CHAPTER 1

A LONG INTRODUCTORY SURVEY OF SOME ASPECTS OF WORLD ENERGY

Perhaps the three most important topics in energy economics at the beginning of the new millenium were the availability of oil in the near future, the deregulation of electric (and perhaps also natural gas) markets, and last but very definitely not least, global (or climate) warming. The supply of natural gas in the long run also deserves some attention. As a result, this long introductory chapter will concentrate on a non-technical presentation of these items, although my aim in this book is to give readers enough insight into the logic and rhythm of energy economics, so that they can fully comprehend the most important aspects of a topic that has started to receive the attention that it deserves. I would like to do the same for environmental economics, but this book is too short for me to provide serious readers with more than a few comments.

Where the debates concerning oil and global warming are concerned, the most important thing just now is the utilization of an informal Neumann–Morgenstern (1944) approach which emphasizes the significance of avoiding unfavorable (and irreversible) outcomes. To me, this means that the value of nuclear energy should not be underestimated, the Kyoto Protocol — and particularly the trading of emissions permits — should be regarded with considerably less enthusiasm than at present, and the growing "scarcity" of conventional oil should be recognized and carefully studied. Furthermore, I would like to see global warming dealt with at the highest governmental levels, on a continuous basis, instead of in mammoth conferences attended by persons who often lack a suitable background in science or the kind of economics presented in this book.

1. An Introduction

Things move fast in the great worlds of energy and finance. In fact, there are many observers who believe that they often move *too* fast, and in the wrong direction. One of the reasons for this is the surprising increase in the price of oil that began in 2003–2004, as well as an alarming increase in the price of natural gas.

After the good news of the 1990s for financial markets, there is a palpable risk that at any time the global macroeconomy may take on a different complexion. Although recoveries sporadically appear to be underway, unemployment in Europe remains comparatively high, and in their attempt to restore the situation, governments in many countries are systematically reducing welfare. (For example, pension "reform" has become a favorite mantra of the political movers and shakers.) It also needs to be emphasized that in terms of price-earnings ratios and interest rates (considered on the basis of average values over the last 30 years), share and bond markets could still be out of equilibrium. On this point I can refer readers to my elementary international finance textbook (2001).

Although the energy picture is, to a considerable extent, dominated by unexpected increases in the price of oil and natural gas, and to a lesser degree coal, from the point of view of mainstream economics these price rises were inevitable: the effective supply of comparatively inexpensive *petroleum* (i.e., oil + gas) reserves is probably well under the level predicted by many optimists a few years ago. This is due to both inadequate investment in exploration and production, as well as an actual shortage of oil and gas in the crust of the earth relative to the amount that will be required in the distant *or* near future. Observe that when I say *reserves*, I am talking about known and *exploitable* oil and gas, and not hypothetical resources!

There have also been electricity deregulation miscarriages in many parts of the world (e.g., California, Ontario, Brazil, South Australia, Sweden, etc.), and of course the bankruptcy of the giant energy trading firm Enron. As I have pointed out at many conferences and seminars, it is nothing less than amazing how voters and their representatives allowed themselves to be beguiled for so long by deregulation enthusiasts and their paid and unpaid propagandists. The so-called "opening up" of the electric and gas markets to "liberalization" is in many respects a gigantic blunder, because it is very possible that *smart* regulation of these two quite special industries is the best friend of a free-market system. For one of the best pedagogical treatments of this topic I can recommend a working paper by Coppens and Vivet of the National Bank of Belgium, titled "Liberalization of network industries: Is electricity an exception to the rule?" (2004). As stressed in this textbook, and more extensively by these two authors, electricity is definitely an exception, and the same may be true for natural gas.

At the present time, with newspapers and television constantly assuring us that we live in a new world as a result of the 9–11 attacks on the World Trade Center and the Pentagon (2001), some of us hope that this new world will include a less nonchalant approach to certain crucial economic phenomena, to include those having to do with energy. The latter may now be possible, since President Bush wisely designated energy a "national security concern". It could be argued that until recently, there were excellent reasons (of a "game-theoretical" nature) for several directors of the leading oil companies to pretend that there is still a large amount of inexpensive oil that can eventually be located and brought to the surface, but some question has to be asked as to why so many academics elected to join in the elaboration and spreading of this dangerous myth. In the present context, the expression "game-theoretical" means large firms trying to convince smaller firms (as well as other large firms) that there will be a big supply (and concomitant low price) of oil in the near future, and as a result they should consider selling various production assets to these large firms.

Many of the same academics are also deregulation enthusiasts, but the unmistakeable succession of deregulation miscarriages might eventually cause them to reconsider their loyalties. Lamentably though, it is still too early to conclude that the illogical attachment to electricity and gas deregulation has run its course. At the Barcelona "summit" of the European Union (EU), a former president of France emphasized that Sweden was a good example of a country where, contrary to expectations, (consumer) electricity prices have greatly increased since deregulation, but as it turned out, he was wasting his breath. The shocking visibility of the California meltdown and its aftermath resulted in the EU's energy overseers becoming almost frantic in their efforts to deregulate their unperceptive subjects into the emergency room. What we have here is a simple refusal to acknowledge the many deregulation failures that have taken place around the globe, despite an overwhelming accumulation of both anecdotal and scientific evidence. On a somewhat higher plane, we are encountering a disturbing absence of the requisite microeconomic knowledge.

There are many energy topics in this book. Among other things I have attempted to eliminate a few of the gaps in my (intermediate level) energy economics textbook (2000), as well as to refine or simplify some of the arguments in that book. A small amount of elementary mathematics could not be avoided, but I have attempted to place at least some of this algebra where it can be ignored by readers who find this departure annoying. A minor exception is made in the chapter dealing with electricity, and also in the chapter titled "Energy and Money". However, even here most readers should experience no difficulty in following the discussion.

2. Victory Begins Here (Sign over the Gate at Fort Jackson, South Carolina)

The following quotation introduces an energy survey in *The Economist* by Vijay Vaiteeswaran (10 February 2001): "The world of energy is being turned upside down. The best thing governments can do is to get out of the way". Unfortunately, however, an authentic picture of world energy and environmental problems would reveal the necessity of government involvement. For instance, in the United States, the absence, until recently, of a governmental energy policy was strongly deplored by many executives in the industrial sector, to include the major oil companies, while the executive director of the International Energy Agency (IEA), Claude Mandil, has argued that governments should not leave the development of, e.g., renewables to the market. As he pointed out, "There is too much at stake".

The most commendable aspect of Mr Vaiteeswaran's survey is that he has approached several "hot" topics in energy economics — such as oil, electricity and nuclear energy — that are important for this book. As far as I am concerned, his conclusions about oil are not always correct, just as I certainly cannot agree with most of what he writes about the electricity market; but even so, an hour or two spent reviewing his work will provide a partial introduction to these and other issues. In addition, his comments about nuclear energy were fairly valuable, although it would have been a good idea if a modicum of attention had been paid to a former Secretary General of the OECD.

According to Donald Johnson, greenhouse gas emissions, together with the predicted growth in global population, are "putting the world on a fast track to (unhealthy) global consequences for future generations". As a result, he concludes that "if we are to hand on to future generations a planet that will meet their needs, as we have met ours, it can only be done by incorporating the nuclear option". A similar opinion has also been put forward by a number of eminent international civil servants, as well as many conscientious politicians and journalists who have made a thorough as opposed to a superficial study of energy markets, which means that expressing these sentiments has become a great deal more respectable than was the case just a few years ago.

They might have added that global power capacity is expected to increase by about 45% in the next 14 years, and it will have to grow by a larger amount if the hundreds of millions of households that have *no* reliable access to electricity today (plus those that will be added by population growth) are to be able to obtain a minimal amount of that indispensable "good". (At the present time, about two billion persons in developing countries rely on traditional biomass — such as wood and agricultural residues — for their basic energy needs, and two billion is also Lester Brown's estimate of the number of the world's poor.) Global demand for electricity grew by 2.2%/year between 1990 and 1997, and future demand growth is expected to reach an average rate of 2.5%/year by 2020 (as compared to an expected global population growth of about 1.6%/year). Dealing with this problem without placing an undue burden on the environment will almost certainly call for more nuclear capacity and renewables, with the emphasis on more environmentally friendly motor fuels.

Despite the constant reminders in this book of the importance of nuclear power, I in no way want to downgrade the significance of renewables. Renewables have a crucial role to play in the immediate energy future, but, e.g., the great mistake by many environmentalists is the belief that they are ready to do everything (or almost everything) by themselves, which to me means that economics (i.e., cost) is not being given its proper consideration. As Claude Mandil noted, "Renewables can make major contributions to the diversity and security of energy supply, and to economic development". In particular, his organization emphasizes wind turbines, whose production costs at the beginning of this century were reputedly somewhat less than a quarter of what they were in 1981. According to the American Wind Energy Association, in the US, in 2005, a new wind-generating equipment of worth more than three billion dollars (= $3 bn) was installed, and the IEA apparently believes that by 2030, the global share of renewables in electricity generation should be almost 20% of a very large output of electric power.

Where other renewables are concerned, I do not consider myself qualified to venture an inclusive judgment. The IEA seems to have great faith in solar energy, and it seems likely that in 15 years, the first large US solar plant may soon be constructed in Nevada (and will be called "Nevada Solar One"). Its capacity is 64 megawatts (= 64 MW), and the project is estimated to cost $106 million. The installation uses mirrors to concentrate heat from the sun, and to raise to a very high level the temperature of a special fluid. This fluid then transfers the heat to a steam generator that will produce electricity. It is predicted that the plant will generate electricity for about 12 cents per kilowatt hour (= 12 cents/kWh), which can be compared to 5–8 cents/kWh for coal-fired plants in the region.

All these sound promising, but I heard the same sort of thing about 20 years ago when I gave a short course at the Australian School of the Environment (in Brisbane). As it happens, the Nevada solar facility is not particularly large, and that state has certain advantages with regard to weather that are not enjoyed by many other regions in the US. It might then be suggested that this facility should be considered a pilot installation for similar projects close to Las Vegas, which is one of the most rapidly growing communities in the US. If Nevada Solar One performs according to expectations, then ideally the system will soon be scaled up for use both in Nevada and in other suitable localities.

Something worth mentioning here is that the noble goals of the United Nations and others as to poverty elimination do not make any sense at all without an adequate supply of electricity being available for households, small and large businesses, and industries. A similar observation applies to the availability of oil: oil is used everywhere, and without a large supply many fundamental activities (e.g., transportation, and the production of chemicals) would have to be operated at less than a desirable level. To paraphrase Georges Monbiot, for the foreseeable future, oil is the commodity on which our lives are built.

Unless I am mistaken, the basic *contretemps* will turn out to be when and how governments go into reverse where their present attitude toward nuclear energy is concerned, because for various reasons that will be spelled out in this and future chapters, the irrational ostracizing of nuclear energy cannot be continued indefinitely in a world where voters want less carbon dioxide (CO_2), but where — according to a UN forecast — there will be at least a doubling of the demand for energy over the next 25–30 years. Eventually, this might become apparent to even the Swedish government, and it will be admitted publicly that initiating their nuclear retreat was ill-timed. Moreover, when a new generation of safe nuclear equipment is ready to be put into operation (which may be soon), their present position should be reassessed — and this is especially true if vehicles exploiting a more environment-friendly technology are not available on a *very large* scale.

This latter situation may be a long time coming, given the present age structure of the global vehicle inventory. Similarly, as yet, sales figures for new trucks, automobiles and motorcycles show no signs of attenuating, despite the increase in the price of vehicle fuel. Notice the emphasis above on "very large". For example, a number of major automobile companies have unveiled impressive "hybrid" electric vehicles and as a result of expectations about the oil price, doubts about their commercial prospects are gradually being dispelled. (Hybrids are vehicles where a conventional gasoline-driven motor is placed alongside an electric one powered by batteries that are recharged whenever the vehicle coasts or brakes. One of the best known examples is Toyota's "Prius" hybrid. Considerable emphasis is now being placed on plug-in hybrid vehicles, whose batteries can be recharged overnight via the electric grid, and thus take advantage of low off-peak power prices.)

Hopefully, the hybrid market will soon be expanding rapidly enough so that producers will be able to fully exploit increasing returns to scale in the manufacture of these vehicles, which in turn will permit them to offer lower prices. At the same time, there have been claims that hybrid vehicles should be regarded as an intermediate technology, and in the long run hydrogen fuel-cell vehicles may be preferable because fuel cells are twice as efficient as combustion engines. Another factor working to make hydrogen the fuel of choice is its availability: some observers insist that it takes just one-and-a-half gallons of water — one toilet flush — to create enough hydrogen for a day's driving of 30 miles (= 48 km). Let us put it this way: hydrogen is very definitely going to be an important energy resource, but where vehicles are concerned, the long run could be longer than we anticipated a few years ago as a result of hybrid technology becoming more impressive.

In July 2001, Mr Brian Wilson — the newly appointed UK energy minister — visited the US in order to discuss energy security with the US vice president and the US energy secretary. These gentlemen wanted to see more nuclear facilities in the energy portfolios of their countries; however, environmentalists in both the United States and United Kingdom, their sympathizers, and most importantly their political "support", indicated that they will do everything possible to block any and all actions having to do with nuclear energy. As Marcel Boiteux (the eminent French economist who at one time was president of Electricité de France) once remarked: "In the United States and elsewhere, they have succumbed to the dictatorship of the anti-nuclear minority". In almost every country in the world, this minority is busily claiming that it is possible to achieve energy and environmental goals without initiating a renewal of nuclear power station construction. Instead, they insist, attention should now focus on an accelerated provision of renewable energy.

But they began saying this at least two decades ago, and in my opinion they are still too impetuous. At the same time though, it needs to be made clear that at some point in the future — and perhaps the not-too-distant future — they will see the light: *renewables are indispensable, but so is nuclear energy*. Moreover, the science academy of the UK Royal Society has warned the UK government of the inadequacy of proposals to put the main weight of reducing global warming on strategies like the soaking up of carbon dioxide (CO_2) in forests and farmlands (i.e., "carbon sinks"), and to this should probably be added funneling CO_2 into the depths of the ocean. These are not entirely futile initiatives however, and are probably justified to a limited extent. Similarly, the suggestion of President Bush, Sr, that efforts should be made to plant a billion trees undoubtedly deserves consideration, but as far as the academy is concerned, none of these are long-term substitutes for unequivocal reductions in CO_2 emissions — although at the Bonn Meeting on climate control, in order to obtain some sort of compromise that would be acceptable to several important industrial countries, a number of misleading assumptions had to be treated as indisputable scientific reality. According to the academy, achieving a meaningful decrease in carbon emissions can only come about if, among other things, there is more emphasis on the construction of carbon-neutral energy sources such as nuclear power and wind turbines.

My thoughts on these matters move in several directions. I find it hard to believe that we will *not* have to experience what Professor Ken-Ichi Matsui calls the Seventh Energy Revolution, which he pictures as being based on nuclear energy; but it could happen that it will become possible in the not-too-distant future to efficiently "store" large amounts of electricity (in one form or another), and in these circumstances, options like wind turbines could become much more important in the world energy picture than they are at present. Someday, readers of this book might be in a position to help decide exactly how important.

The chapter on natural gas is the longest in my previous energy economics textbook (2000), but it needs to be emphasized here that some people are likely to be disappointed about the long-run availability of "the fuel of the future", to include observers who believe that large, centralized power plants are passé, and small-scale distributed-power-generation plants burning natural gas are the wave of the future. At the turn of the century, global electric power generation was about 40% coal-based, hydro and other renewables were 20% of the total, nuclear 15%, natural gas 15%, and oil 10%. By 2020, the share of gas in global power generation could be well over 20% of a much larger total. *Ceteris paribus*, this could have a dramatic impact on gas prices everywhere.

Present predictions are still that the growth rate for oil consumption should be on the order of 1.5%–1.75%/year, although it could move above that level, largely due to the exceptionally high macroeconomic growth in China, as well as the striking economic progress that seems to be taking place in India and which could easily take place in Russia. I can, however, accept the argument that in many isolated regions it may be economical to rely on small-scale power sources, since it might be too expensive to expand or extend the main power grid. Something that deserves to be carefully observed is that while at the present time coal accounts for slightly more than 50% of the fuel input for power generation in the US, some estimates have this eventually reaching 60%. We can only hope that higher authority has studied in detail the environmental consequences of a coal intensity of that degree.

Now let us complicate the discussion slightly by noting that 1000 cubic feet (= 1000 ft^3 or 28.3 cubic meters) of gas has an average heating value of approximately 1,000,000 (= 1 m) British Thermal Units (Btu). (The exact figure is 1,035,000 Btu.) One barrel (b) of oil has an average heating value of 5,800,000 Btu. Several years ago, OPEC expressed the intention to keep the world oil price between $22/b and $28/b, and so we can immediately calculate that this corresponds to an energy-equivalent gas price of $3.8 dollars per million Btu (= $3.8/mBtu) to $4.8/mBtu, considering only heating values. (As pointed out in the appendix to this chapter, which some readers should consider looking at now, heating values are often measured in "joules" rather than Btu.)

When oil prices began what appeared to be a definitive escalation several years ago, OPEC "unofficially" raised its price target to more than $50/b, citing among other things a lack of economic damage (to oil importing countries) from high oil prices. Using the figures given above, $50 a barrel for oil corresponds to a natural gas price of almost $9/mBtu. When I began writing this chapter, the gas price was hovering around $14/mBtu; but while the price later "collapsed" to $5.5–6/mBtu, nobody really expects it to stay there. Readers should immediately calculate an energy-equivalent oil price for gas at $14/mBtu, whereupon they may draw the conclusion that a sustained gas price at this level is not a very appetizing prospect. It is interesting to note that only a few years ago, a sustained price of $6/mBtu for gas was considered by some observers to be high enough to endanger the global macroeconomic stability.

At one spot sale in California at the beginning of this century, the price of gas spiked to $60/mBtu (according to the *International Herald Tribune*, 10–11 February 2001). Using the information above or the table of equivalents in the appendix to this chapter, the reader can easily calculate that in terms of energy content, this is the equivalent of oil selling for $335/b, which is indisputably destructive. In fact, it has been correctly pointed out that the increased price of electricity in California (and elsewhere) reflects to some extent the large and unexpected rise in the price of gas. As to be expected, these prices influenced the price of coal (since coal can substitute for gas in, e.g., heating applications), which in turn led to certain industries in the United States and Europe beginning to make plans to move all or a part of their operations to places in the world where they believed (or hoped) that gas prices were (and could remain) on the order of $4/mBtu or lower.

This may well be one of the main reasons why President Bush decided that the US should not support the Kyoto Protocol. Although a major part of new US generating capacity was supposed to be fueled by gas, increasingly expensive gas could eventually lead to an increase in the reliance on coal, which the US still possesses in abundance within its borders. As compared to oil and gas, coal is a comparatively low-priced resource; but *clean* coal might turn out to be fairly expensive, and this is something that cannot be ignored since a great deal of it might have to be consumed. To avoid having to confront choices that might be distasteful from a political point of view, the chief executive apparently decided that while global warming is a fact, the extent of the dangers posed by this phenomenon need to be confirmed by further research before his government can accept comprehensive emission controls of the kind presumably stipulated in the Kyoto proposals.

This is an extremely important subject, and it deserves the attention of everyone concerned with the future of themselves and future generations. Science is ultimately a matter of *bona-fide* scientists, and a huge majority of the world's scientific elite say that global warming is a potentially dangerous phenomenon, and that a large part of it has an *anthropogenic* (i.e., man-made) background. Many of them also say that drastic measures should be taken to address this threat as soon as possible — where by "drastic measures" they are alluding to a more straightforward approach than procedures written into or derived from the Kyoto Protocol.

By way of contrast, a scientist who caught President Bush's ear for a while, Professor Richard Lindzen, not only rejects the dangers that are implicit in the present rate of global warming, but he has also made some strange pronouncements about an important medical problem (involving smoking), which under normal circumstances might have made that gentleman and his judgments *persona non grata* at the White House. What we have here is a situation of the type that appeared following Albert Einstein's presentation of the theory of relativity, when a handful of scientists, several of whom had done outstanding work, decided that an overwhelming majority of the world's top physicists had taken leave of their senses in accepting Einstein's triumph.

A few topics referred to in this section require some elaboration before we move on. In 2006 there were more than 200 million vehicles in the US, and although there was nothing to match this in China, automobile ownership in the latter country may grow five times by 2025, which means 200 million cars in Chinese ownership at that time. The private automobile has also become a fixture in the dreams of many Russian and Indian households, and if these dreams are realized it should easily move the number of vehicles globally from the 800 million estimate by Lester Brown (of the Earth Policy Institute) to well over a billion.

China and India provide a significant insight into the future. Their present and expected demand for conventional motor fuel is so strong that it could virtually overwhelm any conservation efforts that are being made in the totality of smaller countries. As is increasingly pointed out, if the per-capita consumption of oil in China and India reached that of comparatively indigent Mexico, they would require more than 40 million barrels of oil a day. The oil price would then move off the Richter scale.

