Introduction

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Soaring oil prices, which surged to $147 a barrel in mid-2008, have drawn attention to the issue of supply and demand, suggesting that the present production capacity limits are being breached. It leads people to ask if we are running out of oil. The simple answer is: *Yes, we started doing that when we used the first gallon.* But the world is a long way from finally running out. What it does face, however, is the end of the *First Half of the Age of Oil*, which lasted 150 years, giving rise to extraordinary changes in the way people lived.

The Planet supported some 300 million people at the time of Christ, 2,000 years ago, and the number barely doubled over the next seventeen centuries. Most people lived hand-to-mouth rural lives. They were much dependent on local circumstances, facing famine if the harvest failed for climatic or other reasons.

The Bronze Age ended as people turned to iron and steel for better tools and weapons. At first, they used firewood to smelt the metals, before turning to coal as a more concentrated source of energy. When local surface deposits had been exhausted, the pits were deepened into regular mines, and minerals were extracted in a similar way, but the mines became subject to flooding on hitting the water table. Draining the mines led in turn to the development of steam pumps, which evolved into steam engines to power industry and locomotives. Sail gave way to steam as the Industrial Revolution opened. The new transport facilities opened up trade, which in turn led to the development of Empires as trading nations sought to capture and control markets. In parallel came the rapid growth of financial capital as banks lent more than they had on deposit, confident that *Tomorrow's Expansion* was collateral for *Today's Debt*, without realising that economic growth depended on energy supply. The Planet was perceived to hold near-limitless resources to be made available by Man's skill and ingenuity. Even so, in the smaller and simpler communities of the past, banking was regarded with some misgivings, usury having been once treated as a sin by the Catholic Church so far was removed from daily life.

Oil had been known since antiquity but it was not until the middle of the nineteenth century that wells were drilled for it, especially in Pennsylvania and on the shores of the Caspian. At first, it was primarily used as a fuel for lamps, replacing whale oil that was becoming scarce from over-whaling. That itself was a revolution for many people, adding an evening to the working day. The next step came in the 1860s when an enterprising German engineer, by the name of Nicholas Otto, found a way to insert the fuel directly into the cylinder of a steam engine, perfecting what became known as the *Internal Combustion Engine*, which was much more efficient. At first, it used benzene distilled from coal, before turning to petroleum refined from crude oil. The oil industry was born. The first automobile took to the roads in 1882, changing the world in previously unimaginable ways.

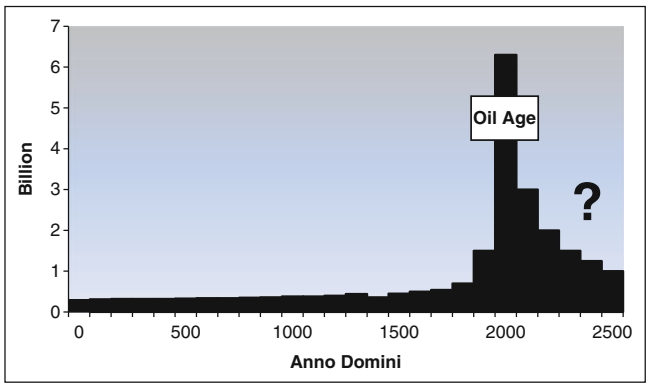

Fig. 1.1 World Population

The demand for food was growing from an expanding population, which was increasingly moving to live in urban conditions. It was proving difficult to feed the people, and in the early years of the last century it was even necessary for Europe to import *guano*, composed of bird excrement, from South America in sailing ships, such was the pressure to improve soil fertility. In 1907, little more than a hundred years ago, came the first tractor, driven by the *Internal Combustion Engine*, to progressively replace the horse and oxen with which to plough the fields, adding greatly to agricultural capacity. Later, means of extracting nitrates from the

C.J. Campbell, *Campbell's Atlas of Oil and Gas Depletion*,
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air by electrolysis were discovered, and natural gas was used to produce nutrients, which, together with oil-based pesticides, improved crop yields greatly. Indeed, agriculture has been described as a process that turns oil into food. It is calculated that mechanisation improved farming efficiency by a factor of 40.

