The Future of Oil as a Source of ENERGY

The Emirates Center for Strategic Studies and Research

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Abbreviations and Acronyms

AAPG	American Association of Petroleum Geologists
ABB	Asea Brown Boveri
AFC	alkaline fuel cell
ANZ	Australia and New Zealand
API	American Petroleum Institute
ARCO	Atlantic Richfield Company
AWEA	American Wind Energy Association
bbl	blue barrels
BCM	billion cubic meters
BCR	benefit–cost ratio
BMW	Bayerische Motoren Werke
boe	barrels of oil equivalent
BP	British Petroleum
BTU	British Thermal Unit
CARB	California Air Resources Board
CBM	coal bed methane
CCGT	combined cycle gas turbine
CDIAC	Carbon Dioxide Information Analysis Center
CDM	clean development mechanism
CEED	Center for Energy and Economic Development
CET	clean energy technologies
cf	cubic feet
CIF	cost, insurance and freight
CO_2	carbon dioxide
cp	centipoise
CP	cumulative production
CSEG	Canadian Society of Exploration Geophysicists
CT	compliant tower
DHFCV	direct hydrogen fuel cell vehicle
DOE	(US) Department of Energy
DOI	(US) Department of Industry
DTI	Department of Trade and Industry
E/GDP	energy/real gross domestic product
EIA	Energy Information Administration
EPA	(US) Environmental Protection Agency

EPRI	Electricity Policy Research Institute
ERG	Energy and Resources Group
EROI	energy return on investment
EU	European Union
EV	electric vehicle
FCV	fuel cell vehicle
FP	fixed platform
FPS	floating production systems
FSU	Former Soviet Union
FT	*Financial Times*
Gb	gigabarrels (billion barrels)
GCC	Gulf Co-operation Council
GDP	gross domestic product
GEF	Global Environment Facility
GHG	greenhouse gases
GM	General Motors
GNP	gross national product
GtC	giga (billion) tons of carbon
GTL	gas-to-liquids
IEE	Institution of Electrical Engineers
ICE	internal combustion engines
IEA	International Energy Agency
IEO	International Energy Outlook
IIASA	International Institute for Applied Systems and Analysis
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
IT	information technology
J	Joule
JIP	joint industry project
JNOC TRC	Japanese National Oil Company Technology Research Center
kWh	kilowatt hour
LDCs	less developed countries
LEV	low emission vehicle
LNG	liquefied natural gas
MB	megabytes
mb/d/yr	million barrels per day per year
MCFC	molten carbonate fuel cell
MIT	Massachusetts Institute of Technology

MMS	Mineral Management Services
MTOE	million tons of oil equivalent
MTP	market transformation program
MWD	measurement while drilling
NASA	National Aeronautics and Space Administration
NEB	National Energy Board
NGL	natural gas liquids
NPD	Norwegian Petroleum Directorate
NPV	net present value
NREL	National Renewable Energy Laboratory
NZ	New Zealand
OAPEC	Organization of Arab Petroleum Exporting Countries
OECD	Organization for Economic Cooperation and Development
O&GJ	*Oil and Gas Journal*
O&M	operation and maintenance
OMI	Oil Market Intelligence
OPEC	Organization of Petroleum Exporting Countries
ORNL	Oak Ridge National Laboratory
PAFC	phosphoric acid fuel cell
PCAST	President's Committee of Advisors on Science and Technology
Pcf	Peta cubic feet
PEM	proton exchange membrane
PIW	*Petroleum Intelligence Weekly*
PM	particulate matter
ppmv	parts per million volume
PR	progress ratio
PS	petroleum system
P&T	pressure and temperature
PVs	photovoltaics
RAEL	Renewable and Appropriate Energy Laboratory
rbl	red barrels
R&D	research and development
REPP	Renewable Energy Policy Project
ROV	remote operating vehicle
ROW	rest of the world
R/P	Reserves/Production
RR	remaining reserves
RRI	Robertson Research International