I have already mentioned hybrids and hydrogen, but despite the relatively low operating costs, hybrids are still not especially a price-competitive buy: after five years in the market they still only amounted to 1.2% of the US vehicle sales. Even the Toyota hybrid mentioned earlier requires that the average buyer in the US might have to wait about five years before recovering the additional cost (or *premium*) over a "standard" model, but this figure will almost certainly decline. The point is, however, that more and more effort is being directed toward improving the technology of these vehicles, and it may be true that OPEC and the large oil companies will realize it could pay off in the not-too-distant future. This might be the reason why they have become prone to claim that there will not be a serious shortage of oil in the future, and so automobile buyers can stick with the orthodox technology.

In the short run, a greater consumption of *conventional* diesel fuel may be the most cost-effective option for reducing what has come to be called "the dependence on oil". The problem here is that environmentally this fuel is not considered ideal, and is unacceptable in a large part of the US. The cleaner-emission diesel that is becoming available may be acceptable to both buyers and authorities, but it is not clear at the present time whether the increased cost of a diesel (car) will be substantially outweighed by fuel savings. Note the term "conventional" above: there is also biodiesel, which is a diesel equivalent fuel derived from biological sources.

In the important debates taking place on *EnergyPulse*, it has been stressed that producing hydrogen is an extremely energy-intensive activity, but it is possible that, e.g., wind and solar technologies may be capable of alleviating the dilemma caused by a negative or near-negative output–input energy relationship in the production process. Another annoyance is the difficulty (i.e., expense) of safely storing and transporting hydrogen in vehicles. As a result, it appears that the hydrogen optimism of a few years ago has to a certain extent been replaced by pessimism. The feeling here though is that hydrogen's availability, along with the relative ease with which it can be directly converted into electricity and water via fuel cells, will eventually allow it to prevail.

In his long awaited energy policy speech in 2006, President George Bush decried the "addiction" to oil and emphasized an increased resort to ethanol, which at the time supplied about 2% of US fuel requirements. Ethanol is probably the best known "biofuel", where the two relevant "brands" of this commodity are ethanol from grains (mostly corn), and cellulosic ethanol made from high yield crops or plant waste. *Switch grass* and *forest thinning* are often mentioned here, as is sugar cane, sugar beets, etc. In the last few years this fuel has had an impressive history in Brazil; but in, e.g., the US, corn-based ethanol gives the appearance of being fairly expensive, and while it is believed that cellulosic ethanol will be cost-effective, it may require as long as a decade of research and development before it can be introduced on a mass basis. In addition, research at the University of Minnesota shows that biodiesel has less impact on the environment, and a much higher net energy benefit than corn-based ethanol.

Peter Huber, writing in *Forbes* (10 April 2006), is of the opinion that cellulosic ethanol — when it becomes economical — will be an environmental catastrophe. To his way of thinking, once science and technology have made its production economical on a large scale, forests and grasslands will be savaged in order to obtain raw materials. Whether this will happen to Washington Park in Chicago or the Bois de Boulogne in Paris is dubious, but in the Third World there could be some very undesirable outcomes.

Some questions as to the ultimate utility of corn-based ethanol also need to be asked. The US is the largest exporter of corn in the world, and expectations are that beginning in 2007 they will convert at least as much corn into ethanol as they sell abroad. Moreover, US energy legislation requires ethanol production to reach 7.5 billion gallons by 2012, which will require a huge amount of raw materials that in turn will drive up the *global* price of corn that normally would be consumed as food. What is happening now is that with higher than expected price of oil, farmers will be converting wheat, soya beans, sugar cane and corn into vehicle fuel. This is not what advocates of ethanol as an environmentally friendly fuel had in mind, nor will it ease their minds to know that according to David O'Reilly — CEO of Chevron — 15% of the US corn crop goes into producing fuel, but it produces only 2% of the fuel. Brown (2006) provides another approach. He sees an "epic competition" between motorists who want to protect their mobility, and "the two billion poorest people in the world who simply want to survive".

I see no reason to claim an expertise that in reality I lack in the matter just above, but on the basis of the information at hand, nuclear and hybrids appear to be the way to go. Biofuels (e.g., ethanol and butanol) must also progressively be given an opportunity to show what they can do. Hydrogen's turn has not arrived yet, but it will come.

3. A Preliminary Look at Oil and Gas, and Also Wind

Contrary to general belief, oil is found in open spaces (pore spaces) in permeable reservoir rock, and not in large open caverns. An oil field consists of one or more distinct accumulations of this nature which, inappropriately, are called pools. If sufficient gas is dissolved in the oil, and the confining pressure is high enough, a well (i.e., pipe) driven into this oil will drive the substance to the surface, sometimes in the form of a gusher. (James Dean was the lucky if unpleasant owner of one of these bonanzas in the film "Giant".) In this situation the oil does not have to be pumped, at least during the early life of the field; however, the rate of production that can be sustained from any particular reservoir tends to decline as the oil in it is depleted, and the underlying pressure decreases.

This arrangement is normally called "free flow". In an extremely valuable paper, Cairns and Davis (2001) stated that between 5% and 10% of the wells in the US fit this description, and a much larger percentage in the Middle East. Unfortunately, the mathematical content of their paper will probably limit its popularity.

If the natural pressure of the field becomes insufficient, the oil is pumped out. The two arrangements mentioned here (natural release and simple pumping) are called primary production. In fields where primary production results in an inadequate yield, secondary methods are also employed. These could involve pumping water into the stratum below the pool, or pumping gas into the layer above, with the intention of flushing out the crude oil clinging to the reservoir rock, or a combination of the two, or even something more exotic. What needs to be appreciated at this point is the crucial difference between reserves and oil-in-place. At the present time, with the available technology, the global average for the oil that is actually available (i.e., reserves) from oil-in-place is about 35%, and this varies from country to country. It also happens that some economists prefer to talk in terms of resources, which includes oil that is likely to be discovered, or even oil which has been discovered but is too costly to exploit at the present level of technology. The so-called "heavy oil" of Venezuela and the so-called "shale oil" in the western US might fit this description. As David Korn pointed out in a letter to *The Atlantic* (October 2006), "The cheap and easy oil — the light, sweet crude that gushes from wells under its own pressure — is a thing of the past. What's left is ever harder and more costly to extract, and ever lower in quality".

When I published my oil book (1980), a great deal was expected from the exploitation of tertiary methods, which involved such things as injecting gases like carbon dioxide or nitrogen into deposits, or using chemicals called surfactants to wash the droplets of oil from rock pores. In the US, these methods have been used more liberally than elsewhere, but even so the results are not particularly impressive. Hope is something that remains eternal, however, and some observers still believe that improvements in technology will make it possible to raise the recovery ratio to about 40%. This is something that I do not expect to take place in the near or medium future, but even if it came to pass it would not change a great deal, given the high rate of growth of oil consumption. It certainly would not mean as much as some people believe that it would mean where such things as production and price are concerned.

Although crude oil is a clearly defined commodity, it is often useful to distinguish a number of varieties. The most widely used criterion for classifying petroleum products and crude oils is the American Petroleum Institute (API) grading scale, which essentially describes the specific gravity of a liquid in terms of an API number that decreases as the specific gravity increases. Thus, Venezuelan *conventional* crude has an API of about 26, which means that it is very heavy, while Algerian crude has an API of about 41, which means that it is very light. By way of contrast, the plentiful Venezuelan resource known as heavy oil — which belongs to the unconventional category — has an API number that is extremely small, whereas gasoline — whose specific gravity is 0.74 — has an API of 60. The principal fuels derived from crude oil are gasoline (i.e., motor fuel) and fuel oil, and these are referred to as oil products. Obtaining them involves refining crude, where the fundamental activity in the refining process is the distillation that separates the various ingredients. Oil and oil products can be moved to markets in a number of ways, of which the two most prominent are large tankers (for transportation between seaports), and pipelines, but trucks and trains are also used for smaller amounts.

It has become clear that even greatly increased drilling may not appreciably increase the present or the near-future supply of gas (or oil) in many large producing areas. A majority of geologists now openly say that the geological prospects for (conventional) petroleum (= oil + gas) in *all* of North America — and perhaps even Mexico — are discouraging when anticipated demand is given adequate consideration. We still occasionally hear claims that Mexico is gas-rich; however, the *imports* of gas into that country could double in the near future, and "listed" Mexican oil reserves have not grown appreciably in nearly two decades. On the contrary, the huge Canterell field (in medium deep water), which may still be the second largest oil producer in the world, has definitely peaked. (The largest field in terms of production and reserves is the Ghawar in Saudi Arabia.) In the US a few years ago, a cycle of frenzied drilling enabled small but important increases in reserve levels to be registered, but while it was expected that the recent near record "nominal" (i.e., money) prices would lead to every available drilling rig being immediately pressed into service, this did *not* turn out to be the case. The main reason was that the major oil companies are not really interested in spending billions of dollars in regions where their geologists have told them that there are no extremely large deposits of crude waiting to be harvested.

Just as interesting, however, when it appeared that the oil price could escalate to almost any level, capital expenditures on energy exploration and more intricate production methods increased throughout the world, and every available rig was pressed into service, sometimes at a very great cost. But even so, only a very modest amount of new oil was discovered. The simple tale here is that the reservoir base is no longer as abundant as it was two decades ago when another exploration boom took place.

The largest oil strike of 2004 involved an estimated one billion barrels of oil in India. *A priori*, a student of oil economics might have thought that a discovery of this magnitude would have taken place somewhere around the Caspian, or off the west coast of Africa; but considering that its location is in oil-poor India, which is now achieving a high rate of economic growth, this leads some of us to conclude that the situation regarding oil reserves is even more abysmal than many geologists believe, because India — like China — will be an increasingly significant oil importer. Interestingly enough, one of the most important international business publications has become very pessimistic about oil and went so far as to claim that *oil discovery* could peak around 2010. In point of truth, however, global (conventional) oil discovery peaked in the mid-1960s. Some students of the oil scene have chosen 2010 as the year when *output* peaks, which is a far more disquieting event. In my opinion a peak this early is unlikely, but far from impossible. This might be the reason that the mayor of Ottawa (Canada), Bob Chiarelli, said: "Finding solutions (to the peaking problem) is a race against the clock". Unlike many politicians, the mayor understands that even in rich Canada, a global oil peak could bring severe social and economic discomfort in its wake.

Until recently, certain observers were constantly talking about the miracles that new technology will achieve in the UK North Sea, but in 2004 the UK imported more gas than it exported for the first time in 11 years, and oil production in the UK definitely peaked around the turn of the century. In a few years that country will be a major importer of both oil and gas, which was inconceivable in the popular imagination just a decade ago. Many corporate insiders and a few other observers knew that this was going to happen, even if they preferred not to discuss it, since they were not enthusiastic about seeing the estimated market values of any North Sea assets they owned decrease. (For what it is worth, I knew that it was going to happen when the trading in North Sea properties suddenly and drastically declined.) One of the most interesting characteristics of the oil business in the recent past was the selling of oil properties by large companies to small companies: the large companies obtain cash that can be used to exploit expensive but in their opinion high-value schemes in one part of the world or the other, while the small companies obtain properties that have seen their best days, but still can yield attractive profits if they are managed by highly competent executives who have access to skilled technical help.

Most of North America is, geologically speaking, a mature production area. This becomes obvious upon viewing the large *natural decline* (or natural depletion) rate for oil and gas in that region, and just as important, though often overlooked, the increase in this rate from its already high level for natural gas in the Gulf of Mexico, which accounted for about 20% of US gas supplies, and 26% of US oil. The last time I inquired, there were 4000 oil platforms and 33,000 miles of underwater pipelines in the Gulf of Mexico, but some influential observers claim that deepwater fields in this region *average* only about a fifth of the reserves in similar deposits off the West Coast of Africa. This is one of the reasons why billions are being spent on the right to look for oil in many parts of Africa, and prospects considered not worth being bothered with a few decades ago are now the object of intense scrutiny.

The "decline rate" can also be touched upon here. The subject categorization is the *natural decline rate* or *natural depletion rate*, and here it might be useful to speak of a "recovery factor", which can be defined as the ratio of the amount of oil expected to be recovered to the amount of *oil-in-place* in a deposit. Normally, this ratio decreases with production, but as far as can be determined, the magnitude of the decrease exceeds that which can be directly attributed to production, which immediately suggests that there is another "force" at work: this is natural decline (which in economic theory is akin to "depreciation by evaporation"). Occasionally we hear of something called the "compounding effect", which includes both the decline rate and the rate of demand growth. This has outwardly become so large that Mr Lee Raymond — the former CEO of ExxonMobil — stated that enough reserves must be located during the first decade of the 21st century to replace about half of the decade's oil and gas production, assuming that it is desirable to satisfy the expected oil demand in the second decade of this century without very large price rises. Another expert, Mr Robert Odd — Vice-President of the oil and gas department of the Bank of Montreal, and a petroleum engineer — informed me that for the world oil economy to remain healthy, an absolute minimum of 4 mb/d might have to be located annually to compensate for the compounding effect.

It would be interesting to obtain a candid outline of Mr Raymond's views on US gas, because some observers feel that US energy professionals and gas consumers are badly in need of a wake-up call on this subject. (Russia, Iran and Qatar have 58% of the world's gas reserves, while the US has only 3%.) Admittedly, Canadian gas sales to the United States may show a palpable increase during the present decade, especially since the US Congress has approved credits to the enterprises that will become engaged in constructing a new pipeline. There is also increased talk of a multibillion-dollar pipeline from Alaska's North Slope down to Chicago, carrying 4.5 billion ft^3/day of gas, but this project was being discussed when I began writing my gas book more than two decades ago. Assuming that these conduits come into existence and are filled, they will still be unable to overcome the North American gas deficiency, and in addition, the gas being transported will be much more expensive than originally conceived. Moreover, if approved, an Alaska–Chicago pipeline might take 10 years to construct.

The same applies even more rigorously to liquefied natural gas (LNG). The LNG that will be transported in very expensive ships from the "new" Norwegian field "*Snow-white*" to buyers in Europe and the US will not be bargain-basement gas. In fact, in the above-mentioned talks between the US and UK energy ministers, it was clearly noted that both countries could be facing a very large continued fall in their domestic natural gas production, which means that in the next few years there may be a much larger reliance on natural gas imports than was anticipated just a few years ago. With this in mind, the government of Qatar just announced that they intend to become the most important supplier of LNG in the world. As is clear from many of the important comments offered by the forum *EnergyPulse*, there are a large number of persons in the US who are less than pleased about their country increasing its imports of gas from the Middle East, and in some cases do not want LNG imported from any source.

As many readers of this chapter know, increased pressure is being put on the US government to open more land to drilling. (Altogether, the federal government owns about one-third of US land.) After Mr Bush won a second term, this alternative was clearly available. However, the theory here is that if there were adequate seismological evidence that this federally-owned land really contained a huge amount of oil and gas, drilling would have commenced a long time ago. Just as important, the exploitation of the extremely rich oil deposits of Alaska did not enable the 1970 production peak in the US peak to be reattained. The estimates of "oil experts" given in *Business Week* (29 October 2001) are not particularly dramatic where future supplies are concerned: 6–16 billion barrels (= 6–16 Gb) of "untapped" oil in the Arctic, 4 Gb in the "lower 48", and with "advanced technology" perhaps 59 Gb somewhere offshore. Some of the oil mentioned here is in areas that are highly sensitive from an environmental point of view, and the "advanced technology" would have to be extremely advanced if environmental sustainability were respected. (As is noted in the Appendix, the "G" above signifies "Giga", or billions.)

According to a declaration of the executive vice-president of Alstom Power, "Nuclear is dead in the water. The capital costs of building a nuclear station are three times those of a gas-fired equivalent, which is why the market is dominated by gas in the developed countries" (*Financial Times*, Tuesday, 20 June 2000).

The present-day (2006) market is *not* dominated by gas in the manner implied by Mr Vice-president, even though just about everywhere in the world there are plans to use as much gas as possible. This kind of decision, however, is as much influenced by political considerations as those having to do with economics. It reflects the political strength of the environmental movements, to include the vocal support and encouragement that they receive from persons who do not vote for the "Greens" — "fellow travellers" they would have been called at the beginning of the Cold War. However, if there should be a shortage of gas in the next 10–20 years, then the sponsors and advocates of gas-based installations may have a great deal of explaining to do, because it is highly unlikely that there will be any shortage of nuclear fuel during this century. And there *could* be a shortage of gas, because according to both the IEA and the work of Al-Fattah and Startzman (2000), the global output of natural gas could peak before 2020 if demand continued to expand at the present rate.

The IEA has also collected some useful cost figures. They say that operating (i.e., variable) costs in the US are 1.8 cents/kWh for nuclear, 2.1 cents/kWh for coal, and 3.5 cents/kWh for gas. On the other hand, what they call capital costs are $2000/kW for nuclear, $1200/kW for coal, and $500/kW for combined cycle gas equipment. In my previous energy textbook, and in this book in Chapter 7 on electricity economics, I call these *investment costs*, and show how capital costs (in $/year) are calculated from them. Calculations have been made by the World Nuclear Association suggesting that in the US, construction costs, *before interest charges*, need to fall to $1000 a kilowatt in order for atomic reactors to be economic. However, a rising price of gas (and coal), a "life" for new nuclear installations exceeding 60 years, shorter licensing and construction times and more emphasis on CO_2 suppression would allow that figure to be increased: if fossil fuels were taxed in such a way as to obtain compensation for their external costs (e.g., pollution), the attraction of both nuclear energy and wind would be greatly increased.

I also want to emphasize that many of the figures given above and elsewhere in this book may only be approximations: diligent readers encounter all sorts of figures where things like energy costs are concerned. But even so, just about everything available is presented here in order to introduce readers to the terminology and the general thinking about energy issues. I therefore suggest that persons who require up-to-date information about the cost of nuclear power relative to, e.g., gas, should examine the cost of producing power at the new Finnish atomic installation, whose capacity (of 1600 MW) is the largest in the world. Given Finland's proximity to very large reserves of gas in Norway and Russia, I suspect they would learn that nuclear power is the most economical.

They might also learn something about renewables. Admittedly, wind may ultimately become one of the "flavors of the month" in that country, as in the rest of Northern Europe, but it is well-known by unbiased observers in Scandinavia that the early adoption of wind in Denmark was due to its competing against high-cost, high-polluting coal, while at the same time receiving a favorable tax treatment. Favorable tax treatments and subsidies explain a great deal where the adoption of wind-based electric generation is concerned in a number of countries, but although we have every right to expect a great deal from this energy source, I suggest that it is best for all concerned if we do not overestimate its capabilities.

In the Northwest United States, hydroelectric-installations (which can be quickly turned on and off) do not have enough remaining capacity to supplement and smoothen the up-and-down generation patterns of new wind farms, and the same may be true of gas-based facilities. As a result, the cost of wind power — including the costs of using other power sources to ensure a stable power flow even when the wind is not blowing — could be much higher than commonly realized. Here it can be pointed out that the maximum rating of a wind turbine is not very useful in considering whether that turbine should be installed, since its “capacity factor” might be as low as 25%. Wind power is probably optimal when used as a power source for non-time-dependent applications such as irrigation, and perhaps as an input for producing hydrogen. (The capacity factor is discussed in Chapter 7.)

At the present time (2006), the Horse Hollow wind farm in Texas (662 MW when functioning at rated capacity) is the largest wind farm in the world. Another large wind facility is located at Storm Lake, Iowa (US), where 257 turbines are deployed across more than 100 farms. Many knowledgeable observers believe that with present technology, this is the optimal arrangement. However, some years ago the UK energy economist Michael Grubb published a paper in which he said that wind installations were ideally suited for supplying the electric *base load* — i.e., the load that is on the line every hour of the day. (He concluded, and correctly, that relying on wind power for peak loads of only a few hours per day was questionable, given the lack of reliability of wind, but like many other economists he overlooked what could be a very sizable “intermediate load” — which might be on the line many hours, and together with the base load could mean a very large total load. It might be worth mentioning here that one of the reasons why gas-based equipment has always played such an important role for the peak load is the rapidity with which it can be brought into effective use.)

Exactly how Professor Grubb came to his conclusion about the relation of wind to the base load is a mystery. The base load is on the line 24 h/day, while the wind blows when it feels like it. That makes wind a comparatively unreliable source of power because for base load use, a “backup” would be mandatory that (in theory at least) might have to be large enough to carry the entire base load if the wind stopped blowing. What he should have said was that wind should be able to *contribute* to supplying the base load: in a sophisticated system it could possibly be "switched in" to replace some fraction of the output of conventional base load equipment, perhaps on a continuous basis, and thus reduce the variable cost of running this equipment. This assumes, of course, that when wind-based power is injected into an electric network, it does not upset what power engineers call "the stability of the system".