In mediaeval days, oil was collected from seepages and even hand-dug wells, but before the nineteenth century had closed, drilling technology, which had already been developed for salt extraction, was adapted to the oil industry. The cable-tool, consisting of no more than a bullet-shaped weight on the end of a rope which thumped its way into the earth, was followed by the more efficient rotary rig, comprising a bit on the end of a rotating shaft, allowing the search to go deeper. Great technological progress was made in all aspects of the operation.

The oil industry grew to supply this essential oil-based fuel, on which the world began to depend utterly. The early developments were concentrated in the United States, starting in Pennsylvania before major new discoveries were made in California, Oklahoma, Texas and elsewhere. But the most significant development of all came in 1908 when a well being drilled at Masjid-i-Suleiman in the foothills of the Zagros Mountains of Iran blew out, sending a plume of oil high into the sky. It had fallen upon what was to prove the world's most prolific oil province, located around the Persian Gulf. It was later found to hold almost 40% of the total endowment of the world's prime quality oil, much formed in very special conditions, 150 million years ago, in rifts that developed between the African and Eurasian continents.

While much early exploration was undertaken by the so-called wildcatters, drilling by guess and by God, it did not take long to discover the essential geological controls of source, reservoir, trap and seal. At first, petroleum geologists relied on surface observations to identify promising prospects, endowed with the rare, right combination of circumstances, but before long they developed geophysical techniques to scan the depths. Both the technology and the interpretation became ever more sophisticated, assisted in more recent years by massive computing power. Perhaps the most important development of all was a geochemical breakthrough in the 1980s which elucidated the conditions for oil generation itself, making it possible to map accurately where oil was formed and where it was not (see Fig. 1.1).

In technological terms, a major development was the semi-submersible rig, mounted on relatively stable pontoons beneath the wave-base, which opened up the continental shelves of the world to exploration, bringing in new production to replace the traditional onshore fields that were depleting. Even more elaborate floating production facilities later tapped the few deepwater areas having the necessary geological conditions to yield oil.

A coal deposit covers a wide area, and is at first mined only where the seams are thick and accessible, meaning that more becomes commercially viable if prices rise or costs fall under normal economic rules. It is effectively a matter of concentration. Oil, or to be more exact *Conventional Oil*, by contrast, is characterised by a certain polarity because it is either present in profitable abundance, or not there at all, due ultimately to the fact that it is a liquid concentrated by Nature in a few preferred locations. This particular characteristic has had an important impact on the nature of the industry itself, which has had a certain *boom or bust* character. Even a small oilfield delivers great wealth to its owners, as money effectively flows out of the ground under its own pressure. That wealth in turn brought power, allowing the more successful, or lucky, to swallow the smaller and weaker enterprises, a process that led to the formation of the great international oil companies. The first of them was the Standard Oil Empire of the Rockefellers which reached its zenith in 1911 before being dissolved by the US Government under anti-trust legislation designed to break its overweening power. Its daughters, including Esso, Mobil and Chevron to name the largest, grew up to become major international oil companies in their own right. Several of them later merged to survive in the face of contracting exploration opportunities, when they found it easier to secure their reserves by acquisition than exploration. The seven major international companies (BP, Chevron Exxon, Gulf, Mobil, Shell, Texaco), which previously controlled world oil supply, are now reduced to four by merger.

The polarity of oil is well illustrated by the discovery of the massive East Texas field in 1930. It delivered a flood of oil that depressed the price, spelling ruin to producers in other parts of the country. It forced the Government to intervene again: this time by instructing the Texas Railroad Commission to curb production to support price. Most oil in those days was moved by rail, so the Railroad Commission was in a position to exercise control. It set rules defining the number of days in a month that the wells could be produced.

