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Energy

'Time is the only capital that any human being has, and the one thing that he can't afford to lose.'

Thomas Edison

The Return of King Coal Adds a Warm Glow

A visit to the Forbidden City in the centre of Beijing provides a fascinating insight into China's rich historic past. For almost five centuries the imperial palace was home to 24 emperors, and the city – a vast array of ancient preserved wooden buildings – was the political centre of the Chinese government throughout the Ming and the Qing dynasties. But it is outside the Gate of Heavenly Peace, looking across the stretch of tarmac separating the old imperial palace from Tiananmen Square under the watchful gaze of Mao, where you get a real picture of the China of today, and of tomorrow. The 12-lane road is clogged with cars, four-wheel drives, trucks and buses. One or two cyclists are glimpsed in the traffic, but pedal power is a fringe mode of transport on the first proper ring road in Beijing, millions of Chinese having ditched their bicycles in favour of cars.

The Forbidden City was once China's most important symbol of power. Today the Volkswagen Santana and Jetta, the Geely or Xiali mark individual power and wealth of the Chinese consumer. The icon of Mao just a few hundred metres away is a stark contrast to the symbols of capitalism on the road ahead, marking the dualism of a China still strongly connected to its past while intent on progression. The main goal of the Chinese Communist leadership today has moved beyond equality between its citizens to economic equality between Chinese people and those in the developed world. And, in the process, for China to regain its mantle as the world's most powerful economy, a position it last held during the fifteenth century (Kynge, 2006).[1] China is now pursuing the same trappings of the modern lifestyle long enjoyed in the US, Europe and Japan. It is a trend that you'd think would be applauded by proponents of the US car industry, where the car is viewed as a symbol of freedom and wealth. But the growing demand for motor vehicles among the increasingly affluent Chinese is creating a huge dilemma for the global energy sector.

In 2007 China overtook Japan as the world's second largest car market. It is predicted to become the biggest in the next decade, overtaking the United States by 2015. It's a dramatic turnaround for China, especially when you consider that in 1990 it had in total around a quarter of the number of cars on British roads. In the space of 25 years it will have become the largest car market in the world (International Energy Agency, 2007; Department of Transport, 2007). The fact that more Chinese citizens are able to afford cars is thanks to China's nearly unbroken 30-year economic expansion. China has become the 'workshop for the world', as factory owners in the West relocate their manufacturing facilities to China to take advantage of the lower wages and industrious work ethic of the Chinese. But the 37 million cars and 60 million motorcyclists on China's roads[2] need fuel, and, increasingly, imported fuel: China was last self-reliant for its oil in the mid-1990s. Its thirst for oil is growing fast, which has prompted the Chinese government and many of its state-owned companies to scour the world for other sources. What is striking is that they're going to places the US dares not, such as Sudan and Iran;

completely changing the world geopolitical landscape. The number of cars, trucks, SUVs and vans on Chinese roads is expected to increase to a staggering 270 million by 2030 according to the International Energy Agency, so barring a major technological breakthrough in automobile engines or alternative fuel supply (neither of which is expected to be commercially available within the next ten years) China will need even more fuel. China is expected to become as 'addicted' to oil as the US within the next 20 years.

The transferral of much of the world's manufacturing industry to China has also stimulated one of the largest movements of humans in history. Its cities have doubled in size in the past 20 years and hundreds of millions of Chinese citizens have moved from the countryside to apartments equipped with electricity – a stark contrast to their rural dwellings, which were largely without power. About 200 of China's cities have a population of more than one million, and about 40 % of its total population of 1.3 billion live in cities, with another 130 million expected to move from rural to urban areas over the next ten years (International Energy Agency, 2007).