Apparently, the initial satisfaction accorded wind power in Germany has encountered some "snags". With 18,428 MW of capacity, Germany was the largest user of wind power in the world in 2005. (Spain was next with 10,027 MW and the US had about 9350 MW. Total global capacity was about 60,000 MW.) Unexpectedly though, the *Deutsche Energie-Agentur* (Dena), a government agency, recently concluded that wind power is in certain respects uneconomical and technically unsatisfactory, and intimidated that its technical deficiencies were played down by the media, and German taxpayers were largely unaware of the large subsidies that it has obtained. This was a very unwelcome surprise for the "Greens" in the UK, who have made a point of praising German wind power efforts to the high heavens. Texas has the most wind power in the US, or about 2400 MW (which they claim can supply electricity for 600,000 homes), and California has slightly less. Wind, though, only supplies about 1% of the power in the US, and it will not supply much more if tax credits for wind power entrepreneurs are not renewed. It has also been calculated that about 20,000 large turbines could supply the demand for power in Paris (France). Exactly what that would mean in terms of "backup", however, remains to be seen, and it is best not to discuss how Parisians would feel about their marvellous city being surrounded by 20,000 large wind installations.

An interesting discussion of wind power was initiated in an article by David Dixon in a recent edition of *EnergyPulse* (September 2006) with the title "Wind generation's performance during the July 2006 California heat storm". The comments on this article suggested, however, that wind has been greatly overrated. According to Rod Adams (2006), it often happens that the capacity factor of wind is only 4–10% at the time when it is most needed, and in addition, "Taxpayers have provided huge quantities of cash to wind turbine operators, constructors and salesmen" that, presumably, could have been better deployed. Len Gould (2006) added to this criticism the uncomfortable fact that "the capital cost of every wind unit must have added to it the cost of its required backup unit". (As noted, the capacity factor is discussed in Chapter 7 of this book.)

At the same time, the goal for wind power in the UK is fairly modest — i.e., about 10% of total energy use — and given the supply of wind in the vicinity of Britain, this should turn out to be manageable. Note the expression "supply of wind", because this is seldom used; but it appears that in Germany there is a "repowering" of some wind installations, with larger units replacing smaller and older turbines at sites with strong wind conditions. In other words, even in the windy north of Germany, wind conditions are not uniform, and there is not a large supply of sites where wind turbines are appropriate.

The first offshore wind farm in the US was planned for the Northeast Coast (south of Cape Cod), with construction scheduled to be completed sometime in 2006. Capacity would be 420 MW, and the expected cost is $600 million. (The largest proposed installation is in Ireland, with a capacity of 620 MW.) The expected per-kilowatt (capital) cost at present rates of interest comes to about $1400, and with hardly any variable cost, this is quite attractive. Little has been said, however, about capacity factors, backup costs, etc., and some observers think that a smaller project makes more sense at the present time. Of course, on the positive side, if this wind farm is economical, it can perhaps be expanded. It should also be noted that wind might turn out to be ideal for supplying the energy input needed to obtain hydrogen, assuming that storing the hydrogen is, or will eventually become, a cost-efficient proposition.

I can say here that my way of viewing energy and environmental economics turns on the work of Neumann and Morgenstern (1944). Conjecture about, e.g., oil should focus on the possibility (or probability if it can be determined) of something going wrong, and the kind of shortage suddenly materializing that weakens the macroeconomy, perhaps causes a traumatic adjustment of financial markets, and could lead to dangerous political tensions between oil exporting and importing countries, as well as within importing countries. For more on these matters, see Beyer (2007), Giegler (2007), Gould (2006), Hopf (2007), Hunt (2007) and Kok (2007).

The same type of (cautionary) observation, multiplied by a very large number, applies to global warming where, if some really bad news were to appear, it could be too late to do anything about it. In his review of climate policy (1995), Professor Richard Cooper of Harvard University spoke warmly of the ability of humans to make optimal adjustments in the face of approaching disaster. However, history has provided sufficient counter-examples to show the almost total incorrectness of this belief. Had Professor Cooper been given the opportunity that some of us enjoyed to view various post-war vistas in Europe and Asia via the sponsorship of the US Army, he might have come to a very different opinion.

In these circumstances, it may be appropriate to suggest that, ideally, thoughtful voters should do as much as they can to encourage the election of political leaders who have a predilection for making the right decisions in the face of excruciating uncertainty. The kind of uncertainty that cannot be completely eliminated, but which — even so — must be intelligently *managed*. Managed how? By deciding under what circumstances considerable amounts of resources should be taken from other uses, and deployed to reduce uncertainty. In other words, in order to reduce (the output of) pollution, relatively less efficient (or more costly) production processes might have to be accepted. This may sound abstract, but actually it amounts to no more than being aware that if data indicating that human activities are responsible for the major part of global warming turns out to be accurate, emissions curbs are inevitable, and the longer they are put off, the more draconian (i.e., costly) they will probably be.

Utilities often tend to be against regulation, but faced with the prospects being alluded to here, even important firms like the American Electric Power Company (AEP) have concluded that "establishing reasonable regulations is better than continuing in the present state of uncertainty" (*Business Week*, 9 April 2001). Needless to say, the insurance industry has become the most outspoken component of the business community where this issue is concerned, and its executives make no secret of the fact that they are in favor of a drastic change in energy use if this is what it takes to bring carbon emissions under control.

Arriving at an optimal set of answers to the *economic* dilemmas that are discussed in this book requires considerable imagination and a reasonable amount of creative intelligence. It will also require a great deal of work, because not only do certain influential energy and environmental economists know so little, but because they also know so much that is irrelevant, and they continue to get such lovely opportunities to publicize their bizarre opinions and promote their equally bizarre policies.

When using the expression "bizarre opinions", very little in modern times can match those associated with the deregulation of electricity. The initiation of this experiment suggests to me that large portions of the human race no longer take seriously the adage "self preservation should be the first law of nature". On this point, see David Walters (2007).

4. California's "Deregulation Plan" and "Tough Love"

California is a key state in the United States. In 2006 it may have produced approximately 14% of that nation's output, or more than the smallest 22 US states combined. In addition, with a Gross Domestic Product (GDP) of $1.5 trillion (in 2006), it ranked eighth in GDP — just behind China (and with the US on top). As a result, it is important for the entire world economy as well as the economy of the US. Assuming that decision makers on the US energy scene have partially come to their senses as a result of scrutinizing the deregulation failures in California and elsewhere, it might eventually become possible to take the steps that will facilitate an optimal energy policy for the entire United States. This, in turn, could benefit in a number of ways the citizens of many other countries.

Perhaps the best way to commence an examination of this topic is to look at the deregulation experiment in California, which along with Sweden and the UK was supposed to provide a model for the rest of the world. California started out with an electric industry which was typical in that *utilities* (i.e., electricity suppliers) were regarded as natural monopolies consisting of three major integrated components: electricity generation in very large power plants, transmission in high-voltage and very expensive power lines, and distribution to final consumers via low voltage lines. (Generators are sometimes called wholesalers, and distributors are called retailers.) Utilities were almost always described as *natural monopolies* because not only did they display increasing returns to scale, but potential rivals would have to make huge investments in order to become serious players. Regulation came about in order to keep natural monopolies from abusing the market power they attain as a result of their being in position to function as "price makers" as compared to "price takers".

(Increasing returns to scale means that *average costs* fall with increasing size, and thus a very large electricity supplier could outcompete several smaller firms supplying the same load because the large firm would have a lower unit cost than the smaller firms. Furthermore, if the smaller firms could not accept this reality and tried to compete, they would be risking a great deal of money due to the large expense associated with entering a very capital-intensive industry.)

The California deregulation show hit the road when it was decided that the retail market could and should be opened to competition. The strategy here was that geographical limits on power supply would be removed, and so independent retailers (or for that matter a new form of utility in the form of transmission firms with some retail outlets) could buy power from both local and out-of-state generators (who were later called out-of-state criminals by California Governor Gray Davis, when they began to "game" the market by withholding power, which naturally caused its price to increase). Ideally, the comparatively few retailers would become very many, and at the same time be able to buy electricity from many generating firms. The market would also be altered so that everyone had the legal right to transmit power through any "wires" that had available capacity, as long as they paid the market price.

Why would there be many generators? The reason offered by the deregulation booster club was that technological development reduced and in some cases eliminated economies of scale in electric generation. If so, there was now scope for the mass introduction of relatively small combined-cycle gas turbines, which also meant that wholesalers (i.e., generators) could become smaller. (Brazil was a country in which there were great expectations along this line.) In addition, it was postulated that in the best of all possible worlds, large industrial firms could generate their own power and even sell some of it to external buyers.

Now we can examine some price theory. Competition among retailers was supposed to lower prices to households and small businesses, while competition among generators — of which there would now be many both locally and in the surrounding states — would lower prices to retailers. The key element that was supposed to make everything work smoothly was the increase in efficiency that deregulators claimed was inevitable when competition worked its wonders. This arrangement has overtones that are similar to what a California journalist described as throwing a letter intended for foreign shores into the ocean, and hoping that friendly tides will take it to the intended destination.

Since the Enron bosses had promised the governor and people of California that retail prices would fall by 40%, the retail price was "regulated" down by 10% in order to convince doubters among voters and legislators that everything would go as promised. This annoyed retailers, but they maintained their composure because they expected that competition among a fairly large number of generators would reduce the cost of the electricity they purchased.

The actual outcome was that generators got rich, while retailers suffered losses amounting to billions of dollars. In San Diego, competition was allowed to determine the retail price, and that price increased by so much that it led to demonstrations and consumers refusing to pay their electric bills. Eventually the price in that city had to be capped, and the legislator who had led the fight to introduce deregulation deserted the deregulation booster club and signed on with the opposing side (led by Governor Davis). Similarly, on the East Coast of the United States, Senator Ernest Hollings brusquely abandoned the deregulation sinners who had seduced him into the ways of competition and began to call himself a "born-again regulator". Quite possibly, the senator noticed that as the smoke was clearing from the California meltdown, one of the old sayings introduced aboard some unlucky US Navy ships in World War II began to apply: "When in danger, when in doubt, run in circles, scream and shout".

It has been suggested that factors other than deregulation were at work in the California meltdown, such as rising fuel costs and drought (in the Pacific Northwest). There was no drought in New York (State), where a California-like deregulation scheme boosted retail prices, nor were there fuel shortages in Sweden and South Australia where deregulation fiascos took place. What there was in these and all other deregulation showplaces was the gaming of the system (i.e., price manipulation) by generators who — to use the words of the Irving Berlin song — were only doing what comes naturally. The *market power* of generators is not a fiction but a reality, because the returns to scale that deregulators said did not exist actually do exist, and they became relatively more important when natural gas prices increased by a very large amount. Something else that was real were the rolling blackouts that were experienced as capacity fell or stagnated or was "gamed down" while at the same time demand increased, as tends to happen in regions that become larger and/or richer.

The reaction of the deregulation booster club to these events was not unexpected. Consider, for example, Ms Laura Cohn of *Business Week* (19 February 2001), and Mr Spencer Abraham, the former US Energy Secretary. They immediately concluded that what they called the Bush Administration's "tough love" gambit was capable of resolving California's electric deregulation fiasco. By that they meant that the government would show its love for the citizens of California by not interfering with their problems. In other words, they rejected the opinion of the governor of Washington (State), Gary Locke, who said that "Energy deregulation began with the federal government, and that is where the problems created by failed deregulation efforts must be addressed".

Secretary Abraham could be expected to reject it, because when he was a US Senator he sponsored legislation to abolish the Department of Energy. He was also sympathetic to persons in the US automobile industry who, according to Bill Ford, chairman of Ford Motors, ". . . did the minimum to comply with the (fuel economy) law and fought virtually every (congressional) initiative".

Neither Ms Cohn or Mr Abraham seemed even faintly aware that the analysis of a typical electric grid should begin with physics as well as economics, because electricity is different: it cannot be readily confined to a *linear* path, which greatly complicates the *access* issue — i.e., the ability of consumers in a given district to obtain the amount desired at the lowest quoted price by simply stringing a wire between their location and the "point" featuring the most attractive price. Put another way, it might not always be possible to economically integrate markets in *different* locations into one large "competitive" market, with "the law of one price" being valid (or almost valid) within the limits of transportation and various transaction costs, and as a result the theoretical benefits associated with this scheme becoming available for everyone.

(In its least sophisticated form, the law of one price states that in a "perfectly informed" or price-wise transparent competitive market, if there were two or more prices for the same good, then it would make sense for some market actor to buy at or slightly above the lower price, and sell at or just under the highest. This *arbitrage* should tend to eliminate price differences. In addition, there would be a positive welfare effect due to goods being transferred into the possession of buyers who valued them the most, in return for a sum of money equal to or greater than that reflecting the value placed on these goods by the seller. As already noted, the ostensible fall in electricity prices would not dishearten generators and distributors, because the increase in efficiency that supposedly would accompany deregulation would result in lower production costs. Needless to say, most of this is an elaborate falsehood.)

Unfortunately, even if the physics could be played down and if supply were boosted, there is still the matter of the extreme volatility of electric prices. Why should households and small businesses acquiesce in the establishing of a system in which price spikes were automatically passed along, when it would probably mean that they might occasionally find themselves being requested to pay enormous amounts of money for their electricity? If we take this as a question, then the answer is that they would almost certainly not do so if they bothered to become aware of the personal misfortunes that this choice could bring about. *This is the undesired lesson that households in both Sweden and Norway have received the past few years*. However, experience seems to show that the experts who could assist them in avoiding this kind of mistake are often less than helpful. For instance, one of the most conspicuous finance icons of the 20th century is the former governor of the US central bank (i.e., the Federal Reserve System), Alan Greenspan. During his period as an aggressive libertarian, Mr Greenspan wrote that "The basis of regulation is armed force" (*The Economist*, 27 November 1999). Once it becomes profitable for academics and the business press to spread this particular variety of wisdom, then anything can happen.

The persons mentioned above, and others, cannot envisage how a restructured electric sector would function in the *real* as opposed to the *textbook* world. Under the new system, long-term arrangements (where electricity was contracted for over a long period) between utilities (i.e., distributors) and generators were supposed to be played down, and spot contracts (involving spot prices) promoted. (A spot price is the price for the immediate or near-immediate delivery of a commodity.) Unfortunately, this means that given the invariably faulty *derivatives market* in which futures and options contracts for electricity are traded, participants will find it difficult or even impossible to optimally *hedge* against price uncertainties. According to Professor Laura D'Andrea Tyson of the University of California and London Business School, the California deregulation plan included abolishing long-term arrangements (*Business Week*, June 2001). However, this ivory-tower agenda could not be sustained. The same is true in Brazil, where price volatility and inadequate investment soon caused the government to change its mind about the desirability of spot arrangements.

To make matters worse, the deregulation theorists were, and are, completely unable to grasp that the so-called "waste" that deregulation was supposed to eliminate could be magnified by the kind of investment program that would be necessary to compensate for and/or correct the badly conceived and orchestrated departures from vertical integration that were initiated in California and elsewhere.

It might be educational here to observe what happened in Australia when the government decided to sell some electric assets: the market immediately established the value of these assets at only a fraction of that which was expected. The underlying economics is simple, although it seems to be missing in most of the learned expositions on deregulation. The initial value of these assets was based on their integration into an existing, *comprehensive* electric supply network. When fragmented, their technical viability was reduced, and so (*ceteris paribus*) their economic values had to decline.

Before continuing, let me offer a comment on what happened in places like California, Brazil and energy-rich Alberta (Canada) where, with the help of a barrage of clumsy falsifications, a few influential economists and commentators succeeded in convincing both decision makers and voters that there would be a sizable fall in electric prices once networks were exposed to what they call "competition". Brazil, for example, soon found itself facing an energy crisis of the California variety because the Brazilian energy bureaucracy foolishly came to believe that "liberalization" would provide a miracle cure for potential energy supply deficiencies (via increased investment). Instead, a worsening energy crisis and chronic underinvestment threatened to cut economic growth by half, which brought Brazilian politicians at least partially to their senses. (An important element in this crisis was the belief that gas-based power could be less expensive than nuclear or hydro-based electricity, and given the opportunity via deregulation, private firms would detect this and invest accordingly.)

But as a minister (Pedro Parente) said, “The market is not enough to ensure an increase in the power supply. You need a bigger state role in regulation and supervision”. Someone who agreed, to the surprise of everyone, was Lutz David Travesso, the president of AES, which is an American-owned power company operating in Brazil. He said that: “The market has not been working. Postponing liberalization is not bad but prudent, and for us even positive” (*Financial Times*, 17 January 2002).

At one time it appeared that the winners in the Swedish exercise would be large industrial and commercial firms (which is good for the economy as a whole), but as things turned out when electricity prices began to escalate, there was talk of energy-intensive firms forming a syndicate to buy power from coal-based installations in East Europe and Russia. Households now fully comprehend that they are losers and furthermore, Haas and Auer (2001) argue that almost all price decreases scheduled for Western Europe would, if realized, be temporary, since mergers, uncertainty, unbundling, etc., could lead to a (relative) fall in generating capacity as firms become more intent on acquiring the assets of other companies instead of expanding (through physical investment) their productive facilities.

This kind of spectacle is also visible in the international petroleum industries. Newly merged entities have often lowered exploration and drilling budgets below those existing in pre-merger conditions: in other words, the exploration and drilling whole became less than the sum of the parts. As pointed out in *Business Week* (10 March 2003), large producers found it more expedient to “merge and cut costs than to invest the time and money to bring new fields on line”. What that discussion did not say was that the reason for this approach was they had become convinced there were no large new fields to be found.

Some state governors in the US asked Mr Abraham to impose a temporary ceiling — or “price caps” — on *wholesale* (i.e., generator) electric prices. The former Secretary — who preferred a large *retail* (final user) price rise — rejected these requests, maintaining that price controls would only aggravate the supply crisis. By way of supporting him, Ms Cohn turned to no less an authority than Paul W. MacAvoy, a Yale School of Management professor. MacAvoy called the price caps that Senators Dianne Feinstein (a Democrat) and Gordon Smith (a Republican) requested a "bad, bad disease".

I remember MacAvoy's previous intrusion into energy economics. Several decades earlier, he (and Professor Robert Pindyck of MIT) did some econometric work which led them to believe that taking away price regulations would lead to a sizable increase in the reserves of natural gas in North America. What they unfortunately failed to consider is that in the last analysis, the amount of reserves available from wasting assets like gas or oil are determined by geology, and not econometrics. In these circumstances, I sincerely doubt whether Professor MacAvoy's qualifications improved to an extent that they matched the identikit profile of a world-class expert on the very important topic of deregulation.

But even the most conscientious "servant of the people" — to use an expression mouthed by John Wayne in the film "McQ" — is susceptible to error when in the grip of the deregulation mania. "The best energy policy in the entire world", is how Ms Hazel O'Leary, a former US Secretary of Energy, described the newly deregulated Pakistan electric industry. According to the anti-corruption authorities in that country, it was better than the best if the financial benefits were flowing in your direction. Otherwise it was an abomination in practice and misleading in theory, although it was not until various market actors began to shoot at each other with real guns and bullets that Madame Secretary realized that her judgment had been a trifle premature.

In the old days, most love stories had a happy ending — even those involving tough love. The same is true here. With bad news expected everywhere on the energy front, President Bush imposed what was termed a "market-based mitigation plan" (for prices) that was extended to 11 Western states. The hated price caps thus made their appearance, though under a new name. "A rose is a rose no matter what it is called", Senator Dianne Feinstein remarked, and so another electric market that had gone wild was tamed by the toughest regulator of all: political expediency.

5. Oil and Economic Logic

"To look is to think"
— Salvador Dali

I picture this chapter as a long and important review of topics that many readers will someday extend and present to students, colleagues, friends and even enemies. For instance, imagine my surprise (and near panic) when I was severely chastised (at the 22nd international meeting in Rome (Italy) of the International Association for Energy Economics) for daring to express my belief in an interpretation of the Reserve-Production (R/q) ratio for petroleum similar to that which will be presented in some detail in this book.

I also became the object of some "attitude" on the part of other delegates when I made a friendly remark about the work of Dr M. King Hubbert that dealt with the ultimate availability of petroleum. Among other things, I was sanctimoniously informed that oil reserves are "dynamic", and basically are dependent on human ingenuity (i.e., technology) — which as all thoughtful persons are supposedly aware, would ultimately come scampering to the rescue in case the energy wolf appears at the door. Finally, I was assured that economics and technology were always the correct aperture through which oil reserves should be scrutinized. Geology was taken to be of minor importance.

A passing comment in the survey of environmental economics by Professor Richard Cooper indicated that he was prepared to take a similar position — at least when that survey was produced (1995). To his way of thinking, oil was certain to be cheaper in the future because technology would reduce costs. The matter of oil exhaustibility apparently did not occur to him, although even at that time oil production in the US was on a downward trend from which there was no recovery. Of course, the events of the past few years have probably changed his mind about a lot of things having to do with that commodity. At the present time there is a hectic scramble for oil, with China, India, South Korea and Japan together importing more than the US (or about 12 mb/d). Their import dependence is rising faster than that of the US, even though China and India — the two most populous countries in the world — are far behind the US in per-capita income and per-capita consumption of oil.