While the United States dominated the world of oil during the first half of the twentieth century, important developments were taking place elsewhere, especially in the Middle East. In 1914, just before the outbreak of the First World War, the British Government took a controlling interest in the Anglo-Persian Oil Company (later BP) to obtain a secure fuel supply for the British Navy that was converting from coal to oil. The war itself led to the defeat of the Ottoman Empire, hitherto the principal power in the Middle East, which was broken up by the victorious allies into independent countries, including Saudi Arabia, Iraq and Kuwait whose oil potential had been recognised. Saudi Arabia fell to a group of American companies led by Standard of California (Chevron), being later joined by Texaco, Esso and Mobil, as

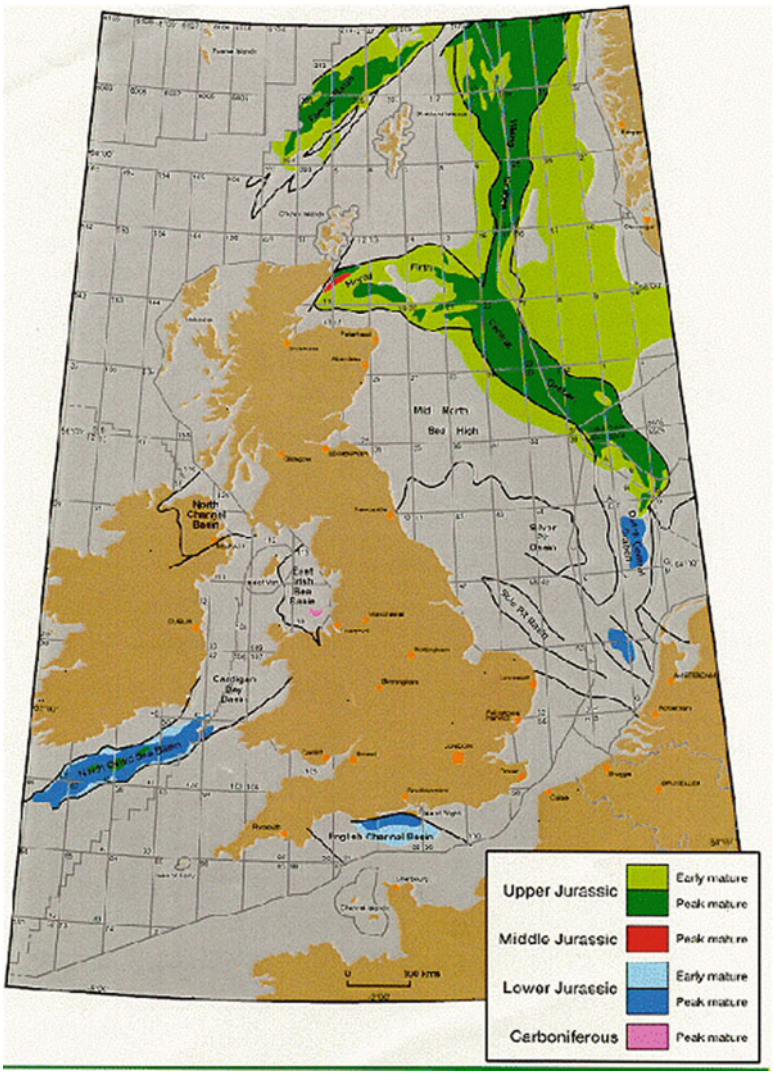

Fig. 1.2 Location of oil generation in NW Europe

owners of the Arabian American Oil Company (ARAMCO); Kuwait went to Gulf and BP, working as the Kuwait Oil Company; and the Iraq Petroleum Company was acquired by BP, Shell, Esso, Mobil, CFP of France, leaving its founder, Mr. Gulbenkian,[1] with his famous 5%. BP retained its exclusive position in Iran, which had not been part of the Ottoman Empire.

While the Middle East was to emerge as the World's most important oil province, it was by no means the only one. Mexico and Venezuela rivalled the United States in the Western Hemisphere with Shell, which had rather missed out of the Middle East carve-up, taking a strong position. The Caspian was another major oil province until eclipsed by the Bolshevik Revolution of 1917, while in the Far East, Shell was developing large finds in Borneo and Sumatra (now Indonesia).

