last for about 40 years. This figure remained relatively constant throughout the 1990s, and continues to be considerably higher than at any other time in the history of the oil industry. Even if consumption were to increase by 2 percent a year (roughly its historical average rate of growth), and with no additions made to reserves, then current reserves would still last for 25 years. Although the world appears to be comfortable in its ability to meet forward requirements for many years, it is the asymmetric distribution of these reserves, and the associated political risks, that still drive the search for, and development of, reserves outside of the OPEC countries and the former FSU. For example, the United States still maintains a strategic petroleum reserve of about 570 million barrels of government-owned crude, stored in tanks and natural caverns in Texas and Louisiana. This remains as a legacy of the 1973–74 OPEC oil embargo.

3.2 Oil Resource Outlook

There is much speculation surrounding estimates of future technically recoverable oil, particularly where new locations (such as deepwater and polar sites) become open to exploration due to advances in exploration technology. The United States Geological Survey has derived an estimate (including current reserves) amounting to 2.1 trillion barrels—equivalent to about 85 years' supply at current production rates. Potentially this figure could be increased further if cost and environmentally effective methods of extracting oil from tar sands and oil shale could be developed.

However, discoveries of major oil fields are now relatively rare. Although discoveries during the last four decades of the twentieth century outstripped extraction in terms of oil volumes, additions to the reserve base were in relative decline. No field with more than 27 million barrels, approximately one year of global consumption at current rates, has been found anywhere since Safaniya in Saudi Arabia was discovered in 1951. The more prospective areas are currently the Gulf of Mexico, the Caspian Sea, and coastal West Africa, but mega-deposits have proved elusive.

Advances in technology are providing major opportunities for cost reductions at both the oil exploration and recovery stages, thus permitting "new" fields to be discovered and brought on-line where previously they would have been considered either prohibitively expensive or technologically too difficult. Thus technology is offsetting depletion. Examples are:

- horizontal drilling, which permits bores to take the least cost route to an oil reservoir;
- deep-water drilling technology; and
- three-dimensional seismic data that, utilizing digital satellite communications, can produce a detailed three dimensional model of a potential oil field in a matter of hours.

Improvements in seismology have led to a dramatic improvement in the success rate of exploratory drilling. Thus a success rate of one in ten holes drilled in the 1980s has been improved to one in two for the most technically advanced companies.

3.3 Non-Conventional Oil Resources

With the exception of the FSU, data on oil reserves and on ultimate resources relate to "conventional" oil in deep underground reservoirs from which extraction is achieved through well-based production systems whereby the liquid oil is brought to the surface.

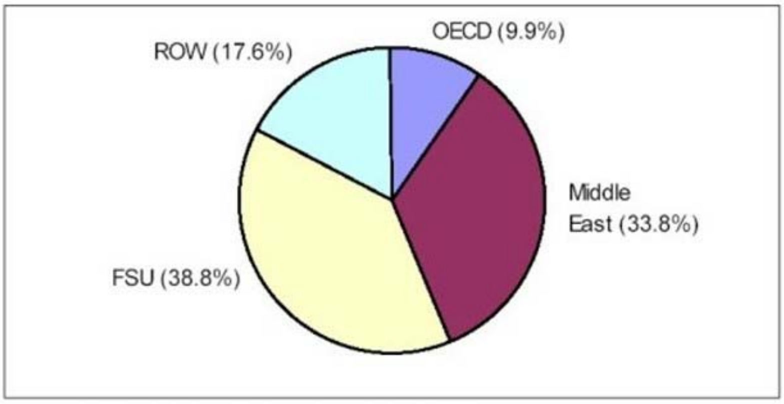
It rises to the surface either under its own pressure, or by means of secondary recovery methods that involve re-pressuring the reservoirs or a reduction in the viscosity of the liquid. “Non-conventional” oil reserves refer to the occurrence of oil in different habitats and/or the production of which requires different technologies. The FSU makes no such distinction.

Non-conventional oil deposits are widespread and potentially very significant in terms of volumes. Non-conventional deposits include the tar-sands of Athabasca in Western Canada, the heavy oil belt of the Orinoco region of Venezuela, and oil shales in Brazil, India, Madagascar, the United States, Zaire, and many other countries. However, there has not yet been any systematic evaluation of the locations and distribution of the occurrence of non-conventional oil. Estimates of its volumes on a worldwide scale extend as high as 40 000 billion barrels. However, technical, economic, and environmental factors combine to render most of this resource currently unusable.