As a comment on this situation, the *Financial Times* (10 January 2005) said that western oil consumers will be able to deal with the competition for Middle East oil by countries like the above foursome by turning to non-OPEC sources such as the North Sea, Gulf of Mexico, West Africa, the Caspian and Russia. One certainly hopes that the governments of the "western" countries do not take this kind of advice too seriously because in about a decade, by my calculations, all of these will be of greatly reduced significance where the ability to export oil is concerned. In fact the UK North Sea is already in irreversible decline.

One of the reasons why we have to suffer so many errors of judgment on the part of various observers of the oil scene is that their fundamental mode of thought is still many years in the past, when the global consumption of oil was, e.g., 50 million barrels per day (= 50 mb/d), and could fairly easily be raised an extra million barrels or so (per day) by increased exploration and drilling, and/or a wider and more intensive application of various scientific or technological improvements to existing deposits. During the year in which this is being written, however, with consumption approaching 86 mb/d and a predicted need to add well over a million barrels per day to output every year over the foreseeable future, it could be a momentous indiscretion to accept or to even contemplate theories claiming that new projects in exotic locales can compensate for the near stagnation in production that could take place in certain oil-rich countries if these states decided to exhibit the same interest in their own long-range economic development as they have graciously shown in ensuring that adequate quantities of this vital commodity reach their clients.

For example, both the IEA and the US Department of Energy once suggested that one of the reasons why there will not be a peaking of global oil production in the next two or three decades is because Saudi Arabia has the capacity and willingness to produce 20 mb/d of oil in the not-too-distant future. However, as I point out in Chapter 3 of this book, it is unlikely that the Saudis would sign up for a *sustained* output of more 12 mb/d. As for their capacity to go much higher, even if they were willing, this is also dubious according to influential observers of the oil markets like Matthew Simmons, a Houston (Texas) investment banker and former advisor to President Bush, and one of the leading oil consultants, Herman Franssen (2005).

Furthermore, although one well-known oil optimist is correct when he repeatedly points out that "we keep looking for more oil, and finding more oil", he invariably forgets to note that, in terms of quantity, the aggregate amount of oil discovered is on a falling trend. Nearly 365 billion barrels were discovered in the 1960s, about 275 billion barrels in the 1970s, 150 billion in the 1980s, and the figures that I have seen for the 1990s suggest that less than 40 billion barrels were put on the books. My lectures on oil always begin with this unpleasant piece of information. At the present time, only one barrel of oil is being discovered for about every three being consumed, which I choose to interpret as the worst possible news for anyone on the buying side of the oil market, regardless of the relationship they may have to goods and services using oil.

It should also be noted that even if it were true that technology is "overwhelming natural depletion" — as some oil optimists still claim — and reducing costs all along the line, without an increase in the amount of oil discovered, preferably in the form of larger deposits, production cannot continue to rise. This is one of the major results derived from the work of M. King Hubbert, and clearly explained in this book as an *economic* as compared to a geological phenomenon. It is probably worth mentioning that few, if any, executives of the major oil companies in any part of the world expect a major alteration in the existing supply–demand picture, regardless of what they may say when the TV cameras are turned in their direction.

Let me emphasize for those persons who are uninterested in geological or economic arguments, and have no desire to read the next few chapters in this book, that a close look at the figures does not substantiate the exasperated point of view put forward by the oil optimists when they encounter opposition to their pet "theories". Since 1981, US oil output has fallen from 8.6 mb/d to less than 6 mb/d, although firms now drill deeper (to an average of 6105 ft, as compared to 4512 ft 20 years ago). Moreover, the cost of the average production well declined to about $769,000 as compared to $855,000 (in real terms) in 1981, and the success ratio has reached 80% as compared to the earlier 70%. (These figures apply to the beginning of 2002.)

The profitability of some international operations is also impressive. BP's return (i.e., yield) on investment and exploration seems to have reached a new record in 2005. The story behind its ability to do so well turns on the relatively inexpensive reserves that this firm succeeded in obtaining, as well as its ability to keep production costs lower than for major competitors ExxonMobil and Shell. [As in game theory, I often explain the cause of this situation as a combination of strategy, skill, and luck — and particularly the latter. In a world in which oil in the ground is becoming scarcer, BP's *bets* (on, e.g., the West Coast of Africa) paid off, although a key factor in explaining the value of West African oil to large foreign companies is corruption in the countries possessing this oil.]

At the same time though, BP's earnings (i.e., profits) in 2005 were only $22 billion as compared to $23 billion for Shell and $36 billion for ExxonMobil. (Here it can be mentioned that in 2005 all the major automobile makers together earned about $21 billion.) Despite all this money, Shell and Exxon have experienced some disappointments. Shell replaced only 60–70% of its production in 2005, while ExxonMobil managed only 19% in 2004. One conclusion that can be drawn here is that despite enormous capital resources, the failure by these firms to replace production is a sign that even worse tidings might eventually appear, although since BP's Lord (John) Browne (of Madingly) would not deny the possibility of oil costing $100/b at some point in the future, I doubt whether, e.g., ExxonMobil will be deprived of its position at the top of the corporate income league. Moreover, 2006 was an even better year for Big Oil, although voices were heard suggesting that Lord Browne should begin shopping around for another line of work due to some problems with BP's Alaskan assets.

One of the points being made in the above discussion is that since it is not unreasonably expensive to look for, find and produce conventional oil, the root of the oil problem in, e.g., the United States, is an incurable shortage of *large quantities* of conventional domestic reserves, and the same thing now also applies to, e.g., the North Sea (where just a few years ago journalists still talked about "exciting" prospects). At that time, certain oil companies heavily endorsed the idea of plentiful future oil (which implies low oil prices in the future) because they understood that merger-related cost reductions were more sensible than looking for "cheap" oil that is not there. In addition, if expectations are that oil prices will more likely fall than rise, then (*ceteris paribus*) the objects of their affection might find proposed mergers a great deal more attractive. The shares of the "target" firm might also be cheaper.

Put as simply as possible, some firms are to all intents and purposes looking harder than ever for oil, and it is not unthinkable that they will succeed in finding more; but collectively they are moving farther away than ever from finding enough. Take as an example the Russian Federation. It was recently announced that the largest discovery in 10 years has been made in the Caspian Sea. What this "find" comes to in production terms might eventually be 100,000 b/d, which is paltry: it amounts to only slightly more than 1% of present production. (I can add that with economic growth picking up in Russia, and additional energy required for electric power and vehicle fuel, the position of that country as an oil exporter is destined to weaken.)

The fallacy of composition comes to mind here — the simple fact that if something can be done on a small scale, it causes inattentive observers to jump to the conclusion that it can be done on any scale; however, you can be confident that the persons in the executive suites of the large firms that are active in places like North America, the Caspian region, the Gulf of Mexico — or any other region or gulf — are not confused by incidental statistics, nor the fallacies to which they may give rise. With a huge number of wells drilled, every large firm in the US, as well as the government of that country, now realizes that even a much higher success ratio cannot keep the (domestic) production/import ratio of the US from descending. During the periods reviewed above, US imports of crude and refined products moved from being important to being crucial.

A concept that most executives are familiar with — and which will be treated later in this section — is a "rule" associated with M. King Hubbert, which might be called the "mid-point depletion rule": in a given oil-producing region, *when half the oil discovered and likely to be discovered has been produced, production will level off and begin to decline*. A short discussion in the next chapter argues that this is as much an economic as a geological phenomenon; however, I want to state now that while Hubbert's geometry appears to work well for a majority of large deposits, this is because it is not the mid-point of reserves (50%) that is relevant, but a band around the mid-point from about 40% to about 60% of ultimate reserves.

An item that should never be overlooked is the location of oil. Global proved reserves in the low-cost, easily accessible class are overwhelmingly located in the Middle East, and according to Teitelbaum (1995), some very rich investors in the United States staked a great deal of money that a large fraction of those reserves will stay in the ground unless buyers in the oil-importing countries were willing to pay realistic prices for their extraction. As the Texas billionaire Richard Rainwater stated when he began purchasing oil assets five or six years ago, the rising global demand "paints a picture for me that doesn't have any other outcome. The price of oil is going to have to come up". His optimism definitely seems to have paid off, since beginning in the last quarter of 1999 the long-shunned gas and oil sectors generated profits at a lovely pace. Besides, as another billionaire — the late Marvin Davis — generously informed the inquisitive, "you don't have to be a cockeyed genius to see this coming".

Some attention can now be paid to the R/q ratio (which actually ties in with the work of M. King Hubbert). The concepts that are presented below are gradually being understood to the extent that they deserve, although not fast enough as far as I am concerned, which is one of the reasons that I make it my business to repeat them as often as I can. An irritating problem here is that even the many outstanding microeconomic textbooks to which our students have access insist upon treating the production of depletable resources in terms of an almost completely inappropriate model developed by a brilliant economist, Hotelling (1931). This exaggerated and scientifically meaningless respect for elegant irrelevance is one of the major reasons why academic economics is increasingly subjected to ridicule. "Narrow rationality" is what the superstar physicist Murray Gell-Mann has termed this kind of behavior, which features (easily) quantifiable nonsense being rated far above non-quantifiable plausibility.

The story of the R/q ratio is simple. When it falls below a "critical value" — 10 was the number assumed in the seminal article of Flower (1978) — this ratio will determine production in the sense that production should adjust in such a way as to hold the R/q ratio constant (or more realistically, nearly constant). If this were not done, then it would be tantamount to "overworking" the deposit, and as a result of accelerated (physical) depreciation, reducing the amount of oil that can ultimately be obtained. Let us put this in a slightly different way: if the R/q ratio falls below a certain level — probably somewhere between 10 and 15 — then the deposit is being "damaged" in the same manner that sucking too hard on a straw will damage an ice-cream soda (or — to take a more unpopular metaphor — firing a rifle on automatic will, *ceteris paribus*, reduce its length of its useful life relative to firing single shots). This particular R/q ratio can be designated the *critical* R/q ratio, or θ^*, and for simplicity I always take it as 10 — although Flower (1978) prefers the higher figure. This topic receives a short comment in this chapter's appendix, and will be treated with some simple algebra in the next chapter.

What happened in the US was that the reserve–production ratio fell below 10, and surprisingly continued downward until it was approaching 9. At that point the inevitable happened in the form of one of the largest declines in US oil output in modern times. Of course, oil production in the US had begun falling many years earlier. In 1962, Hubbert published an updated version of a highly controversial report in which he had claimed that oil production in the "lower 48" of the United States would peak between 1966 and 1970, at a point where approximately half of the *total* amount of US reserves had been produced. (Total here means the sum of the amount of oil already extracted *plus* proved existing reserves.) The peak came about the end of 1970, and in the "lower 48" has been trending down ever since.

Hubbert's warning of potential oil shortages was in general ignored because of an ingrained — and to a considerable extent understandable — belief by his potential readers in the efficacy of the price system: higher oil prices should supposedly speed up the introduction of a superior oil recovery technology, and at the same time increase exploration as well as the amount and intensity of drilling. The main difficulty here is that technological progress cannot find (conventional) oil that does not exist. (It can, admittedly, locate and produce "heavy" oil, oil from tar sands and unconventional oils from, e.g., shale; however, these resources are in a higher cost class.) It also needs to be carefully noted that the formation of the "efficiency" prices that are explained in advanced undergraduate or graduate courses in economics — and which convey the kind of information that will induce a logically meaningful reaction from producers and consumers — does not always take place in the presence of uncertainty, and this definitely applies to geological uncertainty. Before oil supply curves move to the right — i.e., before production will actually increase following a rise in prices — some of this uncertainty might have to be dispelled by increased seismological and/or drilling activities. (Supply curve movements to the left often seem less complicated. For example, when the oil price declined in 1998–1999, 136,000 of the 574,000 oil wells in the US were shut down temporarily or "permanently". High oil prices, though, may have cancelled this permanence.)

A few observations were offered earlier about the comparatively low recovery factor of oil reserves from oil-in-place. This is not a satisfactory state of affairs, but there is not much that can be done about it in the short run. The production of conventional oil involves reservoir fluids flowing under pressure out of the reservoir rock into a production well (or borehole). Initial production tends to be constant for a period ranging from several days to several years. Then, as the pressure drops and the oil has to move a longer distance through the reservoir rocks in order to reach a given borehole, the output will tend to decline — *ceteris paribus*. One of the things that will reduce the pressure is a too rapid depletion. This can result in the deposit being damaged, which in turn makes the oil more difficult to extract (for the same cost), as well as decreasing the ultimate recovery factor. Now we see why the R/q ratio is so important: when operating below the *crucial* R/q ratio (= 10 in the previous discussion), we are overworking the deposit. Something else that should be recognized is that petroleum engineering is a serious profession, and few economists have the background to understand the more abstruse facets of oil production. Thus, for economists, levels and changes in the R/q ratio can, if properly interpreted, sum up considerable important geological information.

This discussion can be slightly extended. As shown in my previous energy economics textbook, the production profile for a typical oil field — where a field is a group of reservoirs in the same general area — usually exhibits rising production, a plateau, and then falling production. Obtaining this profile calls for drilling a number of production wells. Initially, the flow from successive wells exceeds the depletion (i.e., production decline) of those already drilled, and so we start out with a rising production pattern. Then, new drilling takes place at a pace that is designed to keep output more or less constant; and finally drilling slows because as the amount of oil remaining in the field declines, the cost of extra wells is high compared to the additional amount of oil obtained. The downturn in drilling accounts for the declining portion of the profile. Naturally, this exposition also applies to gas.

A few statistics might be useful. The conventional oil already produced is close to 1000 billion barrels (=1000 Gb). The consensus figure for *proved* *reserves* available now is somewhat over 1000 Gb. The (estimated) amount that will still be found is 300–500 Gb, and thus *ultimate* reserves — the total amount available past and future — can be put at about 2400 Gb. Optimists, however, say that ultimate reserves are closer to 3000 Gb, and pessimists say 1900 Gb is a better estimate. If we look at the forecasts of the IEA for world demand, we see crude oil demand in 2010 at 95 mb/d, and in 2020 it reaches 115 mb/d. Taking ultimate reserves as 2400, and applying a variation of Hubbert's rule, the peak production year turns out to be somewhere around 2010, with the production of conventional oil at 95 mb/d (as compared to about 85+ mb/d just now). Thus, using the assumptions of this forecast, enough additional reserves would have to be found to enable an extra 15 mb/d of conventional or unconventional oil to eventually be produced in order to push the peak out to 2020. (2010 for peak production is too early to suit my taste. 2015 strikes me as more reasonable.)

Like most forecasts of future oil production and/or consumption, the above estimates may turn out to be quite far from the *ex-post* values, but even so this kind of approach has led some very serious people to believe that the age of (conventional) oil — in the most comprehensive sense — is slowly drawing to an end. Let me suggest, however, that it is highly unlikely it will draw to an end before 2010, and the same applies to 2020, or for that matter 2030, since plenty of oil will be produced and used after that time. Furthermore, some "back of the envelope" calculations that I once made assure me that we will not see a global production peak before 2015, although in case you are exceptionally impatient, I consider it unlikely that you will have to wait until 2020 to experience this traumatic event.

Now for one of the most important concepts in the widespread debate on the future availability of oil, which deals with the global oil supply. In the American Army, the United States at one time was frequently referred to as "The World". (In fact a former heavyweight boxing champion, Mohammad Ali, actually used that expression in public on one occasion.) Let us begin the analysis by pretending that the United States is actually the entire world, and take a brief look at what happened to its production of oil. If we examine the "lower 48" to begin with, we know that the modern oil age began in Pennsylvania (and perhaps also on the shores of the Caspian Sea). Output peaked in that region in a short time, and eventually also in California and

Oklahoma, and perhaps elsewhere in the US. But in the huge oil province of East Texas, output continued to rise, and as a result, if we examined the production curve for the entire lower 48, we would see the output of oil continuing to rise.

Though generally unexpected, output also peaked in East Texas, and in these circumstances it became impossible to maintain a rising production in the lower 48. Once the production of Alaska (where reserves were twice as large as East Texas) began to accelerate though, and this output was added to that of the lower 48, then the aggregate production curve for the *entire* US began moving up again, but even so it never attained the 1970–1971 maximum. Thus eventually, and even before output peaked in Alaska, the output curve for the US (i.e., the entire 50 states) peaked again (though not as high as the previous maximum). Equally as significant, although the huge Prudhoe field in Alaska was discovered as late as 1968 (with reserves estimated at 25 Gb), it peaked only 20 years later.

What happened in the US will happen in the entire world sooner or later. It will almost certainly happen when or even before output in the Middle East begins to slide. (Saudi Arabia is roughly operating on an undulating plateau at the present time, and while perhaps — *perhaps* — that plateau will move up by another million barrels a day or thereabouts, it might be possible to argue, as Matthew Simmons argues, that the bad news has already arrived.) Of course, what we would like to know is when (*ceteris paribus*) the output of the Middle East more or less duplicates the pattern exhibited as in the US.

There is some talk of a composite peak happening around 2030, but I would be very surprised if anybody in the executive suites of the major oil companies believes that it will take so long, and the same is true of many top politicians in North America and Europe, and perhaps elsewhere. Once again we can turn to Neumann–Morgenstern reasoning: regardless of when it actually happens, in the light of information shortages and the inexactness of calculation techniques, it is asking for trouble to count on it happening later rather than sooner. There is also some opinion coming from the IEA that Chinese imports will be as large as those of the US in 2030. Maybe so, but regardless of the actual quantity, these imports will not be rising because globally, there is not likely to be sufficient oil to support an increase in imports of the extent implied in that estimate.

A superficial examination of many oil production curves gives the impression that the decline from the peak tends to be more rapid than the approach to the peak. An interesting suggestion as to why this is so follows from an observation by Ali Samsam Bakhtiari of the National Iranian Oil Company: "it's not that you've eaten half of the pie, you've eaten the good half".

Until recently, energy economics featured an acid-like debate on the subject of oil depletion. This continues to a certain extent, and in citing my many contributions to this dispute I always enjoy pointing to the situation in neighboring Norway, where fewer exploratory wells were drilled in 2003 than in any year since 1977 — despite high and rising oil prices. Only a third of these ventures were judged successful, as compared to a half the previous year, and gas rather than oil was the principal discovery: in fact, it has been at least 11 years since a significant amount of oil has been discovered in the vicinity of Norway. That rich oil province has seen its best days, and from here on in the accent is going to be on gas.

I occasionally hear from people who have a different opinion from mine about the future of oil in the Norwegian North Sea. I have even heard it claimed that the unexploited field "Goliath" may contain five times as much oil as previously calculated. The probability of that being true is certainly greater than zero, although I intend to continue to believe that this estimate is unsubstantiated balderdash of the kind that is often circulated in order to increase share prices and/or obtain more investment dollars.

Similarly, there is a new twist (or spin) that deserves our consideration. Many of the optimists have become vaguely aware that technology and investment cannot overwhelm the laws of physics, and thus locate resources where in reality none exist. As a result, considerable attention is now focused on oil from Canadian tar sands. In stock form, these unconventional resources contain an amount of oil/energy that matches — and perhaps exceeds — the proved resources of Saudi Arabia and Iraq. I have nothing at all against believing that someday a technology will appear that will permit these unconventional assets to be economically exploited on a much larger scale, but thus far there is a shortage of proof. As far as I can tell, the production of oil from tar sands is increasing at a rate that is only slightly larger than the rate at which the output of conventional oil is declining.

The key word above is "someday", which in this context does not mean tomorrow: it means — in the best of cases — a long time in the future. Even in the most auspicious situation, the Canadian output will likely be well under 3 mb/d in 2010, and under 4.5 mb/d in 2020. Furthermore, regardless of when this oil becomes available, there is still this matter of the *energy return on energy invested* (EROEI), which involves calculating the "yield" from both the direct and indirect energy inputs employed in the production process. Professor Ugo Bardi of Florence University (Italy) has emphasized this approach in his recent work, and suggests among other things that it casts doubt on the viability of the "hydrogen economy". [You can refer to his on-line paper (in Italian), "A critical approach to the concept of a hydrogen based economy", at www.aspoitalia.net.]

According to some observers, the EROEI — which might be thought of as a kind of energy profit — tends to decline over time for all energy resources examined. They cite an EROEI for oil and gas in the United States of 17 today, as compared with 100 for the 1930s. More relevant for the present exposition, they say that the energy input required to produce conventional oil from the heavy oil in Venezuela and tar sands in Alberta is almost equal to the energy content of the final product. (To be specific, the long-chain hydrocarbons of the oil obtained from tar sands must be split into lighter, more usable molecules. This not only decreases the net energy yield, but greatly increases the amount of carbon dioxide released into the atmosphere.) I have also heard it said that an EROEI that is "much greater than one-to-one (1 to 1) is needed to run a society".