The great wealth that flowed from oil brought with it corresponding tensions that began to manifest themselves in various countries around the world, especially as the stability imposed by the British Empire was eroded by moves to independence. Russia was the first to strike when it nationalised the holdings of foreign oil companies in 1928, followed 10 years later by Mexico, reflecting moves towards what can be termed National Socialism in the face of perceived foreign exploitation. Iran followed in 1951, when it nationalised BP's long-standing exclusive concession, which a war-weary Britain no longer had the stomach to enforce by military

[1] Calouste Gulbenkian, who laid the foundations for the Iraq Petroleum Company (see Yergin, 1991).

means. Perez Jimenez, the Oil Minister of Venezuela, was at first hesitant to move towards outright nationalisation, proposing instead to form an international organisation of oil producers that would curb production to support price, following the precedent of the Texas Railroad Commission. This initiative led to the formation in 1960 of the Organisation of Petroleum Exporting Countries ("OPEC") to which the following countries now belong: Algeria, Angola, Ecuador, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, United Arab Emirates and Venezuela. But it proved to be only partially successful, and was followed by the subsequent outright nationalisations of foreign oil concessions in the major producing countries: Iraq in 1972, Kuwait in 1975, Venezuela in 1976 and Saudi Arabia in 1979. State oil companies were also formed in other countries, including Britain and Norway, often taking dominant privileged positions.

The efforts of these countries to control their oil assets did not however meet with unqualified success, for the major international oil companies moved to replace the loss of their prime supplies by stepping up exploration in new areas, especially offshore, at a time when there were still substantial new areas to bring in. This initiative was notably rewarded by the discovery of a major new province in the North Sea, where oil was found to have been generated in rifts that formed as the Atlantic opened, 150 million years ago. It is the largest new province found since the Second World War, yet, to give a sense of proportion, holds enough to meet less than 3 years of world consumption.

The international companies worked flat out in the new areas under a competitive open-market environment, which was in fact ill-suited to deal with the *boom or bust* character of their business. Prices fluctuated widely, collapsing in 1986 for 3 years during the so-called oil-glut. This put pressure on the OPEC countries, which, with their burgeoning populations, had become utterly dependent on oil revenues. The calculation of their agreed production quotas to support price became subject to difficult negotiation behind closed doors, with the prime criteria being the size of reserves and population.

They had to face the issue of calculating and reporting reserves head on. The volume of oil-bearing rock in an oilfield can be measured relatively accurately with modern methods, but the amount that can be extracted depends on many subtle characteristics, including porosity, permeability, homogeneity, water-saturation and pressure, as well as such operational elements as well density, pressure maintenance and water injection (Table 1.1).

The rules for reporting reserves had been set by the Securities and Exchange Commission (SEC) in the early days of oil in the United States. They were primarily designed to prevent fraudulent exaggeration and smiled on under-reporting as laudable commercial prudence. In short, the rules recognised *Proved Producing Reserves* for the expected future production of current wells; and *Proved Undeveloped Reserves* for the anticipated future production from infill wells before they had actually been drilled. The international companies, when still in control of Middle East production, had routinely reported reserves under this system, such being compiled in various databases, of which that maintained by the *Oil and Gas Journal* was perhaps the foremost. By all means, they may have been conservative estimates but it came as a surprise when Kuwait increased its reported reserves from 64 Gb (billion barrels) in 1984 to 90 Gb in the following year, although nothing particular had changed in the oilfields themselves. It is possible that it started reporting the total amount discovered, (*Original Reserves*) rather than the amount remaining (*Remaining Reserves*), and increased the estimated recovery factor. But, whatever the explanation, it had a strong impact on its quota, in turn affecting the other OPEC countries. Two years later, it announced a further small increase to 92 Gb, which might have reflected a genuine new find, but the move evidently exhausted the patience of its neighbours, leading them to announce massive increases to match Kuwait in various degrees. Abu Dhabi exactly matched Kuwait at 92 Gb, (up from 31 Gb); Iran went one better at 93 Gb (up from 49 Gb); while Iraq capped both with a rounded 100 Gb (up from 47 Gb). Saudi Arabia could not match Kuwait because it was already reporting more, but in 1990 announced a massive increase from 170 to 258 Gb, possibly likewise reporting *Original* rather than *Remaining Reserves.* Venezuela for its part announced a corresponding increase from 25 to 56 Gb in 1988, followed by an increase to 211 Gb in 2010, achieved by the inclusion of heavy non-conventional reserves, not hitherto counted. Whatever the explanations for these anomalous increases, it is clearly implausible that the reserves reported by these countries could have remained substantially unchanged despite subsequent production: the most extreme case being Abu Dhabi that continues to report 92 Gb, unchanged since in 1987.