Power for the People

Electricity in the vast majority of Chinese homes is generated by coal-fired power stations. Until 2007 China was self-sufficient in coal (as home to the largest coal reserves in the world, it should be!). But China has been building more power stations to provide electricity for expanding demand; its power network expansion in 2006 alone was bigger than the electricity generation of the entire UK. It would be inconceivable to think of Britain, or indeed any other country, installing as much electricity generation capacity in one year. It has plans on the drawing board to expand its power network even further, which would equate to the construction of new infrastructure as large as the entire power grid built across Europe since the Second World War – that's all the homes, buildings, restaurants, factories and sports venues stretching from the Baltic countries to the west of Ireland, and from the tip of Norway to the Greek Islands in the Mediterranean.[3]

This planned expansion will light up millions of new homes, for even greater numbers of consumers (many of whom will become car owners for the first time). The country's demand for energy is so great that it is projected to overtake the United States as the world's largest consumer of energy, coal, oil and nuclear power at the end of the decade. Considering that as recently as 2005, the US consumed over a third more energy than China, it represents growth of astronomical proportions. The scale and the speed of the increase meant that in the three years prior to 2005, China's increase in energy demand was the equivalent of all of Japan's annual energy needs,[4] and at this pace China's need for more energy supplies has become critical, pushing oil prices above $100 a barrel in 2008.

The increase in electricity consumption is primarily due to more homes connecting to the power network, which in turn stimulates the demand for consumer electronic goods. Rapid income growth and declining prices mean that almost every home in Chinese cities now has at least one television, a washing machine and refrigerator. Air-conditioning systems are now found in four of every five homes. These appliances account for more than a fifth of total residential energy (International Energy Agency, 2007). Electrical gadgets may well have improved the quality of daily life for Chinese consumers, but these appliances in fact suck much more electrical power than their equivalents in developed countries and emit much more carbon pollution. This is one of the reasons why China's energy demand has risen so rapidly.[5]

The Comeback King

Coal's re-emergence as a major fuel source is a significant factor in the rise of CO_2 emissions. Coal overtook wood during the 1800s[6] as the world's major fuel source and fuelled the Industrial Revolution in Britain and the United States of America. It was during this era that the phrase 'King Coal' was coined by 19th century economist William Stanley Jevons who said: '(Coal) stands not beside but entirely above all other commodities.' King coal held onto its crown in the US until

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just after the Second World War when oil from the Middle East and Venezuela changed things,[7] by which stage the US was the largest coal consumer in the world. Usage declined further in the 1930s when coal was banned from US homes, and a decade later in trains. By the 1950s and 1960s, nuclear and gas were set to replace coal altogether – that is until the Three Mile accident halted the expansion of nuclear power. Gas was ready to step in, and between 1975 and 2002 every power station built in America was gas-fired (Goodell, 2006). But gas, too, had its shortcomings.

China's industrial revolution has followed the pattern of Britain's industrialization, which started about 250 years ago, in that it is fuelled by coal and has stimulated the renaissance in global demand for the black rock. In China's case coal is burned in power stations, not the home or factory; it is out of sight and out of mind for most consumers, who rarely make the connection between switching on a light or watching the television and the emission of greenhouse gases. An inconvenient truth much less acknowledged is the role of the always-on internet-connected world in boosting electricity demand from coal-fired stations.

Coal's re-emergence confounds predictions in the second half of the 20th century that coal had a dim future. Coal was used to heat the Victorian-built home in London that I lived in as a child. It wasn't very effective; while it heated the room where the fire was located, the rest of the house was freezing. It was my job to fill a bucket with coal from the cellar (which today is probably used for the wine collection of an Islington family). Our coal was delivered each autumn by the coalman, who would empty sacks of coal down the coalhole (a feature of Victorian houses) in front of the doorstep. But the coalman's days were numbered when hundreds of thousands of UK households switched to natural gas in the 1960s and 1970s, piped from the new gas fields in the North Sea straight to people's houses. The gas central heating system that replaced our antiquated coal fires heated the whole house with the flick of a switch. It was great – I no longer needed to sleep under five blankets or to huddle around the small electric fire in the lounge. Nor was it necessary to do those cold trips down to the cellar each night. That was it – coal was history, and gas was the future.