The expression "run a society" does not sound particularly elegant to my ears, even if it turns out to be important for the sequel. What we want to consider at first-hand is the flow of energy through a system in such a way as to locate all of the energy inputs relevant to the output of a well-defined good or service. In the case of conventional or unconventional oil, there is a direct energy cost of obtaining the item, to which are added the various energy costs associated with processing, transportation, etc. Slesser (1978) provides a useful introduction to these matters, and among other things notes the utility of input–output (I/O) analysis. Once this expression (I/O) enters the discussion, it becomes possible to think of a modified version of the Hawkins–Simon (H–S) condition (1949), which — though generally ignored — can provide a partial theoretical basis for EROEI.

We can look closer at this phenomenon with an observation from one of the most important economics books of the 20th century, *Linear Programming and Economic Analysis* (1958). The H–S condition turns on the theme that it should not "take more than a ton of coal to make one ton of coal". (You can use barrels of oil here instead of tons of coal.) Thus, "if we add up the direct and indirect inputs of coal that go into a ton of output (the coal to make coal, the coal to make coal to make coal, the coal to make the steel used to make coal . . . etc., *ad infinitum*), this should be less than one ton". Essentially, this is equivalent to the (less than of equal) one-to-one EROEI specification alluded to above, and intuitively it makes considerable sense on the "social" level — i.e., the level dealing with social rather than private profit.

However, if we leave coal (or oil) and think in terms of energy, then even if a barrel of produced energy contains, directly and indirectly, more than a barrel of energy inputs — with outputs and inputs measured in an energy unit such as Btu or joules — we might still find it attractive to do business, at least in the short run. This is because the barrel of energy at the output point might be different in composition from that used as an input. For instance, the output might be a barrel of oil from tar sands, and the input two barrels of coal containing more Btu than the oil obtained. If the price of oil were high, while coal was cheap, then it might be good economics to pump billions of dollars into the production of this liquid, even if in the fairly long run a negative energy yield could not be avoided — or, to use the terminology above, we are embarking on a bad way to run a "society". In the very long run, however, we are riding for fall with this particular arrangement.

(Of course, in the great world of neo-classical economics, it is unnecessary to worry about this kind of dilemma, because a comprehensive set of perfectly competitive spot and futures markets are theoretically capable of providing rational producers and consumers with the *scarcity prices* needed to make perfect decisions. As noted in a later chapter, in the real world we do not have — nor will we expect to have — anything approaching this ideal.)

It so happens, though, that despite their public affirmations, in private many geologists, petroleum engineers and executives of the large oil companies are sufficiently acquainted with technological realities to still believe that it makes more sense to search for large quantities of oil on the floor of the oceans than to invest as much as $30,000 per barrel per day for oil originating in the sensual north of Alberta (Canada). They may also be aware that, according to the opinion of Professor Bardi (and probably other physicists), the EROEI is based on thermodynamic factors, and thus in some sense may turn out to be largely (or nearly) impervious to the upgrading of technology. (See also the editorial in *Petromin*, October 2004).

One well-known executive, Mr T. Boone Pickens, recently informed a "60 minutes" interviewer that if we cannot get the oil that we need from the Alberta tar sands, then we are going to have to do without. I suspect that not a great deal of attention was paid to this remark, which conceivably was passed off as "infotainment", however the record shows that Mr Pickens is the kind of man who goes to a great deal of trouble to avoid making mistakes where items like oil or money are concerned.

What it comes down to then is whether the reader believes these oil industry decision-makers or, by way of contrast, assorted pundits (i.e., people whose opinions are relentlessly solicited by others), who refuse to accept that in reality the crust of the earth is not overflowing with inexpensive oil. According to their cheerful way of looking at these proceedings, if by some odd twist of fate a supply predicament should emerge, all you will need is enough dollars to finance the digging of an additional hole, following which you stand there with a bucket and your oil dreams will come true.

Given the social and political consequences of a sudden peaking of global oil, in addition to my almost complete inability at the present time to envisage even the tinge of a solution for this potentially explosive situation, I am afraid that it is completely impossible for me to side with my fellow academics.

6. Great Expectations: A Brief Perspective on Natural Gas

Since the publication of my book on natural gas (1987), dramatic changes have taken place in this market. The growth rate of the demand for gas exceeds that of all energy media except renewables, and unlike the situation 15 years ago, gas is highly recommended as an input for power generation. The reason is the advent of *combined cycle* gas-burning equipment with a very high efficiency. What happens here is that in addition to the gas turbine, there is a secondary turbine producing steam from the waste gases/heat of the gas turbine, and this enables the generator to produce additional electricity. At the same time, it should be recognized that if recent price tendencies continue, they could drastically alter the favorable economics of gas-based power generation that resulted from advances in combined-cycle technology, and in many cases made gas a competitor to coal and nuclear in generating the base load.

As bad luck would have it, there are very many misconceptions in circulation about natural gas, to include those having to do with its deregulation. Some question needs to be asked as to why and how these misconceptions came into existence, and it appears that the answer has to do with the very short time horizons of producers, as well as the short time horizons and carelessness of consumers. In some parts of the world, producers have expressed and conducted themselves in such a way as to suggest that there is a near infinite amount of natural gas reserves available for exploitation, when in truth, in many regions, demand could outrun local supply in a comparatively short time. For instance, in much of the US, exploration and production have started to yield disappointing results; and expectations about, e.g., the Gulf of Mexico, often have an air of unreality about them. With certain exceptions, many gas buyers are almost totally unaware of how supply and demand could develop in even the present decade, and instead continue to make plans for a future which they envisage as featuring all the moderately priced energy they believe they will need.

This might be a good place to repeat that in Brazil, deregulators counted on gas-based power being cheaper than hydroelectricity. As they now admit, this supposition was completely wrong. The problem in Brazil, as in many places, is that huge investments are required to move gas from seller to buyer. "Shortages amid plenty are the underlying irony of it all", was how Jed Baily of the Cambridge Energy Research Associates (CERA) of Boston described the situation (*The Economist*, 11 February 2006). There is plenty of gas in Venezuela and Bolivia, and perhaps also in Peru, where the largest gas field in South America (the Camisea Field) is located, but the question is whether it is more economical to transport a large part of this gas by pipeline or in the form of LNG. *The Economist* concluded that once distances exceed 3000 Km, LNG makes more sense than pipelines. However, on the basis of today's technology, the figure is probably greater than 4000 Km. Given the location of gas in South America though, the most economical transport pattern might involve both fairly long pipelines *and* sea transportation. Exactly how dramas of this nature will play out remains to be seen, because although 20 years of discussions and studies seem to have finally resulted in agreements to construct some very large pipelines from Canada and Alaska to the US mid-west, it may still take a decade before this gas starts flowing.

According to the IEA of the OECD, fossil fuels will account for 90% of the world primary energy mix by 2020, which is a big increase over 1997. Gas demand could rise by 2.7%/year, and its share in world energy demand move from 22% to at least 26%. (Oil's *share* should fall, but this might be more than compensated for by the increase in world oil demand.) Gas is expected to surpass coal after 2010, with its total demand rising by 80% between 1997 and 2020, but clearly in the long run the large availability of coal should assure its primacy. (The IEA base year is 1997.) Pipelines are expected to continue to handle the greater part of international trade, and gas-fired power generation could greatly increase, although the recent gas price increases may change this picture in that they change expectations, regardless of occasional price declines. In the OECD, imports of gas are expected to continue to expand, and OECD Europe alone could account for about 19% of the increase in world demand in the period 1997–2020. There is also an assumption by the IEA that higher natural gas use will reduce carbon dioxide emissions by 10% in 2020. The population basis for these estimates turns on an expected global figure of 7.4 billion persons in 2020.

Russia, which provides more than one-third of global gas exports, will continue to be Europe's main gas supplier, but will also probably contribute to the increased imports that will be required by — among others — China and Korea, especially if it becomes possible to construct large pipelines through North Korea to South Korea. In examining expected growth rates of gas demand, China, East Asia and South Asia stand out from the rest of the world. In the long run, their high rates of growth could have an important effect on the supply of gas to OECD Europe and North America, and if the gas deregulation plans of the EU energy directorate are carried out, there could be some ugly surprises where gas prices are concerned.

The IEA also deserves to be mentioned here. That organization has mostly got it wrong where oil and the liberalization of the electric sector are concerned, and as a result it is difficult to respect their ability to analyze the structure and mechanics of world gas. However, since even the experts of the IEA are capable of comprehending that major uncertainties exist about the ability to develop and transport the more distant gas reserves, then it might be appropriate to suggest that no capricious ideas about restructuring should be allowed to get in the way of sound engineering practices. After pointing out that the question of electric industry reform has several dimensions, to include technical, environmental, economic, social and political, Deepak Sharma (2001) goes on to note that "The ongoing debate … is being conducted exclusively in the economic realm, which for practical reasons has been further relegated to the economic indicator of price. The underlying assumption is that economics encapsulates all relevant dimensions of reform. This is shortsighted and likely to be potentially damaging to the overall health of the economy".

To this it can be added that where natural gas reform is concerned, the economic debate is not particularly impressive, and in some cases is conducted by persons without the slightest feel for either the economics or the engineering aspects of natural gas industries, and this includes economists with a modicum of engineering training in their background. They have not bothered to find out, for example, that an important component of the financial sector — in the form of several leading investment banks that are heavily involved with commodities — are scaling down their risk management commitments in some commodity markets. Warburg Dillon Read — the investment banking arm of of the large Swiss bank UBS — closed down its electricity derivatives business as early as 1999, and in the same year Merrill Lynch announced its withdrawal from over-the-counter derivatives in natural gas. (Once again, *derivatives* are paper assets such as futures and options contracts associated with physical items such as electricity and gas, which are called the *underlying*.) The decision about electricity may have been reversed later, but if so, this is a comment on the gullibility of their clients rather than a boost in the efficiency of this market.

While this was going on, a consensus of commodity traders and analysts were still willing to wager that derivatives activity in gas and electricity would take off once market liberalization achieved a *critical mass*, and as it turned out, in electricity that condition was not too long in coming, although it did not turn out to be durable: it barely lasted long enough for the most important commodities exchange in the world (NYMEX in New York City) to declare its electricity futures contract hopeless, and also to dump one of its natural gas contracts. Some of this language may sound excessively informal, however later in this book readers will find a fairly long but elementary chapter in which I attempt to examine futures and options with the help of some simple algebra.

Like oil, natural gas is a high-quality energy resource and is probably much more valuable to society than was indicated by its (exceptionally low) price at the beginning of this century. The argument here turns on its superior environmental qualities as well as the comparatively large amount that is available in Russia and the Middle East, although occasionally there is some confusion on this point. The Chairman of the Ford Motor Company, Bill Ford, is concerned about the possible shortage of conventional energy sources in the not-too-distant future, and wants his corporation to lead the way into a hydrogen economy rather than to fuel Ford vehicles with, for example, compressed gas. However, it should not be forgotten that hydrogen is a derived energy source: it is extracted from, e.g., gas, coal or water, and the energy cost of this transformation is as yet considerable. On the other hand, in the long run, given the rate of population growth, it seems almost certain that hydrogen will have to play a major role in the world energy economy. Readers desiring interesting discussions of this topic are referred to *EnergyPulse* (www.energypulse.net).

At the Third Ministerial Meeting of the Gas Exporting Countries' Forum in the Qatari capital Doha in 2003, the Emir of Qatar, Sheikh Hamad Bin Khalifa Al Thani, noted that world gas consumption was growing at rates higher than oil and coal, and the share of gas consumption in total world energy use would continue to rise. He also mentioned that the Middle East possessed about 40% of the world's gas reserves, and since the consumption of the region is low, its potential export capacity is immense. The same observation — though on a lower quantitative level — applies to Bolivia, Peru and Venezuela in South America. These are countries where domestic consumption is far under production possibilities, though the opposite disposition prevails for Argentina, and perhaps Brazil.

Among the countries identified as a very large market for gas from the Middle East was the United States. At the time that I was writing my gas book, it was almost unthinkable that the US would import large amounts of that commodity from countries on the other side of the globe; but unthinkable or not, it is in situations of this type where we see that economics is different from other academic disciplines: the quandaries imposed by uncertainty and information shortages — and in particular those due to the special nature of geology and the irrationality of some market actors — are enormous, and despite what your favorite teachers of mathematical economics may tell you, we are no closer to dealing with them today than we were a quarter of a century ago. This is one of the reasons why it is so difficult to judge the quantity and quality of the energy assets that we will have at our disposal at any given time in the future.

As an example, we can cite the reputedly huge unconventional resources of natural gas languishing in or beneath such things as coal, shale and sandstone deposits, or mixed with salt water and buried under tremendous pressure beneath the Gulf of Mexico and perhaps other bodies of water. Despite the optimism of many important economic researchers, they continue to elude energy companies that are desperate to renew their reserves. This desperation has to some extent turned to resignation, since many of these organizations are now concentrating on maintaining profit *rates* rather than expanding reserves or production. It has also become clear that the new resources that were supposed to come into existence because of gas market deregulation are as non-existent as ever. Fortunately, the failure of electric deregulation is so shocking and extensive that gas market deregulation has been held in check to some extent.

Among the observers of the gas scene who have chosen to go public with their apprehensions is the former Chairman of the US Federal Reserve, Alan Greenspan. On several occasions he has warned of possible traumatic spikes in the price of gas that could have disagreeable macroeconomic consequences. He has also said that North America will forever be condemned to a volatile and inefficient gas market unless it enjoys a guaranteed access to the vast reserves of gas located far from its borders. The same kind of opinion is undoubtedly circulating in some upscale localities about oil.

Many persons still have some difficulty in accepting that the rapid increase in the price of oil might be sustainable. However, countless managers of gas-based electricity generating installations are thinking seriously about restoring gas to its traditional place in the electricity-generating merit order.

To understand what this is all about, it is useful to recall that until the availability of very inexpensive gas and very efficient combined-cycle gas-based generating equipment, natural gas was customarily used to generate the peak load, while the base load — the load that is on the line 24 hours a day — was customarily serviced by coal, nuclear or hydro. As explained in my earlier textbook, and will be repeated in Chapter 7 of this book, the logic here turned on gas-based equipment displaying low capital costs and high variable (i.e., fuel) costs, and in addition this equipment was easy to turn on and off. What happened with the appearance of combined-cycle technology and cheap gas was the promotion of gas to generating the base load (which, among other things, meant a much larger daily input of gas). For instance, in California, a very large fraction of all new power investment in the 1990s involved fairly large gas-based installations. Somewhat earlier in the UK, the "dash for gas" was a similar spectacle.

Once again we get a glimpse into the force of uncertainty in economic theory. When gas prices suddenly increased, these gas-based facilities were often judged to be sub-optimally deployed: the base load was perceived as being generated with the wrong equipment, particularly in situations where the price of the gas being used had not been locked in by long-term contracts. As bad luck would have it, these are the kind of contracts that deregulation/liberalization was dedicated to eliminating, because according to the offbeat gospel of deregulation, they were at least partially responsible for the inefficiencies that supposedly plague the electricity and gas markets.

The electric deregulation circus got under way in Europe — in Scandinavia and the UK — while natural gas deregulation began in the US about 20 years ago, but comparatively slowly. I make no secret of the fact that I am an opponent of almost all electric and natural gas deregulation, but at the same time I am sympathetic to the natural gas buyers and others in the US who felt that the regulatory climate at the time of the "gas bubble" in that country did not correctly address either efficiency or equity concerns. What eventually happened though was that a claque of economists, consultants and various "researchers" were provided with a forum in which they could unleash a barrage of pretentious ideas for correcting what they construed as intrinsic shortcomings, while at the same time promoting a radical transformation of the entire natural-gas sector — from "wellhead" to "burner tip".

How does one treat a collection of misunderstandings and blunders of the magnitude and extent involved here? In the courses on energy economics that I taught in Sweden and France, and in my previous textbook, I did not treat them at all, because unlike the deceptive electric deregulation circus, gas deregulation has not been able to get up full steam. Hopefully this will continue to be the case.

One of the reasons for this was that in the US, and perhaps elsewhere, some important politicians and industry people and genuine experts from the academic world took issue with gas deregulation proposals. For instance, when Professors Arthur DeVany and W. David Walls claimed that the natural gas market in the US was informationally efficient — in the sense that spot gas prices at widely separate points follow each other so closely that it is possible to conclude that these points are in *one* market — their conclusion was disputed by John Herbert and Erik Krell of no less than the US Energy Information Administration, which is an establishment that would like nothing better than to turn the assertions by DeVany and Walls into a holy writ. Instead, Herbert and Krell (1996) found it necessary to state that "it is not clear why they make the claim that the price paid by gas customers is the same, adjusted for a constant basis differential, for all gas markets. Moreover, they do not address some key issues and problems in the operation of gas markets".

It may not be clear to those two researchers, but it is clear to me. DeVany and Walls had an agenda to sell, although to my way of thinking, instead of writing a book, they should have settled for a video clip. How, for example, should we interpret the following statement? "The good news is that the futures market is alive and well, and its price discovery mechanism is reliable and unbiased". If that were true it would indeed be something to shout about; however, in reality, the gas futures market in the US is desperately unwell. Moreover, if a former CEO of British Gas was correct in his contention that the "half-baked fracturing" of the gas markets in order to bring about competition is essentially counter-productive, then a gas futures market is greatly diminished in status, and should expect to eventually be reduced to considerably less than its originally conceived magnitude.

As interesting as various misunderstandings about derivatives markets are for me as a teacher of finance, they are paltry in comparison to uncertainties created by the transition from what DeVany and Walls call "planning" to what they interpret as the "freedom" of spot markets. As far as I am concerned, large and complex gas systems operating in a climate of uncertainty are most efficiently run on an integrated basis that emphasizes long-term contracting. This kind of arrangement promotes optimally dimensioned installations, although this may not have received enough emphasis in your economics textbook.

If pipeline-compressor processing systems which fully exploit increasing returns to scale in order to obtain minimum costs are to be financed and constructed, then — as I interpret the evidence — the kind of uncertainties associated with short- to medium-term sales arrangements should be kept to a minimum as much as possible. Failing to do so could cause a reduction in physical investment, and in the long run higher rather than lower prices. It was the proposed shift from bilateral transactions to spot markets that contributed to what I call *deregulatory uncertainty*, and a possible shortage in local (generator) capacity in California and Alberta (Canada).

In Europe, the EU Commission first mandated the completion of gas market restructuring by 2005. While I can imagine that they were serious when they concocted this pipedream, I would be very surprised if they believe any longer that restructuring can be taken any farther than liberalization, by which they mean that anyone, anywhere, should be able to buy anything that they can afford; and if this "anything" is not for sale, then the rules should be changed so that it could be put on the block if the price is "right". The rest of the restructuring package — bringing into existence what they originally announced would be the kind of "gas-to-gas" competition that is supposed to provide consumers with huge savings — will have to wait, and probably indefinitely. One of the reasons for this is almost certainly a morale problem in the deregulation booster club due to the widespread failure of electric deregulation, but another is the negative attitudes displayed by high-profile industrialists and their experts, and lately some influential politicians.

An example of the experts is Mr Ron Hopper, who was with the US government's Federal Energy Regulatory Commission (FERC) for 11 years, and as a private consultant was an advisor to the EU Energy Commissioner, and also OFGAS (in the UK). Hopper calls himself a strong believer in deregulation, but even so he said that "It is difficult for me to see the potential for pipeline-to-pipeline competition".

I am sure that it is difficult, because he knows as well as I do — and most likely much better — that "looping" and/or increasing compression is often a viable alternative to constructing the new pipelines that deregulation might entail, unless large increases in demand are anticipated. Hopper has also pointed out on several occasions that there can be considerable difficulty in obtaining rights-of-way.

I would be very surprised if Mr Hopper failed to share some of his knowledge of the trials and tribulations of FERC with his EU employers. If so, I hope that he remembered to tell them about a very odd claim by FERC that it had prepared an extensive economic analysis detailing the benefits that would accrue to the national economy in general and gas consumers in particular, if the natural gas sector was restructured. That "claim" led to FERC being sued by Citizen Action — a US consumer organization — and eventually "deciding" to assert that no comprehensive analysis had taken place. This raises an important question: why had there *not* been an in-depth study by FERC's economists or outside consultants? The answer to that must be that there almost certainly had been — it could not have been avoided; and perhaps it was carried out by someone as competent as Ron Hopper.

Assuming that such was the case, then what that unacknowledged study had to reveal was that local distribution companies and consumers would be forced to pay the billions of dollars in transition costs that would be involved in going from regulation to re-regulation. Note: *not* in going from regulation to deregulation, but in going to a different brand of regulation. Incidentally, this is exactly what happened. Consumers and distribution companies (i.e., utilities) *were* burdened with higher costs, *and* found themselves assuming more of the price risk that accompanied the various changes that were made. One of the reasons why things turned out this way is because, according to the deregulators, consumers and distributors were going to be big winners due to the changes being made — though perhaps later rather than sooner. Incidentally, the matter of reliability was simply overlooked, although as *Forbes* (22 January 2001) intimated, deregulation has "whittled away" at the guarantee that many gas users had of a secure gas supply, since, e.g., pipeline companies no longer had the incentive to resort to as much expensive underground gas storage as before, nor to use long-term contracts (with producers) to the same extent.