The international oil companies, for their part, generally reported conservatively under the Stock Exchange rules, in effect quoting only as much as they needed to deliver a satisfactory financial result. It made commercial sense to smooth their assets to cover lean discovery years and any temporary set-back in their operations around the world. Under-reporting also significantly reduced their tax burden in some countries. The practice of under-reporting however now passes into history as the stock of giant fields, which offered the most scope for under-reporting, depletes. The erosion of the major companies' reserves was probably one of the main reasons that prompted a spate of mergers over the past decade which saw Exxon merge with Mobil; Chevron with Texaco; and BP with Amoco and Arco. Shell, for its part, did not make any major acquisition, which forced it to downgrade its reserves in 2005 in a move that caused something of a financial furore, costing the Chairman his job.

Table 1.1 Implausible reserve increases reported by OPEC countries

OPEC RESERVE REPORTS								
	Abu Dhabi	Dubai	Iran	Iraq	Kuwait	N. Zone	S.Arabia	Venezuela
1970	12	0	70	32	67	26	129	14
1980	28	1.3	58	31	65	6.1	163	18
1981	29	1.4	58	30	66	6.0	165	18
1982	31	1.4	57	30	65	5.9	164	20
1983	31	1.4	55	41	64	5.7	162	22
1984	30	1.4	51	43	64	5.6	166	25
1985	31	1.4	49	45	90	5.4	169	26
1986	30	1.4	48	44	90	5.4	169	26
1987	31	1.4	49	47	92	5.3	167	25
1988	92	4.0	93	100	92	5.2	167	56
1989	92	4.0	93	100	92	5.2	170	58
1990	92	4.0	93	100	92	5.0	258	59
1991	92	4.0	93	100	95	5.0	259	59
1992	92	4.0	93	100	94	5.0	259	63
1993	92	4.0	93	100	94	5.0	259	63
1994	92	4.3	89	100	94	5.0	259	65
1995	92	4.3	88	100	94	5.0	259	65
1996	92	4.0	93	112	94	5.0	259	65
1997	92	4.0	93	113	94	5.0	259	72
1998	92	4.0	90	113	94	5.0	259	73
1999	92	4.0	90	113	94	5.0	261	73
2000	92	4.0	90	113	94	5.0	261	77
2001	92	4.0	90	113	94	5.0	261	78
2002	92	4.0	90	113	94	5.0	259	78
2003	92	4.0	126	115	97	5.0	259	78
2004	92	4.0	125.8	115	99	5.0	259	77
2005	92	4.0	132	115	102	5.0	264	80
2006	92	4.0	136	115	102	5.0	260	80
2007	92	4.0	138	115	102	5.0	264	87
2008	92	4.0	136	115	102	5.0	264	99
2009	92	4.0	138	115	102	5.0	260	99
2010	92	4.0	137	115	102	5.0	265	211

The major companies are also selling off secondary refineries and marketing chains, evidently perceiving a looming shortage of supply, although they are understandably reluctant to admit to that in the commercial world.

These few words provide the background for addressing what becomes one of the most important issues affecting the modern world. Sufficient is now known about the origin of oil to state unequivocally that it was formed in the geological past.[2] In fact, the bulk of the world's production comes from rocks laid down in just two distinct epochs of extreme global warming, 90 and 150 million years ago, providing the conditions for the prolific algal growths that provided the organic material from which it was formed. This fact alone tells us that it is a finite resource subject to depletion. Given its central place in the economy, it is important to know not only how much is left, but to recognise that production must peak, and then decline during the *Second Half of the Age of Oil*, reflecting the constraints of Nature.