SCSSV	sub surface safety valve
SEC	Securities and Exchange Commission
SEI	Stockholm Environment Institute
SI	International System of Units
SOFC	solid oxide fuel cell
SPE	Society of Petroleum Engineers
SPFC	solid polymer fuel cell
SS	subsea system
STEO	short term energy outlook
SUV	Sport and Utility Vehicle
tb/d	thousand barrels per day
Tcf	tera cubic feet (trillion cubic feet)
TES	Transportation Energy Strategy
TLP	tension leg platform
toe	tons of oil equivalent
TVD	total vertical depth
UAE	United Arab Emirates
USDOE	US Department of Energy
USDOI	US Department of Industry
USEPA	US Environmental Protection Agency
USGS	US Geological Survey
VLEV	very low emission vehicle
W	Watt
WD	water depth
WEC	World Energy Council
WO	*World Oil*
Wp	Watts-peak
WPC	World Petroleum Congress
WTI	West Texas Intermediate
ZEV	zero emissions vehicle

FOREWORD

Oil has always been regarded as a key component of the crucial energy sector, which drives economic progress. However, the global predominance of oil as a source of energy has been affected in recent years by several developments. Positive and negative determinants are shaping the future prospects of oil. Given the finite nature of the resource, the relative merits of alternative sources of energy, the possibility of major technological breakthroughs and new environmental concerns and imperatives, significant shifts are likely to take place in the global energy scenario.

Greater diversification in energy sources and the growing use of alternative and renewable forms of energy have been prompted by economic, ecological and security considerations. Non-conventional sources, such as photovoltaics, fuel cells, microturbines and wind power, are becoming increasingly viable and pose challenges to more conventional sources of energy. All indications are that the fossil fuel era will not last indefinitely and that the world is undergoing a transition from a hydrocarbon-based economy to one based on renewable forms of energy.

The future of oil is a matter of profound concern not only to petroleum companies, but also to oil-producing nations and oil-dependent economies. Energy experts who assembled in Abu Dhabi for the ECSSR Sixth Annual Energy Conference, held on October 7–8, 2000, focused attention on various aspects relating to *The Future of Oil as a Source of Energy*. The main thrust of their presentations, which are compiled in this book, identifies the significant trends and factors influencing the global position and price of oil.

Among the important topics discussed at the conference were the realities of oil as a finite resource, the complexities of energy forecasting and the positive and negative drivers affecting the position of oil. The comparative advantages and disadvantages of different energy sources were highlighted, and the viability of alternative and renewable sources assessed. Furthermore, the rising importance of natural gas was analyzed in the context of the trend toward decarbonization and "clean energy" sources. The need to control volatility and to maintain stability in the oil market was underlined.

In the ultimate analysis, it would appear that resource availability is less likely to determine the future of oil than other economic, ecological and technological considerations. Collectively, the conference presentations

afford a clearer picture of the current energy transition and the anticipated position of oil in the emerging scenario. For the oil producers and oil-dependent economies of the Arabian Gulf, valuable guidelines are offered on how to meet the inevitable challenges posed by an era in which oil may no longer be the prime source of energy.

ECSSR takes this opportunity to thank all the distinguished participants of the Sixth Annual Energy Conference for their stimulating presentations. We would also like to express our appreciation to the panel of expert referees who reviewed these papers and offered their valuable comments. ECSSR is grateful to Mr. Robert Mabro CBE, Director of the Oxford Institute for Energy Studies, for sharing his expert views on the subject through his introductory chapter and concluding observations. A word of thanks is also extended to ECSSR editor Mary Abraham for coordinating the publication of this book.

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Director
ECSSR

Section 1

INTRODUCTION

The Future of Oil

Robert Mabro

Does oil have a future? This question is being asked from time to time by those who live in countries heavily dependent for their economic well-being on revenues accruing from petroleum exports. I also suspect that oil companies concerned about business prospects in the very long run ask themselves this question. BP's recent choice of the "Beyond Petroleum" motto may suggest that this concern is genuine, although some cynical commentators believe that the only purpose is to placate environmentalists and other petrophobic groups.