Coal's perceived decline in the 1980s and 1990s and the popularity of gas was due to the efficiency of gas-fired generating plants. They convert more primary energy into electricity than coal-fired plants and they are cheaper to build than coal or nuclear plants and gas is a cleaner fuel than coal and oil. This view was endorsed in the 1980s when coal mines across Britain were closed. The price of coal had plummeted and the government-owned mines were now uneconomic: they had no place in the Conservative government of Margaret Thatcher. The decision led to bitter battles between police and British coal miners. The closure of the British coalmines was another sign that the world had moved beyond coal.

The gas coming from the North Sea territory was not enough to heat, light and power Britain; now gas is piped from Norway, Belgium and shipped from Algeria and Qatar. The decline in gas supplies from politically secure areas such as the North Sea and the Gulf of Mexico has left consumers more reliant on Russia, the Middle East and Indonesia for gas supplies. The political risks long associated with oil imports now apply to gas; in particular, Russia, which has used its market position as the world's largest exporter to threaten cuts in supply to some consumers if they do not pay. Gas exporters have also become friendlier with each other, raising fears about the creation of a gas Opec (Organization of the Petroleum Exporting Countries).[8]

Coal has resurfaced, and Britain is now importing record volumes. The port of Immingham in Lincolnshire on the east coast of England is the largest import point for coal in Britain; the mountains of coal around the port turn the snow black in winter and the coal dust which rises into the air in the summer has to be hosed down with water. Much of the coal feeds the nearby Drax power station, the largest of its kind in the UK. Coal still accounts for less than half of Britain's electricity power supply (Energy Information Administration, no date).

Coal's key role in the British Industrial Revolution was firing the first steam engine that started the railway revolution. This, in turn,

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helped move vast quantities of commodities – from grains to minerals – from producer to industrial consumer. Steam turbines were used for electricity generation: the efficiency of steam turbines has improved vastly since the 19th century. The size of the coal-fired power station has increased too, by 1500 times from the start of the 20th century, which means more coal can be burned to produce more power (Jaccard, 2006).[9]

Coal can easily be transported via railways and boats, so it can be moved from pit to power station without the political connotations associated with gas or oil pipelines. Coal also has the largest of all fossil fuel reserves in the world. Global coal reserves are concentrated in North America, the former Soviet Union, China, India, Australia and South Africa. These reserves of fossil fuels are finite; something which demand for electricity shows no sign of being. Its abundance and perceived low political risk has also made coal cheaper than the fossil fuel alternatives, gas and oil. Gas prices have risen because they are linked to oil prices: most gas is exported on a sales contract between the buyer and seller whereby the price is indexed to oil prices, in order to ensure that gas remains competitive. Coal prices rose by more than 50 % last year, but they remain competitively cheap compared with oil and gas.

Coal Play

The increase in energy demand globally is largely due to the simple fact that there are more people living on the planet. The world's population is projected to reach 8.2 billion by 2030, from 6.4 billion in 2005. The population rise in the second half of the 20th century corresponded to a huge increase in energy demand. A trend that looks set to continue in the first third of the 21st century.[10]

The world's demand for energy is projected to rise by 55 % by 2030 from 2005 levels (International Energy Agency, 2007). This means more power stations, and more copper and aluminium electricity lines to transmit the electrons from power stations to homes, factories, offices and street lights. Less than a fifth of the world's energy supply is projected to come from less polluting sources, such as nuclear, hydro, biomass, wind and solar. The majority of the increased demand will be met by power generated from fossil fuels.