Production and marketing possibilities both for orimulsion from Venezuela’s Orinoco oil belt and for oil derived from the processing of the Athabasca tar sands are currently sufficient to indicate that some part of these resources can be designated as reserves. As the technology for their efficient recovery evolves, such resources may eventually add significantly to global reserves.

4. Natural Gas

Although reserves of natural gas are far more evenly distributed worldwide than oil (Figure 2), nevertheless OPEC countries are endowed with a substantial proportion of the total. About 73 percent of the world’s natural gas reserves are located in the FSU and the countries of the Middle East. Russia and Iran together account for almost one-half of the world’s gas reserves. However, the widespread distribution and relative abundance of gas reserves (the reserves to production ratio is over 60 years), and its use in applications where substitutes are generally readily available, means that it does not have the same strategic value as access to oil supplies for the vast majority of developed countries.



Source: *BP Statistical Review of World Energy*

Figure 2. World Reserves of Natural Gas

Estimates of gas reserves are expected to grow over time because, as with any mineral resource, uncertainty is reduced and technology develops, new sources are discovered, and upward revisions are made to identified reserves. In many parts of the world, reserves of natural gas are known to exist, but the lack of a suitable infrastructure to get them to consumers means that they are not currently considered economic.

These finds are referred to as "stranded" gas. It is likely that this gas will increasingly be exploited as existing pipeline systems are extended, as markets are developed closer to stranded gas reserves, or via gas-to-liquids technology. In addition, unconventional gas reserves may be exploited as technology develops and gas prices rise to make it economic to do so.

The United States Geological Survey estimates ultimate conventional gas reserves at 320 trillion cubic meters (tcm). Natural gas is anticipated to be the fastest growing primary energy source over the early decades of the twenty first century. Many industrialized countries view natural gas as a way to reduce greenhouse gas emissions and, as a result, are expected to expand their use of it.

In addition, because natural gas is a cleaner fossil fuel than oil or coal, and is not as controversial as nuclear power, it is expected to be the fuel of choice for many countries in the future. Although developing countries are also interested in the environmental benefits of using natural gas, often they are more intent on using natural gas to diversify fuel mix for strategic reasons.

Delivery systems are the main constraint on expansion of the international natural gas market. Where natural gas is available, and its delivery to the market economically feasible, it is the preferred fuel in power generation, water and space heating, and industry. There are also favorable market opportunities for gas in household cooking where retail grids are developing, notably in Asia.

Once gas delivery systems have been built (with substantial capital investment), the marginal cost of supplying gas in the short term is low, provided spare supply and delivery capacity exist. In practice, gas demand will develop differently from one world region to another, depending on the size of the reserves, their distance from the markets, and competition from other energy sources, predominantly coal and oil. Approximately 20 percent of natural gas consumption crosses at least one border, either by pipeline (around 72 percent) or in the form of liquified natural gas (LNG) (around 28 percent).

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www.rmi.org. [The web site of the Rocky Mountain Institute contains detailed assessments of the potentials for selected "cutting edge" renewable energy technologies.]

Biographical Sketch

Anthony David Owen B.A., M.A., Ph.D., F.S.S. Anthony Owen is currently Associate Professor of Economics at The University of New South Wales, where he has been employed since 1974. He was Director of the Centre for Applied Economic Research (CAER) from 1989 to 1995, and has been Director of the University's Energy Research Development and Information Centre (ERDIC) since 2000. He has almost 30 years of research experience in the fields of econometrics, energy economics, and environmental economics, and currently serves on the International Editorial Boards of *Energy Policy* and *Energy Economics*. He was Conference Chair for the 23rd Annual International Conference of the International Association for Energy Economics, held in Sydney, June 2000. He has had extensive consulting experience with the Organisation for Economic Co-operation and Development (OECD), and the Governments of Australia, Norway, and the United Kingdom. Professor Owen is the author of four books, five monographs and more than 50 papers published in academic journals. He is a Fellow of the Royal Statistical Society (FSS).