The question, no doubt, is legitimate. Oil, like gas or coal, is a physical resource. Nature may have been very generous but the size of its mineral gifts is finite. Sooner or later, all the reservoirs that exist on our planet will be discovered. And, if the demand for fossil fuels remains positive for as long as supplies are forthcoming, full depletion will inevitably occur. On this assumption, supplies will dry up at some future date, which is as yet highly uncertain.

However, physical exhaustibility is not the only threat to oil, or for that matter to any commodity, good or service. Primary commodities, whether exhaustible or renewable, often give way to substitutes, which in turn give way to other commodities that emerge on the world scene. In energy, firewood gave way to coal, then coal to oil. In other fields, plastics replaced metals in a wide variety of uses; artificial fibers superseded cotton, silk and

wool. In all cases, however, the original commodity always continues to be used, retaining a small share of demand, or carving for itself a niche in the market. Thus, firewood is still being used as a fuel, not only in developing countries; coal still supplies some 20 per cent of world energy; natural rubber remains irreplaceable in the manufacturing of aircraft tires; and silk and cotton are sought after by high-income customers who can afford to dislike the airtight texture of artificial fabrics.

Primary products are not the only victims of substitution. There is a product cycle for manufactured goods. The invention of color TV eventually kills the black and white set, which for a time retains a share of the demand from low-income groups until the color TV becomes affordable by most consumers. The typewriter has given way to the computer and the slide-rule to the hand calculator. One can multiply the examples *ad infinitum*.

However, the fact that a displaced commodity or product retains some use for a long time is of no great consolation. Those who worry about the future of oil are concerned about the size and the growth of its market. To know that some oil will be consumed for a long time in some small markets or for some esoteric purposes does not alleviate these worries.

Thus the issue remains whether oil is threatened by an economic demise that may precede, perhaps by a long time, the physical exhaustion of the natural resource. The threat to oil comes from two sides: on the supply as well as the demand fronts.

Let us first consider the supply aspect. It is important to recall in this context that crude oil is not consumed as such, except in very rare situations. Crude oil is an intermediate good. The final demand is overwhelmingly for petroleum products obtained from refining the raw material. Some of these products have substitutes. Fuel oil, for example, which is used to raise heat under boilers, can, and indeed has, been replaced by primitive biomass, coal, natural gas or sophisticated nuclear. Gas oil, when used for space heating, competes with natural gas, coal, wood and primary electricity. Other petroleum products are, however, at the other end of the substitution spectrum; there are no readily available substitutes. These are the automotive fuels – gasoline and diesel – and the fuels for aircraft – jet kerosene and aircraft gasoline. Products used as petrochemical feedstock have imperfect substitutes.

The oil domain, therefore, is the transport sector. The threat, on the supply front, in this sector can come from the discovery of a new fuel that

can power cars and airplanes both economically and efficiently. Research is under way in the search for a new product that meets these conditions. It should be recalled here that a change in fuel requires changes in the engines that will use it. For batteries to replace gasoline, one needs to develop new types of batteries and design the electric car. It seems that the latter is easier than the former.

The fuel cell, a technology that elicits much enthusiasm in some quarters and much skepticism in others, will also be associated with some adaptations, minor as they may be, to the engine. But this is a small side issue. The important ones relate to the likely time horizons – the time required for research to lead to discovery, for the discovery to be developed into an economic (that is cost-competitive) product, and for the building of the infrastructure required to introduce and market this product. A new fuel requires the adaptation of service stations for storage and sales; a new type of car will not replace the existing stock immediately since technical and economic obsolescence take time to set in. Another important question about new fuels relates to the energy required for their production. Electric batteries have to be charged, hydrogen has to be obtained. If the primary source is a hydrocarbon, then the future of oil may be less bleak than assumed.