Most of the rise in the world's population is occurring in the developing world. China and India are expected to remain the world's two most populous countries over this period, but both countries have hundreds of millions of citizens living without electricity, and those who are connected are subject to frequent power shortages. The respective Beijing and New Delhi governments have plans to connect most of their citizens to power networks in the next 25 years. Hundreds of new power stations will be built. Many will be fuelled by coal. So vast is the planned increase in coal demand that the two countries are expected to account for about 80 % of the world's coal growth by 2030, and 40 % of the world's increase in oil demand over the same period.

China relies on coal because it has its own vast reserves, in addition to imports from relatively safe producers such as Australia and South Africa. Coal is also far cheaper than nuclear and natural gas, and since China is not bound by the Kyoto Protocol or any other international pact limiting emissions, it is basically unhindered. The new power stations China is building will undoubtedly breach the emissions levels that the Kyoto signatories are attempting to abide by. All this has earned China the unenviable title of the world's largest polluter; a position it has won in rapid time – it was responsible for an estimated 58 % of the increase in global emissions in the six years leading up to 2006 (in contrast, India accounted for 6 % of global emissions). China's desire to become the largest economy has put the world on a path towards increased global temperatures, which scientists at the United Nations International Panel of Climate Change (IPCC) warn would be catastrophic and irreversible.[11]

A Global Warning

By 2030, global pollution is expected to be more than 80 % above the limit the IPCC considers to be the tipping point for drastic climate change. The current aspirations of China and India in terms of lifestyle are not helping. The International Energy Agency (IEA) estimates that China, barring any major change in energy consumption habits, will emit two-thirds more pollution than the US in 2030 (International Energy Agency, 2007).

To provide us with the heat and light we desire, coal must be converted into electricity in a power plant. The process actually results in a major loss in energy since only about a third of the heat generated from burning the coal is converted into electricity. The same energy loss occurs when crude oil is turned into petroleum products such as gasoline, diesel and heating oil. Pollution levels are therefore a big problem.

International agreements that limit greenhouse gas emissions are not easy to reach due to the difficulty in accounting for emissions. China's emergence as the 'workshop of the world', for instance, has meant that thousands of factories around China are making goods in facilities which are actually owned by foreign companies, or producing goods under contract for foreign companies and brands. Wal-Mart – the US-based retail giant – alone imported about $18 billion worth of goods from China in 2007: a tenth of the US trade deficit with China.

The IEA – energy policy adviser to the developed countries – has estimated that more than a quarter of China's energy is used in the production of goods for export. This accounts for more than a third of the country's emissions. Energy consumption on exported goods has increased its share of China's total energy use – far higher than the proportion of energy expended on exported goods in the US, European Union and Japan.[12] In effect, developed countries are outsourcing not only their manufacturing capacity, but also a significant part of their energy consumption and greenhouse gas emissions.

Despite China becoming the world's largest greenhouse gas emitter, the average Chinese citizen emits less pollution than the average American or European.[13]

At present about one-quarter of the world's CO_2 emissions come from coal, but this share will increase if all the planned coal-fired plants go ahead, adding as much CO_2 over the life of the coal plants as that released by all coal burned in the last 250 years (Goodell, 2006). These estimates are based on the Chinese economy maintaining its current growth momentum. But growth has defied expert opinion for the last decade, and may continue to do so over the next ten years. 'China has become the goldilocks economy, it is always next year that it will slow down, but it never does,' said Mehdi Varzi, energy consultant and former Iranian diplomat.

Fatih Birol, chief energy economist at the IEA, believes that 90 % of China's new power supply will come from coal-fired power stations. 'They will be making CO_2 for the next 60 years and once they are built it would be impossible for them to be shut down. Therefore we may lock in our future and these plants will be with us for a long time,' said Birol. 'If we don't make big changes in the next ten years, it will be very difficult to change. Some of the things we are locking in are irreversible. Each year the situation is getting worse, we are burning more CO_2 using more coal and all we get is more talk, but nothing is done. The next decade is going to be very important for climate change.'