Edward Feigenbaum, the "inventor" of artificial intelligence, based his work on the belief that human intelligence does not spring from rules of logic, but from knowledge about specific problems, and about the world in general. This may well be so; however, the high-spirited promotion of twisted logic is far from irrelevant for anyone having to deal with the supply side of a market like the gas market. If a conclusion needs to be offered about the deregulation of gas (and electricity), I can only say that what it reduces to is an irrational novelty.

A few years ago, the price of natural gas in the United States averaged \$2.2/mBtu, and there were some rumours that it might eventually climb to \$4/mBtu. Since almost half of all US homes are heated by gas, this information was looked upon with some apprehension. What happened in early 2003, however, changed apprehension to alarm, because prices suddenly leaped to \$6/mBtu, and that was only the beginning — although later they "descended" to about \$6/mBtu.

By the end of 2005, gas prices had more than doubled, and the CEO of Dow Chemical told a Senate committee on 6 October that the United States was in a "natural gas crisis". He and his executives gave some indication of what they thought about all this by closing what they called 26 "inefficient" plants in North America and moving them to places where they considered gas to be plentiful (and cheap), which included Kuwait and Argentina. According to *Forbes* (21 October 2005), CEO Andrew Liveris asked the Senate, "How can I recommend investing here?" in the course of attempting to explain why, on that occasion, the global chemical industry had 120 projects under way, with only one in the United States. Among the places where Dow launched joint ventures were Oman and Qatar, where gas was selling for less than a dollar per million Btu.

As implied earlier, the economics taught in Econ 101 will not help serious readers to fully understand the short-run pricing of crude oil, and the same is true where the pricing of natural gas is concerned in, e.g., North America. Once again the availability of gas inventories (stocks) is crucial, and the logic here is about the same as that for oil, which will be taken up at some length in Chapter 2.

In the autumn of 2005 it was estimated that an exceptionally cold winter could reduce stocks of gas in the United States to 500 billion ft^3, which was not a great deal in excess of the amount of gas a pipeline system must have to maintain pressure. Had this happened, a sharp price escalation might have resulted, but fortunately the following winter turned out to be comparatively mild, which also helps to explain the slight decreases in oil and gas prices. The upshot of this is that weather is important for understanding oil and gas prices.

Liquefied natural gas (LNG) from every part of the world is looking increasingly attractive to the United States at the present time, although like the young person across the dance floor, it is impossible to be completely sure of its charms. Price is just one part of the puzzle here, because things like explosions and fireballs are often referred to when discussing the location of LNG terminals. This is perhaps the best place to refer you to an article recently published in *EnergyPulse* by Tam Hunt (2006), and particularly the brilliant comments/discussions on that article published immediately below it. Hunt discusses a few of the arguments against introducing more LNG into California, but it so happens that in this matter the energy consumers of California will have the last say, and they will almost certainly conclude that they cannot do without more gas.

Some statistics might be in order. IEA estimates are that in 2010, (conventional) gas consumption will be 3.2 trillion cubic meters per year ($= 3.2\,Tm^3/y$), as compared with the present $2.5\,Tm^3/y$; and in 2020 forecast demand will be $4.4\,Tm^3/y$. As for reserves, the amount already produced is $60\,Tm^3$, while *proved* (i.e., remaining) reserves are about $140\,Tm^3$. The estimated amount that is still to be found is $60–120\,Tm^3$. *Ultimate* reserves are thus $260–320\,Tm^3$. This may or may not be the actual situation, but readers should get used to seeing and working with this kind of terminology.

Coal will not be taken up in this introductory survey, but this might be the place to mention integrated coal gasification combined cycle (IGCC) technology. What we have here is the gasification of coal which, after processing, is transmitted to a combined cycle power plant. One of the things making this special is that the intention is to remove CO_2 from the coal during the syngas conversion process and store (i.e., sequester) it in underground geologic formations. Some of this is probably being done now, and more will be done later, but in terms of solving the excessive CO_2 problem, it is strictly provisional.

7. A Nuclear Energy Tale

I think it safe to say that while every researcher has his or her private idea of what constitutes success, an intense desire to avoid falling out of favor with the decision makers is something that most of them have in common. This is why in Sweden where, although almost half of the domestic supply of electricity originates in the nuclear sector, there are few economists who take an active part in the nuclear debate. It has been made clear to these ladies and gentlemen that the exposure they prize above all other things in their professional lives will be in the danger zone if they become too friendly toward the "friendly atom".

To get some idea of how this matter is viewed in the "land of the midnight sun", it is useful to know that every year, in conjunction with the awarding of the Nobel prizes, the new laureates participate in a TV program called *Snillen Specularar* (Genius Speculates), where they discuss various scientific topics that supposedly are of interest to a broad audience. In reality, a large part of this "broad audience" that the program hopes to reach would rather have these matters discussed by Sir Elton or Madonna, which is one reason why only a relatively few of them — including academic economists — are sitting in front of their TVs when this distinctive intellectual event takes place.

A few years ago the dominant voice among the laureates was that of the physicist Robert Laughlin, who at one stage of the discussion expressed outrage that in Sweden, scientists who receive their salaries from the government are discouraged from discussing nuclear matters in a serious (i.e., technical) fashion, just as they are prevented by law from participating in organized nuclear research. Of course, if they had conclusive proof in one form or another of the economic and/or technical shortcomings of nuclear energy, then it is likely that they would be warmly welcomed to the corridors and restaurants of government power. However, as many of us are aware, such proof is difficult to acquire.

Social Democratic governments in both Sweden and Germany have now announced that they intend to dismantle their nuclear sectors, although they were deliberately vague about the time frame. As noted earlier, behind this flagrant irrationality are the small but vocally active and politically important environmentalist parties: in Sweden, acceptance of an eventual nuclear retreat is still part of the price that must be paid by the Social Democrats for the political cooperation of the Green party, although in Germany — now that the Social Democrats have entered into a coalition with the Christian Democrats — they may be in a position to alter their anti-nuclear stance. Another part of the price is having to keep a straight face while entertaining the absurd theories that are often launched about things like the economic feasibility of "green electricity", which is an idea whose realization beyond a minor extent is highly unlikely in either Sweden or Germany in the near future.

As already noted, wind power plays an important part in the Danish energy mix because of subsidies, guaranteed access to the wholesale energy market and, especially, the high cost of energy in Denmark — which to a certain extent results from nuclear abstention and a reliance on coal. Similarly, across the Baltic in Germany, it appears that a large part of the present wind power capacity can be attributed to large subsidies. In fact, many of the production costs associated with the so-called *economical* large-scale wind installations in the world are subsidized in one way or another. The claim that we hear quite often these days is that new technologies will soon enable substantial *amounts* of "competitive" power to be produced from wind installations, and therefore subsidies will be unnecessary; however, even if this turns out to be true — which is definitely possible — it will only change the power supply picture marginally, because the "large amounts" that are mooted are not really large at all, given total power demand.

It appears that approximately 70% of the global output of wind power can be attributed to Europe, almost 20% to North America, and about 10% to the Asia-Pacific region. Wind-generating capacity is still growing at a higher rate than any other energy source, but it is not certain that this can continue. The total power generated by one of these installations is a function of wind speed cubed, and as a brief calculation will show, there is a world of difference between Patagonia with its near-steady 40 km/h airstream, and the supposedly wind-favored North Europe with its 27 km/h gusts. There is also the matter of the low *capacity factor* of wind turbines: as any wind surfer will tell you, there are days when there is practically no wind. The operative word is *intermitancy*!

Sweden and Norway are generally credited with having the most inexpensive electricity in the world in terms of cost, but there is an important difference. Norway's electricity is about 95% hydro-based, while Sweden's is approximately 43% nuclear-based, with most of the remainder being hydro, which is generally considered the most inexpensive power. The closeness of the cost of electricity in these two countries should make it clear that electricity produced in *best practice* nuclear facilities is more economical than that produced in fossil fuel installations, regardless of what you may have heard or read about the inexpensiveness of electricity generated from coal or natural gas; and this is even more true at the present time than it was in the past because the nominal "life" of high-quality nuclear plants have been extended to more than 60 years, as compared to the estimated 40 years that was common in the not-too-distant past, and I see no reason why the "life" of new plants cannot be longer. The reason for the lower cost is discussed in Chapter 7 of this book using the annuity formula.

Of course, there is no getting away from the fact that when I say that best practice nuclear power is less costly than fossil fuels and renewables, I am assuming that the scientific establishment is correct when they claim that nuclear "waste" can be safely warehoused over the indefinite future, and more importantly, new reactors are on the drawing board that produce much less waste. What I would like to hear though is that this "waste" will someday be taken out of storage, and the energy in it exploited. In other words, that the nuclear cycle will be "closed" in that waste will be continuously reprocessed until there is almost no extractable energy left in it. In these circumstances, its radioactivity might be reduced to a near trivial amount.

Clearly, a large part of the TV audience seems to exhibit a curious nonchalance about this issue, even though it happens to be extremely importantly for their daily lives. There is also an unrealistic approach to global warming, even though several of the largest reinsurers in the world (e.g., Munich Re and Swiss Re) appear convinced that climate change could bring about a substantial escalation in the number of natural catastrophes in the *present* decade, as well as continuing to pose over the indefinite future a mounting threat to the most populated regions of the globe. [According to McKibben (2001), the insurance industry has seen its payouts increase from about two billion dollars annually in the 1980s, to an average of 30 billion dollars annually between 1990 and 1995.] Much less attention seems to be paid to this nearby menace than the possibility that something could go wrong a thousand years from now in some remote underground storage site for nuclear waste — by which time it is very likely that science and competent governments will be well prepared to do what has to be done to eliminate threats by this waste to life and property.

Although there is no genuine evidence that science and technology is capable of greatly changing the demand or supply for world oil except in the fairly long run, it seems almost certain that safe reactors of virtually any size can eventually be built (employing, e.g., the "pebble-bed" technology). In fact, they could be built in Sweden in the not-too-distant future if many persons in this country adopted a less resentful attitude toward the scientists and technologists who have been instrumental in providing them with one of the highest standards of living in the world, and an even higher quality of life. As for nuclear waste, it may someday be possible to construct reactors (based perhaps on some variant of the Accelerator-Driven Transmutations-Technique technology) that consume so much of their uranium input that there is little or no residue; but even if there were no such things as absolutely safe reactors and it was extremely expensive to safely store "spent" uranium, there is still the matter of global warming.

Consider the situation in France, which around the turn of the century generated between 70% and 80% of its electricity in nuclear installations. According to Dr Hans Blix, the former director general of the International Atomic Energy Agency (and once a Swedish foreign minister), the emissions of CO_2/kWh (of electricity generated in that country) are about 64 g, while in the UK, which employs an energy mix of coal, gas and a small amount of nuclear energy, the CO_2 emissions are 10 times as large. It deserves to be noted that in Sweden the emission of CO_2/kWh of electricity generated is 59 g, while in Denmark the figure is about 920 g. The reader should take this into account when he or she hears about the resounding success of wind-generated electricity in that country. Dr Blix also noted that on a global basis, nuclear power helped to avoid the emission of some 700 million tonnes of CO_2 per year.

At the present time, there are 441 reactors in operation globally. There are, however, a number under construction, and most of these are in Asia. World energy demand is expected to rise by about 2%/year (net), and according to the IEA, developing countries are expected to account for two-thirds of this, with carbon emissions rising even faster than overall energy demand. If this is true, then instead of opposing nuclear energy, environmental movements should commence working immediately to convince all governments and international organizations that they should be preparing a crash-program to construct a great deal more as soon as large-scale versions of "safe" equipment (such as "pebble bed" or the Swedish PIUS and SECURE designs) have been perfected. Surely it must have occurred to them that if the water should ever start rising on Canal Street in Amsterdam or the Reeperbahn in Hamburg, then the good residents of those cities would have about the same chance of reversing the situation as King Canute had when he ordered the tide out.

Given my expectations for natural gas prices, I consider best practice nuclear plants indisputably more economical as combined cycle gas plants (which many observers think the most competitive on a unit cost basis). But even so, at least some of the new facilities that will be making an appearance soon will be even more cost-effective. As for nuclear waste disposal and/or reuse, the open or once-through nuclear fuel cycle employed in most countries can possibly be improved without introducing radical new arrangements. In one proposed scheme, used fuel is recycled to recover uranium and plutonium, after which it is transformed into new fuel using a process called PUREX (i.e., plutonium uranium extraction). This activity is capable of doubling the amount of energy recovered from the fuel, in addition to removing a large part of the long-lived radioactive elements from waste that might have to be permanently stored.

This might be the place to point out that the deregulation crusade moved into high gear when, in the United States, a number of important persons, with the support of the business press, came to the conclusion that the demand for power had ceased to expand, and instead of building more and/or larger power plants, a change in the structure of the electric industry was in order. Implicitly, that change meant an end to the construction of nuclear installations.

At the same time that I advance the above opinions, let me assure all readers that I know — just as they would know if they thought about it — that the opposition to nuclear energy by many members of the anti-nuclear brigades has nothing to do with nuclear safety. What it involves is an almost pathological opposition to scientific and industrial progress, because — many of these people feel — this progress has had or will have a negative influence on their lives. There is a similar attitude toward globalization by many of the same individuals — which I happen to share — but I find it difficult to justify the anti-nuclear scenario. Bringing into existence the kind of alternative, high-quality society that many anti-nuclearites might find attractive could require more rather than less energy. Large amounts of electricity will almost certainly be required for such things as the optimal employment of computers, robots that will improve the quality of manufactured goods, faster and more efficient electric trains, and other means of transport that will increase the attractiveness of ground-level collective travel arrangements, etc. And something that everyone seems to have overlooked is that enormous quantities of dependable power may be necessary to transform biological and other resources to motor fuels, to include providing the electricity needed to produce hydrogen (from, e.g., electrolysis) for use in, e.g., fuel-cell and other applications.

In my lectures I sometimes cite a few examples about things like nuclear and electric deregulation. This might be unnecessary, however, because these examples are everywhere, and it is hardly possible to avoid them. If we take for instance Progress Energy Florida (PEF) at the present time, they have calculated that each megawatt (MW) of power serves 615 homes, and so increasing the gross output of their nuclear facility from 900 MW to 1080 MW will allow an additional 110,700 homes to be served. In addition, they claim that nuclear is now the most cost-effective way to generate electricity, and this increase in capacity is the best way to manage rising fuel costs. The project is expected to cost $382 million, which includes potential transmission-system improvements.

By way of contrast, in Texas the operators of the power grid are proposing to deal with a lack of capacity by a service-interruption system for commercial users. In that state, increased gas prices have caused the utility industry to stop building new gas-fired plant, and instead much more coal will be used. Wind is also very popular in Texas, and as a result we constantly hear about the miracles that will be forthcoming from wind-generated electric facilities. This sounds good, but it happens that together with a stagnation in total investment, this ongoing change in the pattern of generation should ensure that Texas consumers in all categories face higher electricity prices. So much for another purported electric deregulation success story.

8. Kyoto and Its Discontents

According to David Victor (2001), the Kyoto Protocol was 10 years in the making and has become a symbol of the world's resolve to address the problem of global warming (or, as it is sometimes called, the greenhouse effect). It was signed for the United States by Vice President Al Gore in 1997, but only three years later the new president, George W. Bush, decided that the United States could not implement the protocol as it stood because it might place too great an economic burden on his country. The US Senate went along with this by voting 95–0 against having to consider a treaty that ostensibly could damage the US economy. President Bush also had some reservations about becoming a party to an agreement that exempted 80% of the world from compliance for economic reasons. As pointed out earlier, he has been forced to recant to a certain extent, because his rich allies are visibly annoyed about being informed that what may turn out to be the greatest threat to Earth's physical stability in human history should be played down unless the poorest countries in the world also picked up a part of the bill for doing something about it. Note the phrasing here: "what *may* turn out to be the greatest threat …". In other words, it is not completely certain, and this lack of certainty has led to some bad feeling and animosity in the scientific community, as well as elsewhere.

The greenhouse effect has to do with the trapping of heat by certain gases in the atmosphere — often referred to as "greenhouse gases" — and this phenomenon is not, in itself, a dangerous thing. On the contrary, this process is essential for most life on earth, since the trapped heat keeps the earth's temperature warmer than it would be otherwise. What may be happening, however, is that the amount of heat being trapped is excessive, and at the bottom of this unfavorable development we find human (or *anthropogenic*) activities instead of some climatic pattern that is independent of what is, or has been, taking place on earth.

According to the Inter-governmental Panel on Climate Change (IPCC), which includes most of the world's leading climate scientists, it has been suggested that during the present century the earth could warm up by between 1.4°C and 5.8°C, with the median rise working out to an alarming 2.5°C. Almost all of the living Nobel laureates who commit themselves on this matter accept these figures to one extent or another, although a small group of "experts" — most of whom are self-appointed — dispute whether the earth has warmed at all and, if so, whether human activities are responsible.

Let me say here, however, that it should not make the slightest difference whether these figures are correct or not, nor whether these Nobel laureates were sober or tipsy when they expressed their belief in anthropogenic-based global warming (or AGW as it is sometimes called in the literature). Nobel laureates and the cream of climatologists are preferable to the crank chorus working the other side of the street.

These opponents of global warming will not find it easy to promote their convictions, because almost all the leading business periodicals in the world have now published long articles emphasizing that the greenhouse effect is very likely a great deal more than upscale science fiction. In addition, in the United States, the Pew Center on Global Climate Change has a large and growing number of corporate members on its rolls at the present time, to include important firms like DuPont, IBM and United Technologies, and in the US Congress bipartisan bills have been introduced in both the Senate and the House to regulate CO_2 — even if these ladies and gentlemen have come to the conclusion that the Kyoto Protocol, in its present condition, is not worthy of their full attention. "Congress is not going to sit back, if you will, and fiddle while the planet warms", Senator Lieberman informed his president. I think that we can rely on this, especially since sitting back could cost many hardworking congressmen and congresswomen the votes that they might need to continue their political careers. Even the president got that message in a relatively short time, and it is useful to note that his father, when occupying the same office, signed the Framework Convention on Climate Change, which was the treaty that launched the process that led to Kyoto.

An unpopular opinion I occasionally express is that the US government has always been a key player in formulating a global agenda for curbing global warming, and remains one at the present time. This makes sense to me because if something does go wrong, the rich have more to lose than the poor. The people who have caused the trouble are not the hard-line anti-warming legislators in Congress, or business persons, or employees of some of the conservative "think-tanks", but various jet-setting environmentalists and pseudo-environmentalists whose principal concern is not with global warming but with what, for lack of a more appropriate euphemism, I will call their careers. During my long "tour" at the Palais des Nations (in Geneva, Switzerland) I encountered a large number of these careerists, and it is in remembering their various professional defects that I became convinced that it is only through inter-governmental cooperation at the very highest level that the threat of global warming can be adequately dealt with.

But until the time when the leaders of the most important nations meet annually for the specific purpose of examining the state of the global environment, much more is going to be required from Washington than upholding, rejecting or becoming embroiled in senseless debates over controversial policy overtures. First and foremost, a systematic attempt should be made to appreciate the inadequacy of the main proposals forwarded at Kyoto and related palavers, and then putting together and advertising widely some "obviously" superior propositions. What we saw at the elephantine talk shops like Kyoto and Rio were what President Bill Clinton called "the world's most serious environmental problem" disposed of in an abstract (though upbeat) manner that might have been appropriate for dealing with an increased growth of tumbleweed near the Bay of Fundy, but did not really have much to do with ugly events that might cause countless trillions of dollars of economic damage before the new year's eve parties begin in 2099.

In the light of all the misevaluations of the Kyoto exercise, I regard the short article by Victor mentioned previously an important exposition, and the same is true of a later paper by Ruth G. Bell (2006). After perusing the work of Dr Bell on emissions trading, I immediately remembered a communication from an economist working on global warming. According to him, emissions trading has been shown to be viable both theoretically and empirically. In reality, of course, this is not a correct statement. Most high-level conferences are distinguished by the absence of claims to this effect, because economists who say that they have crafted believable arguments as to the efficacy of emissions trading generally have no desire to confront a competent audience with their pseudo-scientific conclusions.

Most of the opponents of global warming believe that there is no trouble ahead, and so they will not — as in the great Fred Astaire song from *The Fleet's In* — have to "face the music and dance"; but even those people are capable of understanding that if things should go wrong, non-linear and self-reinforcing processes could be set off whose complex mechanisms would make it impossible to avoid some extremely distasteful outcomes — even if the output of all greenhouse gases were immediately eliminated. This might also be the place to mention what I call The Tyranny of Small Differences: the fact that many extremely bad things happen so slowly that they cannot be detected, but even so might eventually add up to deep trouble for a large number of unlucky citizens who find themselves in the wrong place when the water starts rising or hot-spells increase in both average length *and* intensity.