At first sight, it would seem to be an easy job to determine the status of depletion by simply consulting the databases to see how much has been produced so far, how much is left in the known fields, and then to estimate future discovery by extrapolating the past downward trend. The world has been so thoroughly explored that virtually all the accessible productive basins have been identified and explored to some degree by seismic surveys and exploratory boreholes. Most of the larger fields within them have also been identified, being too big to miss. But as we dig into the details, we find a minefield of ambiguous definitions, lax reporting practices, disinformation and confusion. As the capacity limits are

[2] Theories about the so-called abiotic origin of oil, as promoted by some economists, can be confidently dismissed not having contributed any material quantity to the world's stock of known oil.

breached, and shortages begin to appear, the issue becomes ever more sensitive, prompting vested interests, including those with political motives, to try to mislead, obscure and confuse. Indeed, it can be said that the skills of a detective are now called for to unearth the truth, and present a sound case sufficiently strong to stand up to withering cross-examination.

One of the reasons why the situation has become so sensitive has been the evolution of what can be described as the financial mind set. In earlier years, corporations were formed by groups of investors with a specific task in mind, such as building a canal or railway, with the payment of regular dividends being their principal reward. In daily life, the blacksmith was primarily motivated by doing a good and worthy job. The farmer ploughed his fields on a similar simple premise. Both received relatively fixed modest wages, seen as a just reward for their work. But those days are long over as the modern world finds itself motivated by financial reward in a corporate conurbation run under complex economic systems. The investment community buys and sells stocks on a massive scale, naturally having little detailed knowledge of the underlying businesses. Its skill lies in having a sharp nose for trading financial instruments and identifying the flavour of the month. An additional element is the role of world trading currencies, formerly the pound sterling and now the US dollar, which delivered a massive hidden tribute to the issuing country. For example, for many years the cost of imports of physical oil into the United States was exactly matched by the expansion of domestic credit, meaning that it effectively secured its supply for free. The credit is, at bottom, nothing more than an expression of confidence in the existing financial system, itself premised implausibly on a continuation of an abundant energy supply to support eternal economic growth. The recent financial crisis, which has left several countries virtually bankrupt, may mark a radical turning point, having been itself perhaps triggered by an oil price surge in 2008. These pressures have in turn led to riots and revolutions especially in North Africa and parts of the Middle East, which may adversely affect oil production in a vicious circle.

It was as if oil provided us with an army of unpaid and unfed slaves to do our work for us. It has been calculated that a drop of oil, weighing 1 g, yields 10,000 cal of energy, which is the equivalent of one day's hard human labour.[3] In other words, today's oil production is equivalent in energy terms to the work of 22 billion slaves. Financial control of the world has led to a certain polarisation between the wealthy West and the other countries which find themselves burdened by foreign debt as they export resources, product and profit.

Many people have come to think that it is money that makes the world go round, when in reality it is the underlying supply of cheap and largely oil-based energy, that has turned the wheels of industry, fuelled the airliners and the bombers, and generally acted as the world's blood stream.[4] Midas-like wealth flowed to those who find themselves having a controlling position in the System.

This book evaluates the current status of depletion of oil and gas, trying to assess the available evidence with which to piece together realistic estimates of the three main parameters: namely, how much has been produced so far; how much remains to produce from known fields (*Reserves*) and how much is yet to find. To simplify matters, it treats everything in terms of production to the end of century, avoiding having to worry about some insignificant tail-end. It furthermore recognises that there are many different categories of oil: some being easy, cheap and fast to extract; others, being the precise opposite. It concentrates on what can be defined as *Regular Conventional Oil*, which has provided most produced to-date and will dominate all supply far into the future. The other categories are also covered in a summary form. Gas is particularly difficult to evaluate as the data are even less reliable, and the trends less clear, but an attempt has been made. The book evaluates the details of 66 producing countries, assessing the resource base and forecasting future production in the light of the individual circumstances. The results are combined to deliver regional and world totals.