The Coal Conundrum

Coal is by far the most polluting fossil fuel compared with oil and natural gas. For every tonne of coal burned in a power station, 2.5 tonnes of carbon dioxide equivalent is emitted, and included in this are other nasty pollutants such as mercury, nitrogen oxide and sulphur dioxide; greenhouse gases that scientists attribute to global warming. It's not just coincidence that the increase in the CO_2 count in the atmosphere has coincided with the world burning more fossil fuels. Coal is the leading source of emissions in the world, overtaking even oil in 2004.

Coal deposits are remnants of plants which grew hundreds of millions of years ago during the Carboniferous period. The plants initially transformed into peat and then into coal when sufficient pressure and temperature squeezed out the remaining water. Oil and natural gas derive from plankton that dropped to the sea floor up to 140 million years ago (Lomborg, 1998). Biofuels also release large doses of CO_2 because they are essentially a plant containing carbon.

Carbon dioxide is the main greenhouse gas, accounting for more than three-quarters of all emissions. It actually fulfils a vital role in the world. Much of the carbon dioxide that is released into the air has already been breathed in by plants and trees – it is needed in order for them to survive – and released again once the plant decays. It plays another important role for the planet, keeping it warm by trapping some of the sunrays that bounce off the Earth and back into space: without this warmth Earth would be too cold and would be devoid of life. Like many things in life though, too much of a good thing is not a good thing: the more CO_2 released into the atmosphere, the more heat is trapped, hence the effects of global warming.

Pollution controls on coal have been around for centuries, but none have worked to halt the increase in pollution. Tighter air pollution controls were introduced in the 14th century to stop the black smoke from the coal that was used by English blacksmiths (Freese, 2003). In the 19th century, the British government introduced laws to reduce smoke from railways and factories. California became one of the first jurisdictions in the US to tighten air pollution control when it passed the Air Pollution Control Act in 1947, and in 1969, it was the first state to pass air quality standards for key pollutants, a move that was later followed by the rest of the US. The problem of coal pollution was the target of President Nixon's speech on the creation of the Environmental Protection Agency on New Year's Day, 1970. He declared that the coming decade was when 'America pays its debt to the past by reclaiming the purity of its air, its waters and our living environment. It is literally now or never.' Nixon's speech, almost 40 years ago, underlined the urgency of addressing environmental issues. Twenty years ago, in 1988, President George H. Bush talked about the 'White House Effect', whereby political power could be used to tighten pollution controls. Many regulations have since passed to no real effect.

The second George Bush used the White House Effect to dismiss the Kyoto Protocol, the international pact to limit greenhouse gas emissions, when he came to office in 2001. Barbara Freese, author of *Coal: A Human History* said that the election of George W. Bush owes much to the US coal industry. West Virginia, the traditionally Democrat stronghold, contributed to the Bush campaign fund, and was vocal in its opposition to Democratic contender Al Gore because of fears that he would tighten environmental controls.

The coal industry has been strongly averse to robust emission limits, and has been among the most outspoken against cleaner air policy. A former coal company executive once said that the Earth was deficient in CO_2 and that more coal should be burned to warm the planet so that plants could feed off the carbon dioxide, thereby making the planet greener.[14]

Shortly after the Bush–Cheney government took office, it launched a National Energy Policy. The report that accompanied its policy did little to suggest there would be any move away from coal (National Energy Policy Development Group, 2001). In fact it said that coal would remain the dominant fuel in meeting increasing US electricity demand.[15] Bush repaid the coal industry further by proposing financial incentives to develop clean coal in the Energy Policy Act of 2005.[16] The Bush–Cheney government gave $5 billion in subsidies to big coal, including $2 billion for research into 'clean coal' power stations, a technical process intended to reduce emissions from burning coal (Goodell, 2006).