In my article in *Energy Sources* (2000), I attempted to point out that the problem with global warming involves stocks rather than flows: specifically, the growing stock of CO_2 in the atmosphere. *The Economist* (7 April 2001) has drawn the conclusion that because most greenhouse gases are long-lived, can remain in the atmosphere for a century or longer, and regardless of their origin can make their combined effect felt around the globe, restrictions — or "strict caps" — make little sense in the short-term since they involve flows.

Since there is a simple algebraic relationship between stocks and flows, it might be argued that, at the alpine heights of pure theory (where annoyances like long time horizons and political considerations are ignored), "caps" make all the sense in the world. However, *The Economist* (and what they call "like-minded boffins") are correct in suggesting that Kyoto should be amended to ensure that — since reducing the stock of pollution is a very long-term project — the economic burden of compliance is both stable and supportable in the long as well as the short run, in that the sacrifices that are made at any given point in time in reducing (or mitigating the increase in) the *total* stock of pollution are not in vain because later some newly elected, near-sighted governments, decide that sacrifices made by previous governments were a waste of time. And, in fact, they might appear to be a waste of time to even far-sighted governments, because locally — due to the non-linear dynamics of greenhouse gases — very precise measurements taken over a fairly long period might unexpectedly give the impression that the worst possible outcomes of global warming are progressively decreasing in likelihood. Personally, I cannot see how this dilemma can be handled unless those persons who genuinely want something done about global warming are prepared to be more rational about nuclear energy.

By selectively expanding — rather than contracting — the global nuclear sector; and by taking greater advantage of government cooperation in the research and development activities of the transportation industries, where greatly increased fuel efficiencies are now almost within reach, time could be bought which conceivably could eventually allow greenhouse gas emissions to be reduced by the balanced introduction of superior technologies, with an emphasis on renewables. In addition, it might be possible to get precise answers to some of the questions that have been raised by climate warming sceptics, which apparently include some very heavy players in Washington, DC.

Let me add that jamborees such as those held at Rio and Kyoto detract from the challenge posed by financing and organizing these measures, because they give the impression that significant progress is, or will soon be, made in reducing environmental hazards if they can get the right signatures on this-or-that document. Hardly anywhere do we see the opinion of observers like the past chairman of the IPCC that if we do not go far beyond what was achieved at Kyoto, atmospheric greenhouse gases will continue to increase in the next decade exactly as they have in the past 20 years. I am tempted to say that this is something we want to avoid at all costs, but I will refrain because I doubt whether the people who are organizing the next environmental talk shop are really interested in hearing how little they have achieved in the past.

At the Kyoto meeting, it was decided that emissions trading was to be the core of the pollutions suppression system. In the paper by Victor referred to previously, he says that an emissions trading system is like a unicycle with rusty bearings. It is worse than that, because it opens the door for the same kind of greed and incompetence that preceded rolling blackouts in California. Apparently, the United Nations Conference on Trade and Development (UNCTAD) was scheduled to set up a unit for the formulation of an international emissions trading scheme, and its director once declared that the details of a practical trading mechanism will be easy to work out. I was glad to hear that, but when I was informed that he expressed confidence that the scheme will be operative by 2008, I knew that this project was hopeless.

The thing to remember here is that although in theory — and perhaps in practice — tradable emission permits might be the best method for dealing with *domestic* atmospheric pollution; this may not be true if we are thinking in terms of the real *international* world, where psychopathic greed, corruption and incompetence are commonplace. I personally see no reason for establishing a cross-border program for dealing with global warming in which these highly undesirable qualities are given a new outlet. Before tens of billions of dollars in highly *fungible* vouchers are passed out, I would like to be certain that they will not be misused. (An asset is said to be fungible when it is freely changeable into another asset. Money is most fungible.)

9. "The Financialization of Energy"

"The financialization of energy" is an expression employed by *Business Week* (12 February 2001) in a long and surprisingly non-partisan article whose purpose was to review the adventures of the Enron Corporation in the great world of electricity deregulation, as well as that firm's involvement with a few less controversial activities. Enron, which was once the seventh largest firm in the United States, has been a persistent and loud cheerleader in the deregulation sweepstakes (for the usual self-serving financial reasons); however, it did *not* pioneer the financialization of energy, as claimed by *Business Week*. This was mostly done by establishments such as the New York Mercantile Exchange (NYMEX) who were responsible for organizing "the best game in town", as the trading of oil futures and options was once called. Readers of this book will find a long elementary exposition of futures and options in Chapter 8, but unfortunately that topic is too out of the ordinary and too important to be introduced at this time, even though it is not intrinsically difficult.

One of the main reasons why I like *Business Week's* presentation is their citing a statement by Mr Douglas Heller, consumer advocate with the Foundation for Taxpayer and Consumer Rights in Santa Monica, California. According to Mr Heller, "Electricity is not a commodity fit for the competitive marketplace. Private investors do not have public safety in mind". He is not the only one whose thoughts move along those lines. Loic Caperan of EdF once remarked: "Electricity is a national asset as well as a right, and is strongly linked to human development and well-being". Please note that the basic issue here is not ownership but abundance: it is providing consumers with the electricity they require at prices they can afford.

Mr Heller's statement is not completely accurate, but it is a good beginning of a necessary debate. That gentleman also advocated a referendum which would result in the government of California buying enough of the California power-system to prevent a repetition of the kind of bizarre energy dilemma to which Californians found themselves exposed several years ago. I favor such a referendum too, and if it took place I might be tempted to move to California once again in order to give my modest support to any and all legislation aimed at liquidating those deregulation remnants that might have survived the great meltdown.

A distinguished foolishness put into widespread circulation was that the form of ownership of a firm was *always* crucial in determining its efficiency, and private enterprise was *always* superior to public enterprise. For instance, according to Jeffrey K. Skilling, when he became one of the kingpins at Enron, the (electric and gas) utilities were "incredibly expensive and provided horrible service to their customers". This was undoubtedly true in a number of cases, but absolutely and totally false in many others. Accordingly, if we employ the logic of neo-classical economics, we can immediately suggest that even in a world of ironbound regulation, it is possible for the managers of utilities to be as smart and effective as the ladies and gentlemen commanded by Mr Skilling, and possibly as *gung ho* as Mr Skilling himself.

Incidentally, most unbiased observers are of the opinion that, on the whole, the electric sector in the United States has generally provided excellent service at a reasonable price. A good example here would be the Southern Company, which is the largest US investor-owned regulated utility, and which dominates electricity supply in Georgia and Alabama as well as owning facilities in Mississippi and Florida, and appears to be on its way to becoming a major player outside the United States. When this was being written, Southern's customers paid 20% less for their power than the US average, and this highly innovative and profitable company regularly finds itself in the top five in the country in customer satisfaction surveys. On the other hand, William Pfaff (in the *Herald Tribune*, 22 February 2001) maintained that "the privatization of public utilities can be a disaster" (i.e., could *turn out* to be a disaster). It may certainly be a misfortune for persons buying electricity from Southern, because as the chairman of the Georgia Public Service Commission, Mr Stan Wise, has pointed out, "Any potential national benefit of deregulation would come at a cost to states such as ours".

This discussion could go on indefinitely, but I think it useful to note that a high-ranking insider in the UK academic world, Professor John Kay, has concluded that the case for renationalizing British Rail (which became *Railtrack*) is "compelling", because in his opinion the competence of the deregulated management was less than gratifying. In addition, after mulling over some economic theory, the bad news from California and New Zealand and the collapse of Enron, he suggests that deregulated electric sectors should be at least partially re-regulated. This is worth noticing because being an insider, he must know that thanks to Enron's presence in energy trading, the UK's electric distribution firms could have experienced a California-like shock. According to Will Hutton in the *Observer* (13 January 2002), it took some arm-twisting by the regulatory body OFGEM to keep the UK lights on. Hutton also says that "smart and effective regulation is the handmaiden of well-run markets that serve the public interest", by which he means markets for *necessities*.

One of the things that I tried to do in my international finance textbook (2001) was to convince readers that financial economics is a fascinating and important subject. "The physics of economics" is my favorite way of describing it, although finance is much easier to understand than physics — despite the grotesque attempts of some finance teachers to convince students of the opposite.

When the UK government passed the Electricity Act in 1989, its three stated goals were to introduce full competition, reduce prices, and open up price and risk management opportunities. The risk management scene, they hoped, would eventually be dominated by exchange traded *futures contracts*, since these could (in theory) generate the visible *scarcity* or *efficiency* prices that we present to our students as being the key to obtaining an optimal allocation of resources in a market economy. The same goals were adopted in Norway. The problem with this ivory-tower vision of the electric market is that when storage is impossible, something called *basis risk* [which causes physical and/or paper (i.e., *futures*) prices to move in an undesirable direction] could be enormous. Thus, unlike the situation with many other commodities and financial assets, transactors can never be sure that futures will provide a "low cost" reliable hedge against price risk most of the time. (Note: *most*, and not *always*.)

At the *Scuola Enrico Mattei*'s Forum on deregulation, I insisted that electric futures trading has been a huge disappointment, despite what sponsors of this trading claim. (The main source of difficulty is a shortage of liquidity. Transactors are constantly disadvantaged in this market, and in the long run they take their money and naiveté elsewhere.) NYMEX is easily the most important commodity exchange in the world, but even so their recent failures include a "natural gas basis contract" and — according to the *Financial Times* (13 July 2001), — "the much hyped electric contract". Much hyped and later delisted to be exact, but almost certain destined to return in one form or another, and if not at NYMEX then at one of its clones somewhere in the world. As a certain, Mr Meyer Lansky pointed out that when he was involved with the operation of dice tables and roulette wheels from Las Vegas to Havana; "The winners are those who control the game. The professionals. All the rest are losers". This being the case, there will always be establishments where the winners roll out lush red carpets for potential losers, and in terms of the financial turnover per employee, those casinos where electricity is traded are beautiful examples.

"Much hyped" is a good expression. It has been noted that on the German exchanges paper contracts are only 2–3% of physical transactions, while on NordPool that figure is 25%. This is supposed to mean that NordPool is a success. However, if we look at a really successful futures contract, such as oil futures in New York or London, we see that paper transactions can amount to as much as four or five times physical transactions. It is only when we have multiples on this order that we can be reasonably certain there is sufficient trading on an exchange to generate the kind of liquidity that is necessary to provide efficient hedging (= price insurance).

Similarly, the very high volatility that is an important cause of excessive basis risk for futures would mean very expensive options. (This contention can be immediately verified by readers who are familiar with the Black–Scholes option pricing formula.) That leaves us with contracts for differences (CFDs) — which are analogous to swaps. CFDs are ubiquitous, and possibly the most important component of the financial side of the electricity scene in the United Kingdom and elsewhere, but they do not provide the price transparency so fondly spoken of by many teachers of economics and finance. In addition, there have been suggestions that the price benchmarks used to settle many contracts can be manipulated. I think that a version of Murphy's Law might be appropriate here: if they *can* be manipulated, they *will* be manipulated. The upshot of all this is that without a fully credible and flexible (financial) mechanism for hedging highly volatile prices, the efficacy of electric deregulation has not even been established on the most elementary theoretical level, and the expression financialization is to some extent a misnomer if applied to the electric market.

The wonders that financial instruments are supposed to work with electricity, but in reality have not worked, are occasionally mentioned in regard to "global warming" or the "greenhouse effect", where the large-scale trading of emission permits — the major market-based alternative to taxes — has been envisaged as having a key role to play in the strategy to reduce the output of CO_2 to acceptable levels. As already mentioned, researchers like Bell and Victor do not believe that these devices are useful in an international setting. Neither did one of the advisors to President Vladimir Putin of Russia. His comment was that emissions trading was about money and not the environment. This impression cannot be examined in detail here, but discussions of the future trading possibilities of these permits are constantly turning up in the more down-to-earth financial literature (e.g., *Risk* magazine), with most of these discussions focusing on the short-run financial gains that emissions trading should make possible for brokers, traders and various "intermediaries".

In my paper "The Kyoto Negotiations on Climate Change: An Economic Perspective" (*Energy Sources*, July 2000), I offer the following assessment: "Measurement and verification problems would be virtually insuperable, although even legally binding goals cannot be attained if implementation is unverifiable. There will also be information shortages that will prevent the formation of the 'scarcity' (i.e., efficiency or competitive) prices that certain theoreticians believe will allow pollution to be shifted back and forth like pizzas in a neoclassical pasta emporium, where management always stands ready to repurchase the piece of crust that you did not eat, in order to sell it to some less fortunate customer". I can add that there would be high transactions costs, biased price signals, and worst of all, cheating and irrational behavior by rogue polluters/states that cannot be easily held accountable for their bad conduct, etc.

A number of economists have worked on issues associated with emissions trading for many years, and they have achieved exactly nothing: most of the work that they have published in the theoretical journals does not apply to the real world. One reason for this abysmal showing is that something like mathematical physics is child's play as compared to obtaining the kind of answers that the Kyoto grandees mistakenly thought that even neophyte economists could provide with a year or two of serious effort. On the basis of the theoretical work that has already appeared and is due to appear in various unread journals, even a century of round-the-clock exertion by a regiment of investigators is unlikely to provide us with a fraction of the information and techniques that we should possess in order to make this scheme work.

Before ending this section, I want to cite what the *Financial Times* (17 May 2006) says about emissions trading: "EU finds carbon emissions trade impossible". This is interesting, because I found it not only impossible but absurd the first time that I heard of it. According to the editor of that publication, "governments are to blame, not the basic market design". I agree wholeheartedly in that governments should never have bought this cockamamie scheme. It is strictly something for those many unread learned journals gathering dust in our university libraries.

Figures released by the European Commission showed that most member states have given their industries too many carbon credits, which undermines the program to reduce CO_2 emissions. What we have to understand here is that when governments have to choose between the profitability of and employment in domestic industries and a harebrained setup that may or may not cut emissions, it is a no-brainer. The thinking here by most individual governments is that some other country can carry the burden. Besides, most politicians and civil servants now realize that the best way to reduce emissions is with a greater resort to nuclear power, along with restrictions on industries that are heavy emitters. These restrictions would be balanced by subsidies and tax reductions that encourage investment in more environmentally suitable facilities.

The director of one large power producer (RWE npower) has pronounced the EU emissions trading scheme as the best approach to getting results in the momentous task of reducing CO_2 output. According to that concerned observer, the program involves 25 member state governments, a host of different industries reporting on emissions from 9400 separate factories and power stations, and last but not least, the (administrative) machinery of the EU itself. Since the machinery of the EU has mangled almost everything it has touched, some question must be asked as to why it should be allowed to get near something as important as environmental legislation.

Just now, many scientists take issue with President George W. Bush's somewhat passive approach to global warming. Faced with the many uncertainties associated with this issue, it might be wise to think of the way that Neumann and Morgenstern might react. Although I have been told that the following is uncouthly expressed, I think that it deserves some attention by sophisticated readers: *global warming is not the same thing as a global tour by some rap artist that you can avoid by simply not buying a ticket. If global warming comes to town, you get a ticket whether you want one or not, and even worse, you have to use it*. Therefore, a modicum of precautions should be taken in order to make sure that it does not appear at an embarrassing moment.

10. More Deregulation Blues

Before concluding, a few more comments on the far-reaching and contentious subject of deregulation can be offered.

Included in the earlier "research" efforts of some of the academics mentioned in this chapter were attempts to revoke the concept of "increasing returns to scale" (or "decreasing costs" as it is often called with reference to the falling portion of U-shaped cost curves). Interestingly enough, increasing returns to scale may be one part of mainstream economics that is a part of the cosmic rulebook — the way the real world works. As long ago as 1848, in his *Principles of Political Economy*, John Stuart Mill wrote that "The laws and conditions of production partake of the character of physical truths. There is nothing arbitrary about them". To this could be added a recent conclusion of perhaps the leading deregulation scholar, Professor Alfred Kahn. He says: "I am worried about the uniqueness of the electricity markets. I've always been uncertain about eliminating vertical integration . . . It may be one industry in which it works reasonably well".

In these circumstances, I prefer to continue thinking that both your world and mine would be a better place if electric deregulation had stayed at the debating stage for another few decades, or best of all, completely forgotten. The changes proposed by the dreamy functionaries of Brussels should be considered an affront rather than an example to the world at large: they are not a part of the natural evolution of an industrial society, where ideally science, technology, economic theory, journalism and the media, in alliance with the common sense of voters, should focus on such things as increasing employment opportunities and social security, and improving the quality of life rather than indulging flashy bunkum hypocritically introduced in order to widen income differences.

I find it difficult to predict at the present time the bottom line in these deregulation melodramatics, but I am not at all certain that the EU Commission will succeed in making their case in the long run. For instance, General Charles DeGaulle unambiguously said that "the great common sources of wealth", by which on that occasion he meant natural gas, "belong to the nation and would not be used for individual profit making". It was unnecessary for him to refer to electricity, because in conjunction with the Conseil de la Resistance, the general had already made it perfectly clear that French industry and households were not to be denied the electricity they needed, and it was to be made available at modest prices.

This does not mean that French electricity and/or generating assets cannot be sold to foreign purchasers, nor should free markets nor the price system be subverted, but it so happens that in a world in which nuclear energy may be on the verge of making a comeback, the present French nuclear facilities and — much more importantly — the next (technological) generation of these installations may turn out to be extremely valuable assets. In these circumstances, I doubt whether any French government will be able to trivialize these assets in the manner that the present Swedish government is succeeding in trivializing what may still be the most efficient energy economy in the world in order to curry favor with high-flown EU elitists who neither understand nor are interested in understanding even the simplest concepts in energy economics.

A recent German chancellor declared himself unsympathetic to the attitude of the French government, as well he should. If all Europeans have the right to choose their suppliers of electricity (and gas), then many Germans would attempt to utilize this opportunity to purchase relatively inexpensive French energy (although their demand could make that energy more expensive). This could create problems for German utilities, and since deregulation commenced with perhaps 70,000 employees in the German electric sector being turned out of their jobs, it could increase social tensions throughout the country. Moreover, if the price of electricity reacts the way that it has in Sweden, Norway and Finland — first decreasing and then increasing — then electric deregulation can be held at least partially responsible for many other economic torments, such as the movement of important firms to countries where energy prices are lower.

Professor Stephen Littlechild, the considerably-less-than-impressive former UK energy regulator, believes that liberalization will continue because energy consumers want greater choice and freedom. What we really want, of course, is lower prices and a continued high level of reliability. Some of these consumers will probably obtain a taste of the good things advertised by Professor Littlechild, although a majority will find themselves having to settle for considerably less. The calculation in Brussels is that members of the latter group will keep their cool and continue to pay their energy bills on time.

Brussels and the EU governments have put much effort into attempts to find a common EU framework for resolving the liberalization enigma, although up to now the results are paltry. Mr Paul Hennemeyer, a director of Enron (Europe) in those days when it served as a role model for the international energy producing and trading community, strongly disliked the failure of the French government to open its energy market to competition, and he also had misgivings about the German authorities. In fact, he and his associates lived in a bubble for so long that he felt it appropriate to announce that if he were their teacher, he would make the entire EU "stay after school for extra lessons".

Enron was then an imposing firm with a sound business concept, but the sermon that Mr Hennemeyer wanted to preach soon lost its appeal after Enron's shares collapsed and the behavior of that firm's leadership made them candidates for an extended visit to a federal detention facility. On the other hand, the day may come when the EU High Commission in Brussels finds it opportune to utilize Mr Hennemeyer's pedagogical talents, because many voters have gotten in the habit of ignoring their long-term self-interest, and thus might provide him with the audience which he feels he richly deserves. One thing though is certain: he will not get much empathy from the thousands of unhappy Enron employees who not only lost their jobs, but also lost well over a billion dollars of their pension savings due to the fall of that corporation.

11. Final Remarks and Conclusions

"Even a tiny bit of genuine knowledge goes a very long way"
— Paul Ormerod (2006)

This is a very long chapter, and the reason for its length is that it is intended as a preview of the main topics in this textbook. Some readers will find a few things in this chapter — and in this book — controversial; however, I do not think that I will have to answer to the charge of misrepresenting anything. One of the papers presented at the international conference of the IAEE in Berlin in 2006 was called "Why has the Nordic electricity market worked so well?" If you examine this chapter you would be tempted to draw the conclusion that it has not worked well at all, and you would be perfectly correct. In fact, the day that I received a copy of that paper, the front page of the most important business publication in Sweden (*Dagens Industri*) showed a graph of the Swedish electricity price, and it was not a sight for sore eyes. Not only is the spot price on the Nordic electricity exchange (NordPool) more than 70% higher than it was at the same time the previous year, but the electricity-intensive Swedish industry is taking a severe beating.

Interestingly enough, spokespersons for those industries are now asking for an end to deregulation, while several academic economists recently blamed the problems of Swedish industry on a shortage of electric capacity instead of deregulation. As to be expected, those "scholars" were unable to comprehend that the lack of capacity in this country is due to deregulation.