The threat for oil on the demand side is said to come from environmental concerns. Climate change, which may be partially caused by the burning of fossil fuels, is inducing a wave of petrophobia in many countries. The debate over the Kyoto Protocol is familiar. The questions are, first, whether the international community will marshal the political will to cooperate in implementing measures that reduce effectively the volume of greenhouse gases and, second, whether these measures, implemented as agreed in Kyoto, will by themselves cause a significant reduction in the consumption of oil?

The reluctance of the US to agree with the Kyoto measures provides ammunition to the skeptical observers who believe that the agreement will not be implemented in a meaningful way. We shall have to wait and see whether the US will have a change of heart or not and, as importantly, whether a way will be found to involve the developing countries, particularly China and India, in a program which will inevitably fail if it does not obtain global adhesion.

Let us assume, however, that the Kyoto Protocol is implemented and that the cooperation of China and India is secured in a second phase. Yet, it does not follow from this assumption that such an implementation will result in

a significant reduction in oil consumption as compared with a non-Kyoto, business-as-usual situation. The reasons are manifold. First, if carbon emissions are the issue, then coal should suffer more than oil and gas. Second, oil is entrenched in the transport sector where it cannot be easily replaced. Reductions in fossil fuel use will thus fall more heavily where they can be more easily substituted. Third, if permit trading is widely used, the impact on all fuels (and this includes oil) will be significantly mitigated. Fourth, industrialized countries will increasingly seek solutions involving carbon sinks to enable them to meet the targets without disturbing living patterns too much. Fifth, the Kyoto program is not very ambitious anyway. Countries are given the opportunity to avoid reducing emissions by large amounts as they can buy permits from Russia, which enjoys considerable credits. The reason is that Russia is emitting much less than in 1990 (the base year) because of the destruction of its heavy industry, which collapsed with the communist regime.

Some countries, particularly in Europe, may attempt to do more than is required by the Kyoto program, to curb energy consumption. The European Union's view on energy security is that dependence on imports should be curbed through demand management measures. As governments prefer revenue-raising measures to projects that involve increases in public expenditure, they are inclined to use fiscal instruments to manage demand. The easy solution is to tax automotive fuels heavily. This easy solution has been already applied to such an extent in Europe that further increases in petrol and diesel taxes have become politically unacceptable. If governments were serious about the need to throttle the growth in fuel consumption in transport, they would invest in public transportation systems and subsidize research and development (R&D) in car technology. However, they are reluctant to do so, as this means increases in public expenditures.

The question is whether the driving force in energy policy is security or the environment? These two objectives do not conflict if the policy aims at reducing the use of fossil fuels. However, they do conflict if it seeks lower dependence on oil and gas imports by promoting the use of coal or nuclear energy. Coal emits more CO_2 than oil or gas and is far from being environmentally friendly if the concern is global warming. Nuclear energy does not emit CO_2 but is profoundly disliked by environmentalists because of the radiation risks. Both the EU and the USA are talking again about the nuclear option, which was considered to be socially unacceptable until very

recently. Nuclear energy poses a threat to fuel oil to the extent of its current use in power generation. Fuel oil, however, is being increasingly displaced by natural gas, and the growth potential of gas is largely in that sector. In other words, nuclear power represents a greater threat to gas than oil.

Some believe that the solution to both the environment and the security problem will be provided by renewable energy, particularly solar and wind. Renewables can be produced *in situ*: both solar and wind in many regions of the world; solar or wind in others. This reduces import dependence. Renewables do not emit CO_2, sulfur or particles. In this sense, they are environmentally friendly. Solar energy, however, is very expensive except where it is used to produce low-temperature heat. High-temperature heat is needed for power generation and recourse to solar energy in this sector involves very high costs. Windmills are noisy and ugly and as such environmentally objectionable. The solution is to build them offshore, which increases their costs.