Bush's support for the coal industry underlines his prioritizing of energy security over global warming. About half of all US electricity is generated by coal; the country burns more than 1 billion tonnes a year and most of that is met by local production. Almost two-thirds of US coal production comes from mines in Wyoming, West Virginia and Kentucky, with most of the coal moved by train across America. Many drivers that get caught by the red lights at a level crossing in America is often because they are waiting for a coal freight train to pass with dozens of carriages filled to the brim with coal.

Politicians talk about energy security and climate change in the same breath, but so far they have been proven to be largely contradictory objectives. Energy security has become a major focus under President Bush following the September 11 attacks, the wars in Iraq and Afghanistan and the sabre rattling between the Bush government and Iran. This has led the US to formulate its energy policy around securing supplies such as coal and corn for ethanol from domestic sources, and from friendly nations such as neighbouring Canada, which has one of the world's largest deposits of tar sands (an unconventional oil source that requires more energy for its extraction and is a bigger emitter of greenhouse gases than conventional oil sources). The Bush energy security policy has caused a ripple effect across the agricultural world with aggressive US mandatory targets for ethanol, which is made from corn grown in the US. The policy has been a significant factor in the worrying rise in global food prices.

James Connaughton, chief environmental adviser to President George W. Bush has long opposed mandatory emission cuts (which gives an idea of the advice Bush has received on the matter). When Connaughton – who was a lawyer defending industrial companies against environmental lawsuits before he got into politics – talks about the Bush government policy on energy and tackling climate change, he gives the impression that Washington is proactively seeking sustainable energy policies. But the Bush government has tried to stop California from setting a tougher fuel efficiency standard than the Federal government proposed in its 2007 energy bill,[17] and refused to pass the necessary law to set a carbon price in the US, which would provide an economic incentive to switch to cleaner fuels.

At the United Nations Climate Change conference in Bali in December 2007 Connaughton told an audience of journalists that the US was looking at technological solutions to reduce emissions from coal, rather than through a carbon price. 'One of the challenges we face when it comes to producing power from coal with lower emissions and having transportation with lower emissions, is that the technologies are very expensive,' Connaughton said. 'The traditional emission trading mechanism does not provide the price signal that would incentivize the switch to those expensive technologies, so what we have to do in the interim is we have to move as aggressively as we can to advance the research and deployment on low carbon coal power generation technology,' he said.

I Have a Cunning Plan

The US Energy Bill that President Bush signed in December 2007 aims to cut greenhouse gas emissions, bolster energy security and make the US more energy efficient. The US may achieve all of these goals in the future, but it is unlikely to be due to the Bush energy plan. US governments have never been shy of bold energy initiatives. Most have fallen by the wayside; market dynamics ultimately determine the supply and demand of energy sources. The Bush energy plan may well turn out to be no exception, because it is not an effective way to curb greenhouse gas emissions.

US government energy programmes launched in the 1970s fell short of their goals. President Nixon's Project Independence had the somewhat optimistic goal of reaching energy self-sufficiency by 1980. In January 1975 President Gerald Ford proposed a ten-year plan to build 200 nuclear power plants, 250 coal mines, 150 coal-fired power stations, 30 oil refineries and 20 synthetic fuel plants (Yergin, 1991). President Jimmy Carter also unveiled a national energy plan within the first three months of his inauguration, though his bill resulted in the creation of the US Department of Energy. A common factor in the failure of the energy plans of the 1970s was the fall in the oil price due to the discovery of new oil reserves, as well as improvements in fuel efficiency for motor vehicles and the switch from oil fired power stations to gas and coal.

President George W. Bush espouses a similar goal to Nixon, however, his energy policy doctrine was dismissed last year by a team of energy executives, policymakers and analysts, who make up the National Petroleum Council (NPC) in the US. 'Energy Independence should not be confused with strengthening energy security. The concept of energy independence is not realistic in the foreseeable future, whereas US energy security can be enhanced by moderating demand, expanding and diversifying domestic energy supplies, and strengthening global energy trade and investment,' the NPC said. 'There can be no US energy security without global energy security.' (National Petroleum Council, 2007).