Possible sources of controversy in this book are of course renewables and nuclear energy. According to *Business Week* (6 March 2006), President Bush has become a poster boy for renewables, and specifically plant-based (or grain-based) ethanol, wind power and photovoltaics. As a result of my evaluation of the small amount of evidence to which I have access, I am still unable to muster an overwhelming enthusiasm for ethanol and photovoltaics. Ethanol was mentioned in the president's 2006 State of the Union address, and there seems to be little doubt that it is destined to become an extremely valuable item; but according to the argument in this chapter, it has certain important disadvantages. I certainly see no reason to believe that it will exert a significant downward pressure on the price of motor fuel unless much larger volumes are produced than are planned at present. What it could do, however, is to put a pressure on the price of grain and therefore add significantly to world hunger.

According to Alan Jenkins in *EnergyPulse* (2006), biofuels have been "oversold", and in a comment on that paper, Jim Beyer argues that "ethanol makes sense as a fuel additive, but the economics are much less favorable as a significant fuel component itself". Let us put it this way: biofuels, wind power, solar, tar sand oil and other unconventional energy sources are useful and/or promising, but not as useful and promising as we are often led to believe. The real advantage from ethanol will probably appear when the underlying fuel is cellulose-based (e.g., switchgrass and wood) instead of grain- or plant-based (e.g., corn), which means that many more years will pass before it is possible to accumulate enough ethanol refineries to change the global energy picture.

At the same time, it should be recognized that in environmental matters, *social profit* is probably as important as *private profit*, and so measures like production tax credits for ethanol and similar initiatives should be resorted to without hesitation in the battle to reduce the dependency on fossil fuels. It might also be useful if governments consider functioning as buyers for some of the new products, as the US government did with microchips: they provided a market that encouraged producers to move rapidly up the learning curve in order to lower costs (and raise profits) by exploiting economies of scale.

Wind was discussed at some length in this chapter, and it is rewarding to note that in the United States, its use increased by 35% in 2005, which amounted to 2500 MW of additional power. The United States is a very large country and wind resources are considerable, but having noticed the deceleration in the growth of wind-based power in Northern Europe — and especially Scandinavia and Northern Germany — I have to infer that it is not the nostrum that some observers believe it to be. The maximum rating of a wind turbine is not a very good indication of how much energy can be obtained, since its capacity factor might only be 25% or lower. (The capacity factor indicates what percent of rated power is available on average.)

Under no circumstances, though, should the further development and eventual large-scale utilization of unconventional/renewable energy sources be obstructed. However once again, there is no place in the world where governments and voters are friendlier to renewable energy than in Scandinavia, and in addition, technological know-how in these countries is world-class, but even so there is a visible stagnation in the rate at which renewable energy is entering the energy mainstream. For instance, the 1600 MW of new generating capacity that will be installed in Finland could possibly have been provided by wind, but hardly at a price that Finnish voters would have been glad to pay, given the alternatives.

As noted in an editorial in *Science* (30 July 1999), "Affordable energy is the lifeblood of modern society. Without it, the network of transportation, agriculture, healthcare, manufacturing, and commerce deemed essential by many of the world's inhabitants, would not be possible".

Not mentioned in this resumé was entertainment and various other forms of relaxation. When these extremely important activities are ushered onto the scene, then it is quite clear that many of our fellow citizens are not particularly enthusiastic about adjusting their behavior in such a way as to reduce the growth of energy use, nor adopting lifestyles that would facilitate materially reducing discharges of CO_2 into the atmosphere. Changing this situation in the short run is unlikely, although the technological means are now available that will eventually bring this about, and hopefully they will soon be applied.

The governments of many countries have confronted the very (politically) sensitive private transportation issue by engaging in half-hearted attempts to convince motorists that it is in the interests of themselves and their descendants to make sacrifices that might be necessary in order to enable the provisions of the (very overrated) Kyoto Protocol to be realized, but inevitably their entreaties are tuned out as quickly as possible. After all, it would be difficult — to say the least — for a number of politicians to portray themselves as icons of self-denial. This has certainly become true in Sweden, and in particular applies to those politicians dreaming night and day of highly paid non-jobs in Brussels.

According to Michael Farrell, director of the program for global environmental studies at the Oak Ridge National Laboratory (Tennessee, USA), the (average) estimated increase in the global temperature will be 2.5°F for the present century, while even if the provisions of the Kyoto Protocol are fully carried out, the increase will be only slightly less. In addition, Sidney Borowitz (1999) — a New York University physicist — calculated several years ago that the atmospheric concentration of CO_2 was 358 ppmv (volume parts per million), and increasing at a rate of 1.5 ppmv. He considered this to be without precedent over the past 160,000 years. If these assessments are reasonable, or nearly reasonable for that matter, then it might be a good thing if many of the lovelorn references to the Kyoto Protocol should be toned down as much as possible, and a new program for reducing climate warming set into motion by some influential and charismatic person.

The thing to always keep in mind when dealing with this subject is that we are not talking about blackouts or brownouts, or the possibility of irksome increases in motor fuel prices because a pipeline somewhere got in the way of some rockets, but disasters that in earthquake terminology belong at or above the top of the Richter scale. The present President Bush has been awarded the bad-guy role in this drama, but it might be a good idea to remember that although his father once had a similar attitude toward ozone depreciation and acid rain, when the very conservative UK Prime Minister Margaret Thatcher insisted that something be done to diminish this hazard, he felt compelled to go along. Perhaps the new President Bush should also listen to her, or for that matter listen to a group of experts that he recently appointed who argued that anthropocentric-based global warming is the real deal. Moreover, in a fairly recent speech to the Royal Society, Baroness Thatcher said that “We may have unwittingly begun a massive experiment with the system of the planet itself”.

In a lecture that I once gave in Italy, I showed perhaps an excessive amount of intolerance for the fairly low degree of honesty that we find on the part of many people dealing with deregulation. This was regarded as “attitude” by one of the academic deregulation insiders. However, as US Congressman Peter De Fazio remarked at the beginning of the deregulation escapades on the US West Coast, “Why do we need to go through such a radical, risk taking experiment? The answer is that there are people who are going to make millions or billions”. (The academic gentleman to whom I am referring will make a great deal less, but as they once said in the United Kingdom: In for a pound, in for a penny.)

Some of Congressman De Fazio's potential millionaires and billionaires still believe that there is a place for them on the deregulation gravy train, while many of those already on board want to upgrade their tickets. I have no problem with this. My problem is with the so-called energy experts in California and elsewhere who failed to see that when regulated utilities are replaced by unregulated oligopolies, the exploitation of market power by these oligopolies is exactly what their textbooks told them would take place.

Oil and gas play a very large part in this book, both in chapters on these commodities and in the long chapter called "Energy and Money", where I examine some of the mechanics of derivative markets. It might be a good idea, however, to refer to a recent article in the *Financial Times* by Carola Hoyos, with the title "Mideast oil to play bigger role in global growth" (22 January 2006). Several of the points touched upon by Ms Hoyos were considered by me 15 or 20 years ago, and here I am talking about the possible shifting of the center of gravity of world oil refining to the Middle East. I also included petrochemicals, and unless I am mistaken, so did Professor Morris Adelman. It is always possible to say that certain people who should have received Nobel Prizes were deprived of them for one reason or another, but where quantitative development economics is concerned, I have no doubt at all that the late Hollis Chenery was the champion. Unfortunately, his use of linear programming and input–output analysis did not go over too well with the rank-and-file engaged in teaching and studying development economics, but for those of us who taught from his articles and the book that he wrote with Paul Clark (1962), it was clear that the big oil producers of the Middle East should not be eager to ship their oil in unprocessed form.

It has been noted by several observers that the unique feature of recent oil market developments is the near-term capacity constraints existing in some parts of the petroleum industry — e.g., refining in the United States — and the gradual decrease in excess sustainable crude oil production capacity in virtually every major oil-producing country except, perhaps, Saudi Arabia. ("Perhaps" because in both Saudi Arabia and Iraq, things like water flooding have reportedly led to an increase in the natural decline of deposits.) The complacency displayed toward this ominous situation is nothing less than remarkable, although behind the scenes I am sure that the heads of any number of central banks are informing their principals that they should do everything possible to prevent the kind of "anomalous" event (such as a serious political flare-up in or near an oil-producing country) that would remove a few million barrels of oil (per day) from the market, because that is all that it would take to send the oil price to a level where ugly macroeconomic and/or political consequences could follow. In addition, at the present time, the oil price is much more volatile than it was in the recent past, largely because the low investment of the past few years has kept storage and transport facilities from expanding as fast as output, and as a result, increased the possibility of the kind of bottlenecks that lead to wild price swings.

I close this chapter by noting that I still gain some consolation for my earlier and future forecasting failures, to include perhaps some in this book, when I recall that one of the most brilliant and influential physicists of the 20th century, Niels Bohr, once said that "true expertise comes only after making all possible mistakes". At the same time, I think it wise for most of us to accept that it would not be a good thing if we take too lightly the mistakes that are possible concerning the availability of oil and natural gas.

There is also some bad news that might someday be connected with global warming, since together with oil any expertise that we gain might have to be demonstrated in a world with a new and disagreeable economic and political structure — a structure that is not particularly responsive to the application of traditional know-how and procedures, and which features very loud noises and the rather distinctive sound of assault rifles and gunships.

All this and more should be taken note of by those persons who have become receptive to the arguments of the small but strident group of academic dissidents and deregulation buffs who regard global warming as a hoax, and to an amazing extent have a similar opinion of the peaking of the global oil supply, while never missing an opportunity to insist that their own quirky point of view deserves the same respect as that of the large majority of outstanding researchers who say that we cannot afford to be careless in these matters.

Appendix: Observations on the Main Text — Units and Equivalencies

There are two parts to this appendix. The first (A1) attempts to clarify several simple misunderstandings having to do with popular presentations of energy topics. This is an essential part of any energy economics course that I teach, however I am prepared to accept that this departure is not essential for the general reader at the present stage of the game. What is essential though is A2, which consists of the materials on units and equivalencies referred to on several occasions in the chapter and in the rest of the book. Here I can say that regardless of appearances, anyone who has made any calculations having to do with the changing of currencies in their local FOREX or airport, or for that matter on a quiet street corner in Gifu or Schwabisch Gmund, will have no difficulty following this discussion.

Appendix A1: Observations on the main text

(1) The nominal (or current or money) price of a good — e.g., oil — is its market price on a given day. The real price, however, takes into consideration the rate of inflation from some previous date. With this topic we generally limit attention to the real price of the good for a single country, although we could put together some kind of approximation for a group of countries.

In order to calculate the often cited real price of oil (P_r) at time t, we use the relationship $P_r = [\mathrm{CPI}_z/\mathrm{CPI}_t] \cdot P_t$, where the calculation is made with respect to the consumer price index (CPI) at a time z, which may or may not be the base year (b). But for our purposes we will make $\mathrm{CPI}_z = \mathrm{CPI}_b = 100$, and as is usually the case, the base year is the year of the first "oil price shock", or 1973. Thus, it turns out that after 1973 we see as expected an increasing CPI_t (i.e., $\mathrm{CPI}_t > 100$), but P_r moves up and down, depending on what happens with P_t. We can sum up what we have thus far with the equation $P_r = P_t/C_t$, where $C_t = \mathrm{CPI}_t/100$.

According to the good Josh on the television serial "The West Wing", the maximum P_r for the United States over the period 1973–2005 was in 1981. This probably makes sense, since the Iranian Revolution took place around that time, and the oil price surged.

Unfortunately, however, Mr Josh's observation was not particularly useful. In the United States as in Sweden, what we see is a flattening of personal income (or wages and salaries) for a large part of the population over the past quarter of a century. This flattening usually commences at about the age of 50. Thus, the recent oil price escalation is definitely bad news for persons in that age category, as well as many others, because this impacts on them both directly and indirectly: indirectly because of the influence of the oil price on the aggregate inflation rate, and directly because of what it means for things like the price of motor fuel and the cost of heating their homes. In the United States, the latter item mostly involves natural gas, but as pointed out in my natural gas book (1987), the price of gas is often indexed to that of oil. For instance, a simple indexing formula might be Gas Price = (Average price of five crudes/P_{ob}) $\cdot$ P_{gb}. In this expression P_{ob} is the price of oil in the base year (b), and P_{gb} is the price of gas in the base year.

The conclusion must therefore be that individuals who feel that their standard of living is threatened by rising oil or energy prices are correct, and Mr Josh should reserve his opinions about the real price of oil to conversations with his colleagues in the White House, and especially his boss. Needless to say, Mr Josh will probably never be in a position where rising oil prices interfere with the use of his late model automobile.

It can also be pointed out that a total differentiation of $P_r = P_t/C_t$ would give $g_r = g_t - g_{ct}$, where g signifies the growth rate. The claim of Mr Josh thus seems to be that $g_{ct} > g_t$, and so to his way of thinking g_r is in reality descending at the present time — which is definitely not the case.

(2) It was stated in the main text that economics places a limit on the amount (q) that we should remove from an oil (or gas) deposit of R during a given period. We can accordingly write $\Delta R/R \leq \lambda^*$, however $\Delta R = q$, and so we obtain $q/R \leq \lambda^*$. In the next chapter careful attention will be paid to the inversion of this relationship, or $R/q \geq 1/\lambda^* = \theta^*$, because the general discussion of oil shortages usually involves the reserve–production (R/q) ratio.

Incidentally, we often have to entertain strange tales about the R/q ratio in the context of which the expression "dynamic" is used to claim that reserves are adequate. However, if we start at the present date and ask about the development of this ratio, we can write $Re^{\alpha t}/qe^{\beta t}$, and since it is very clear that β is larger than α, the dynamics do not seem to work in favor of the oil optimists. At the same time, readers should remember that the key thing where this topic is concerned is the date at which the global q peaks because, as pointed out on numerous occasions, when that happens the lifestyles of a good many citizens might be in significant danger. In continuing, examine Table 1.1 for some commonly used prefixes.

Table 1.1. Commonly Used Prefixes, with Examples

Prefix	Symbol	Power	Meaning	Example
Kilo	K(k)	10^3	thousand	kW (kilowatt)
Mega	M(m)	10^6	million	MW (megawatt)
Giga	G	10^9	billion	GJ (gigajoules)
Tera	T	10^{12}	trillion	TJ (terajoule)
Peta	P	10^{15}	thousand-trillion	PJ (petajoule)
Exa	E	10^{18}	million-trillion	EJ (exajoule)

Appendix A2: Units and equivalencies

Next, it should be noted that 1 t is the designation of one metric ton, or 1 tonne, which equals 2204 pounds (lbs). We also have a short ton, which in most countries is simply called a ton. One short ton (ton) = 2000 lbs; and 1 t = 1.103 tons. Finally, there is a long ton, which is 2240 lbs. As most readers know, 1 mile = 1609 m = 5280 ft, and so 1 m is approximately 3.28 ft = 39.37 ins, giving us 1 in = 2.54 cm. Furthermore, 1 kg is approximately 2.2 pounds (lbs), and if we have to convert Centigrade to Fahrenheit we use the formula {Fahrenheit = (9/5)Celsius + 32}, remembering that Celsius now seems to be used instead of Centigrade.

When working with energy we are often interested in heat, which is usually measured in British thermal units (Btu) and joules. 1 Btu is the amount of heat needed to increase the temperature of 1 lb of water by 1 degree (= 1°) Fahrenheit. One metric ton (1 t) of bituminous coal has an energy content (on the average) of 27,700,000 Btu, and the reader can convert this to joules using Table 1.2. 1 t of crude oil has an average energy content of 42,514,000 Btu, and one thousand cubic feet (= 1 kcf = 1 kft^3) of natural gas has an average energy content slightly in excess of 1,000,000 Btu. (The exact figure is given below.)

It was often said that Btu would be completely replaced by joules (J), but this is not certain. It would not seem natural at the present time to quote natural gas prices in dollars per joule instead of dollars/Btu, although joule

Table 1.2. Conversions: Joules — kWh — Btu

	Joules (J)	Kilowatt-hours (kWh)	Btu
1 joule	1	0.278×10^{-6}	0.948×10^{-3}
1 kWh	3.6×10^{6}	1	3.412×10^{3}
1 Btu	1.055×10^{3}	0.293×10^{-3}	1

is a member of the international system of units (SI units). The kWh and MWh are very popular and well-known units, and readers should get used to working with them. A short table of equivalencies can now be given.

It is worth remembering that 1 million tonnes of oil equivalent (= 1 mtoe) can be converted to Btu, should this unit be relevant to the discussion. Handy transformations are 1 barrel of oil (= 1 b) = 5,800,000 Btu. We also have 7.33 b (on the average) enclosing 1 t of oil. The most popular unit for measuring the consumption and production of oil is barrels per day (= b/d). For example, the output of the OPEC countries at the present time is about 27 mb/d, and this can be turned into another popular unit — millions of tonnes per year (mt/y) — by multiplying by 50. Thus, 25 mb/d = 1350 mt/y. Where this 50 is concerned, we get it from a simple dimensional analysis: 1 (b/d) × 365 (d/y) × (1/7.33)(t/b) = 50 (t/y), and thus 1 mb/d = 50 mt/y.

Power is defined as the rate of doing work. The best-known units for measuring power are the watt (W), which is equal to one joule (J) per second, and the horsepower (hp). These units will be looked at more closely in the chapter on electricity. However, just now, the following table seems useful:

Table 1.3. Conversions: Watts — hp — Btu/h

	Watts (W)	Horsepower (hp)	Btu/Hour (Btu/h)
1 W	1	1.341×10^{-3}	3.41
1 hp	0.746×10^{3}	1	2.54×10^{3}
1 Btu/h	0.293	0.393×10^{-3}	1

One of the most interesting things about Table 1.3 is the introduction of time into the picture. For example, we go from watts — which is a measure of power — to Btu/h. There is no point in making a big thing of this at the present time; however, if we start with a pile of coal, it contains a certain number of Btu, and these are transformed into the brightness in your kitchen via the bulbs in that room. The larger the bulbs, the faster the coal pile is depleted. I could perform the relevant calculations now, and you would have no problem understanding them, but it is probably best to wait until the chapter on electricity.

Finally, in summary form, some useful equivalencies are:

(1) 1 barrel of crude oil = 42 US gallons, and weighs 0.136 metric tons (t).
(2) 1000 cubic feet (= 1000 ft^3) of natural gas = 28.3 m^3, where 1 m^3 = 35.33 ft^3.
(3) 1 kWh of electricity = 3413 Btu = 860 kilocalories (kcals).
(4) 1 t bituminous coal = 27,700,000 (= 27.7×10^6) Btu (on average).
(5) 1000 ft^3 of natural gas = 1.035×10^6 Btu = 2.61×10^8 calories.
(6) 1 t of hard coal = 4.9 barrels of crude oil (on average).
(7) 1000 ft^3 of natural gas = 0.178 barrels of crude oil (on average).
(8) 1000 kWh of electricity = 0.588 barrels of oil (on average).

Key Concepts

API number
base load and peak load
decline rate
derivatives
EROI
hedging
LNG
M. King Hubbert and peaking
money and real prices
oil-in-place
primary recovery ratio
reserve–production ratio
reserves
retail and wholesale prices for electricity
secondary recovery
spot prices
tar sands
tertiary recovery

Questions for Discussion

1. What do you think about my version of Murphy's Law: "Any financial system that can be manipulated will be manipulated!" Do you think that Gordon Gekko would agree?

2. Explain: The peaking of the oil supply in the United States can be explained by economics. Geology is a constraint! "Hubbert's Peak" was mentioned in an episode of the "West Wing". Pretend that you are President (and professor of economics and Nobel Prize winner) Jed Bartlet, and explain it to your admiring subordinates.
3. There seems to be plenty of natural gas in Alaska and Northern Canada. Why is there a growing gas deficiency in the "lower 48" of the United States?
4. What are the arguments for and against an expansion of nuclear energy? What are the arguments for and against a rapid expansion of renewables.
5. How do you think Neumann and Morgenstern would handle this matter of global warming, given the approach to uncertainty in their book *The Theory of Games and Economic Behavior*.
6. LNG is not as popular as some people think that it should be. Explain!
7. As far as I am concerned, electricity deregulation has failed. Discuss in detail.
8. Do you think that the oil-rich countries of the Middle East will provide us with all the oil that we think that we need, at prices that we think are reasonable?
9. Emissions trading seems to have worked in the United States for SO_2, but important researchers like David Victor and Ruth Greenspan Bell do not have much faith in it on the international level. Why is this?
10. What are the objections of President George W. Bush and his government to the Kyoto Protocol? What appears to be the objections of the writer of this book? How do you feel about this? What was the former prime minister of the United Kingdom Margaret Thatcher's comment on this topic?
11. Former Governor Gray Davis of California used the expression "Out of state criminals" when discussing the deregulation meltdown in his state. Discuss the background to this unusual terminology.
12. Enron was a brilliant firm that ran into some problems a few years ago. Explain. Not too long ago the price of natural gas in the United States averaged \$14.5/mBtu. What is the oil equivalent price? Often in this book I use the expressions "spiked" and "sustained". Discuss and give some examples.

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