Solar and wind energy also threaten fossil fuels in their use for power generation and for applications such as space heating/cooling, where secondary electricity can displace oil, gas and coal. Their impact on the transport sector depends critically on the development of electric cars, since the batteries that will power them have to be charged. We are still very far from an era in which energy supplies will be dominated by the sun and wind, and probably still far (even if not as much) from the domination of nuclear energy.

We thus have two issues: depletion of finite reserves and economic demise caused either by substitutes, changes in the technology of oil-using vehicles or appliances or by policies that curb the demand for oil. These policies may be pursued for either environmental or security objectives or both.

Exporting countries endowed with large oil and/or gas resources need not worry very much about the issue of physical exhaustibility. The debate on whether the world will be running out of oil in the next 20 or 30 years, or whether the resources are so plentiful as to extend the depletion time horizon well into the second half of this century, has been recently revised by the works of C.J. Campbell and J.M. Laherrère. Their main study, *The World's Oil Supply 1930–2050*, was published in 1995 by PetroConsultants. Although the authors' views have since evolved toward a slightly less pessimistic outlook, their main arguments remain essentially the same as expounded in this major study. Their conclusions can be summarized as follows:

> The phase of oil history in which we find ourselves now is the phase of transition between a period of growth (1959–70) and one of decline which is expected to set in at the beginning of [this] century . . . Resource constraints will begin to be felt in most parts of the world save in the Gulf. By 2050 production would have fallen to the level of 1950, that is some 18 million barrels/day . . . Of course, some oil will be left after 2050, an estimate of 236 Gb.[1]

Critics have pointed out that these views are far too pessimistic because they do not give due weight to the following factors:

- the existence of huge reserves of non-conventional oil that can be profitably exploited if oil prices are sustained at the $25 per barrel level
- the advances in technology that increase dramatically the recovery factor from oilfields.

Insofar as oil-exporting countries with large reserves are concerned, the debate is irrelevant. Even if the threat of physical exhaustibility is relatively close, they will not be the first ones to be adversely affected. In any case, we do not think that this threat is imminent.

A more serious cause of worry is the competition they may suffer from the possible development of unconventional oil in Canada and Venezuela. Such a development will only happen if the energy security objective leads the USA to promote and subsidize it in order to reduce reliance on imports from the Middle East and realize the idea of Western hemisphere self-sufficiency, or if private investors become convinced that oil prices will be sustained (and sustainability is what really matters) at levels that make exploitation of tar sands, shale oil and the Orinoco Belt in Venezuela commercially viable. In other words, there is a threat to the future of Middle East oil, which does not arise from exhaustion but from other types of oil.

The economic demise of oil is a long-run issue because of the time lags involved in the development of new technologies and the penetration of markets. There is no doubt, however, that substitutes will eventually emerge and that the transport technology will be revolutionized. As regards substitutes, gas will continue to increase its share of the energy consumption mix, particularly in the power generation sector. If the environmental concern overrides the security objective in industrialized countries, it will displace

coal. Otherwise, coal will receive a boost in the USA and Europe even though it may give way to both oil and gas in Asia. Nuclear energy may revive if the security issue becomes paramount in the West; and in any case it is likely to increase its share in Asia, where the expansion of gas use may hit constraints due to either politics or high transport costs or both. Nuclear energy has a better chance than solar and wind energy, provided that its acceptability is not undermined further by some serious accident.

As regards transport technology, we shall have to wait and see. Sometimes technological breakthroughs expected with some trepidation do not materialize and sometimes they occur suddenly, taking the skeptics by surprise. Looking ahead, we can consider the future as consisting of two successive, albeit overlapping, periods. The first may take us at the earliest to 2020 and perhaps as late as 2030.

The problem facing the oil world in that period will not relate to reserves but to the development of production capacity. At times, there will be too much capacity, causing potential gluts and depressing prices, and at times too little capacity, causing price spikes with their inevitable adverse consequences for the world economy and the subsequent levels of oil demand. Capacity cycles arise for either political or financial reasons. Managing capacity is the real challenge, and neither OPEC nor the private companies have addressed it as yet. As mentioned earlier, the competition between conventional and non-conventional oil is likely to become an important issue as we advance in that period.