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Until cleaner energies become commercially viable, the world will continue to consume more coal and oil. With the end of the Bush–Cheney government drawing near, the legacy is a more polluted US and a country that is even more dependent on foreign oil. US oil imports now account for 60 % of the country's oil supply, compared with 55 % in 2001, the first year of the Bush–Cheney government, and US CO_2 emissions have risen over this period as the country's fossil fuel consumption is up more than 2 % (Energy Information Administration, 2006).

Clean Coal

Bush and Connaughton believe that clean coal technology is the way to achieve lower greenhouse gas emissions. Clean coal technology is a different process than conventional coal plants, and more costly to operate – hence it is not yet commercially viable.

Conventional coal plants burn coal in a big steel box, the heat driving the turbines that generate the electricity. One of the leading clean coal technologies is the Integrated Gasification Combined Cycle (IGCC), a process that involves 'cooking' the impurities found in coal, such as mercury and nitrous oxide. The cooking cleans the coal which is then converted into a synthetic gas, which is captured and finally burned in a turbine. The impurities and CO_2 are captured through another complicated-sounding process called *carbon sequestration;* a different technology to IGCC. In simple terms, carbon sequestration involves putting all the nasty pollutants into a big bag and shovelling them underground. Though the actual process is not quite as simple as that (for a start the impurities are gases, which cannot be put into a giant bag); the gases are funnelled into pipes that start at the IGCC plant and end in underground aquifers, a tricky process that could be susceptible to leakage.

The IGCC plants claim to be more energy efficient than conventional coal plants; 50 to 60 % efficient compared with 35 % for conventional coal plants. They use less water and reduce wastage – but they are more expensive to construct and operate according to studies by both the IEA and the US Department of Energy. This means that the cost of producing electricity from clean coal technology will be higher. The US does not have to pay for the pollution from coal fired power stations because it does not have a carbon price, but this will change.

The concept of IGCC is not entirely new. Gasification of coal has been used for more than 150 years, and many of the first street lamps in Europe and America were lit by coal gas. Commercial gasification for electricity generation is new though, and the combination of two unproven commercial technologies – the IGCC process and carbon sequestration – working together in the future is a big challenge. Research into the commercialization of the technologies has been taking place for decades. In the 1970s, there was an Office of Coal Research within the US Department of the Interior, which looks after government-owned land (including national parks) and administers Indian reservations. Most of the funding was given to projects controlled by companies with strong links to the oil industry (Ruttenberg and Associates Inc., 1973).[18] In the 1960s and early 1970s, six of America's largest coal producers were owned by oil companies, including Exxon, producing more than a fifth of annual US coal output. Today, the major oil companies have little or no interest in coal.

The federal funding of clean coal research has not always met with success. The US government report 'Lessons Learned in the Clean Coal Technology Program', released in June 2001, stated that, 'Many projects had experienced delays, cost overruns, bankruptcies, and performance problems.' It also identified some projects demonstrating technologies that might have been commercialized without federal assistance.[19]

With the world expected to use much more coal and emit far more greenhouse gases for the foreseeable future, achieving the diametrically opposed goals of continued coal-generated electricity expansion and greenhouse gas reduction may indeed rely on the success of clean coal technologies such as IGCC. But given the unproven nature of the technology and the focus on the bottom line, the coal industry is reluctant to spend the additional funds required for building new coal-based IGCC power plants.[20] The adoption of new energy

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technology such as wind and solar also depends on government assistance and policy. The US government has been generous in its assistance to the energy industry, giving about a third of the income it receives in taxation and royalties back to the sector, through research and development grants, government spending programmes and tax breaks. During the past 29 years, Congress has provided DOE with about $50 billion for R&D in renewable, fossil and nuclear energy technologies (US Department of Energy, 2006). The world is now facing its biggest energy challenge – providing clean energy, as opposed to running out of energy sources – and the spending on energy research and development has fallen well below the levels of the early 1980s.[21]