Attempts are made to place the Oil Age of each country in its political and historical perspective.[5] Certain patterns emerge from the record and deliver a message. Although it is accepted that the results of the study will be found to be a good deal less than exact, given the appallingly unreliable nature of public data, there is sufficient confidence to put it forward as a basis for planning, albeit subject to revision and improvement as new information becomes available. Indeed, in a sense it poses a challenge to the reader to investigate the situation by country and try to come forth with better information with which to build a better world assessment.

It short, it concludes that the world now faces the dawn of the *Second Half of the Age of Oil*, which will be marked by the decline of oil and all that depends upon it. The next few years, which mark the transition, will likely be a time of great international tension, with the outbreak of more resource wars as competing consumers vie with each other for access to the remaining supplies.[6] It will likely see volatile markets

[3] Calculated on the basis of the energy required to lift a ton of sand to a height of 2 m.

[4] See an excellent book, *The Upside of Down*, by Thomas Homer-Dixon, which reviews this subject in depth.

[5] Extensive use has been made of the national summaries provided in *The Rapid Growth of Human Populations 1750–2000* by William Stanton (Published by Multi-Science ISBN 0-906522-21-8).

[6] President Bush justified the invasion of Iraq at a Press Conference in December 2006 with the words: *our energy supply was at risk* (BBC TV). The attack on Libya in 2011 probably also has an oil subtext.

subject to vicious circles as capacity limits are breached leading to price shocks followed by recessions, falling demand and falling oil prices, which may in turn allow economic recoveries before the cycle repeats itself.

Undoubtedly there will be winners as well as losers in the new world that opens. The winners will likely be those who are better informed and plan their lives accordingly. The assumption of perpetual growth may no longer be sustainable, but sound management can make good profits even in a contracting business. There is much at stake in political terms as governments are reluctantly forced to come to terms with the new situation imposed by Nature: some may seek to prolong past postures, policies and structures, whereas others may have the sense and courage to recognise the new circumstances. There is much that can be done in the most positive of ways. The starting points are both to understand the underlying conditions and alert the people at large to what unfolds. Touching the intuitive common sense and goodwill of ordinary people may yield remarkable dividends: this is not necessarily a doomsday message, although it could easily become one if ignored.

As mentioned above, the purpose of the book is to recognise and describe the *Age of Oil*, looking not only at the physical endowment and depletion of oil and gas, but at the wider political, historical and economic developments, by which societies and countries have responded in the past and will respond in the future. The *First Half of the Oil Age* has been a time of general economic growth and technological progress although accompanied by two world wars of unparalleled intensity. We now face a transition to the *Second Half of the Age of Oil*, which will be characterised by the decline of oil and gas, and all that depends on these easy and abundant sources of energy.

It can be said that the only sure numbers in the book are the page numbers. Some estimates are clearly weaker than others, providing ammunition for the detractors who now turn to emphasise the uncertainties of date and decline rate, no longer being able to assault the reality of peak production itself. A vigorous debate surrounds the precise date of peak production, but really misses the point when what matters—and matters greatly—is the vision of the long decline that comes into sight on the other side of it.

The challenge of Peak Oil can be compared with that of crossing a mountain range. The traveller steps out of the dusty plains as he enters the foothills, where the grass is greener, before climbing the heights where the peaks are commonly covered in clouds. But eventually he passes the overall summit and begins his descent, trying to find a pathway between the cliffs and crags, later to emerge safely on the plains beyond.

It is time to ask how we might respond and ensure a better, brighter and more co-operative future for humanity. Certainly, the unparalleled oil-based economic growth of the past 150 years has carried a cost in terms of global pollution, the destruction of habitats and species, and indeed, for many, much human suffering in over-crowded conditions. This behaviour may indeed have released emissions causing the climate to change. The climate has changed many times in the geological past in response to the emissions from massive volcanic eruptions, but this may be the first, and possibly the last, time that *Homo sapiens* is responsible. It is by all means a serious subject.