In the second period, which may begin around 2020, we are likely to hit a peak in the production of conventional oil, which will induce greater investments in non-conventional oil, natural gas and perhaps nuclear energy. The initial inducement may come from a price spike. But even if the price rise is not sustained, the perception that a production peak has been reached will cause expectations of future price rises. This transition may not be very smooth, since the emergence of new supplies induced by price expectations may instead cause prices to fall. As usual, the fear of a shortage leads to the emergence of a glut, which is perhaps temporary. Substitutes and new car technologies will appear and begin to penetrate the market in this second period and slowly threaten the share of oil in energy consumption.

However, one should recall that another force will be operating relentlessly in times of economic growth throughout these periods. This is energy demand growth. The demand for all fuels will expand in the good years by

2–3 percent per annum. The demand for oil will also continue to grow because consumption patterns in developing countries will increasingly include more cars, more modern forms of space heating, more air travel, more electricity. The developing world is still very far from the levels of per capita energy use in industrialized countries and, although catching up will take several decades, much more energy, including much more oil, will be demanded in the years to come. We can therefore look at a period ahead of us during which the share of oil in the energy mix may well shrink but the amounts produced and consumed will continue to increase. In the final analysis, absolute volumes count for more than relative shares.

All that should not encourage any complacency. Countries that depend heavily on oil revenues face the daunting challenge of transforming their economies to enable them to grow in an era of reduced oil income. The time available for this transformation is of the order of 20 or 30 years, but this is not as long as may appear at first sight. In the early 1970s many among us thought that the newly accrued oil wealth should enable the Gulf countries to build the foundations of a non-oil economy capable of sustaining long-term economic growth. Thirty years have elapsed and these foundations are not yet there.

To prepare for an economic future in the period when the prospects for oil will begin to decline requires immediate action. The task should begin today. The policies that favor future economic development do not bear fruit very quickly. Their implementation takes time. They only yield the desired results after very long gestation periods. To delay the formulation and execution of these policies will put the economic well-being of the oil nations in serious jeopardy. The required policies apply to three different areas.

The first of these areas is investment in human capital. This calls for a radical reform of the education system in the oil-exporting countries concerned. At present, education develops the memory more than analytical abilities. It values authority more than the small but necessary amount of freedom that encourages the creative mind. To define and introduce a new educational philosophy is an immensely difficult task, but it is not impossible. The process will inevitably be slow, and this is why it needs to be initiated today.

The second area is the labor market, in which the current pattern of incentives does not favor work in the productive sectors. Even the oil industry, the source of current wealth for exporting countries, fails to attract all

the talent needed for its development. A reform of labor laws, which currently cause private employers to prefer migrant workers to nationals, should also be considered. The present situation involves a serious distortion characterized by rising unemployment among nationals and increasing reliance on foreign migrants.

The third area is regional cooperation. All the Gulf countries are too small in size. Even the larger oil-exporting nations such as Saudi Arabia would benefit from an expansion of their markets. At present, despite the work done by the Gulf Co-operation Council (GCC), the degree of economic cooperation in the Gulf region still leaves something to be desired. Cooperation will enlarge the size of the market and thus encourage investment in industries benefiting from economies of scale and from a potentially significant volume of demand. Cooperation will reduce the incidence of wasteful duplication of projects and activities, and will increase the efficiency of both labor and capital.

Whether the future of oil is threatened or assured, the wise course of action is to prepare for a day when revenues may not be sufficient to maintain living standards. If oil turns out to be under threat, the development of a non-oil economy will provide a safety net. If the optimists turn out to be correct in their view that oil will continue to have a future for a very long time, the development of a non-oil economy will add to the wealth of countries. Nothing will be lost in either case.