Liquid Coal

Coal is also promoted by some as a solution to the other great energy challenge – secure liquid petroleum supplies. There has long been a quest to use coal to make fuels for transportation. Nazi Germany converted domestically produced coal into synthetic fuel to power its Luftwaffe air force and its army, otherwise dependent on foreign oil supplies. Apartheid South Africa, subject to international trade sanctions, developed coal for use as a liquid; in fact the world's largest producer of this fuel is South African company Sasol. The technology may have helped Fascist regimes, but it has never fulfilled expectations as a widely deployed commercial fuel.

The following quote highlights the expectation surrounding turning coal into liquids. 'The development of synthetic liquids and gas will have a marked effect on competition in the energy market. Substitution of synthetic gas and oil from coal will probably reduce the naturally mined oil and gas. It could render obsolete hundreds of millions of dollars of refining plants and mining equipment. The threat to the oil industry is real' (Ruttenberg and Associates, Inc.,1973). These words were written in 1973, but it was not the first time such ambitious predictions were made. In his seminal book on the history of oil, *The Prize*, Daniel Yergin quotes from a story printed in the *New*

York Times in 1948 proclaiming that in the future gasoline would be made from coal, air and water (Yergin, 1991).

Turning coal into a liquid that can be put in a motor vehicle is unlikely ever to live up to this rosy forecast, largely because it is very energy intensive and the conversion process involves emitting almost double the CO_2 of conventional oil. That said, the US, Australia, China and South Africa are all investing in coal-to-liquids technology, with the aim to reduce their dependence on imported oil.

The Answer My Friend, is Blowing in the Wind

The drive to reduce greenhouse gas emissions has created demand for electricity generation that emits low or no emissions, such as wind and solar – known as renewable energies because they come from natural sources (as opposed to fossil fuels, which have a finite supply). Politicians all over the world are falling into line. It is now rare for any government anywhere in the world not to have a renewable energy policy; even the big emitters such as the US and China.

Hydrocarbon rich Russia also has a low emissions energy policy in that it is pursuing an expansion of its nuclear energy capacity and hydroelectric power; although on a global scale concerns about water supplies in parts of the developing world and environmental concerns about dam construction mean that hydroelectric power's share of the overall pie is likely to remain small. Even oil-rich countries in the Middle East are looking at cleaner energies. Abu Dhabi, the richest emirate of the United Arab Emirates, has a $15 billion plan to build a city that will be carbon neutral and will have no cars.

Renewable energy is the fastest growing energy sector in percentage terms, but in absolute terms the gains in coal and gas each year outweigh the additional power generation capacity from wind and solar. The growth of these markets has created new industries and made many 'eco-friendly millionaires'.

Wind power is not exactly revolutionary. Windmills were around when Cervantes was writing his classic *Don Quixote*; Senor Quixote charging at the windmills thinking, in his delusion, that they were giants. But recently, wind power in particular has grown enormously. Today, a long drive anywhere in the world will most likely take in the sight of these whirring giants of the energy sector. I've seen wind farms as far afield as Donegal in northwest Ireland on the very western tip of Europe; in the Alpujarras mountains south of the Andalusian city of Granada in southern Spain; in Iowa in Midwest America and south of Coimbatore in Tamil Nadu in southern India.

It is in India, though, where wind energy has become an essential part of the country's expansion. It started with the Indian Ministry of New and Renewable Energy in 1982 as a backlash against the high oil prices of the 1970s. According to Shri Subramanian, secretary of the ministry, wind has made the most advances because it can be installed at the local village level without building expensive transmission power lines to connect the village to the power grid.

India is the fourth largest producer of electricity from wind in the world and it has one of the biggest global producers of wind turbines in Suzlon Energy. Suzlon was formerly a textile business but shortages in the local electricity supply forced the owner Tulsi Tanti and his brothers to seek alternative power sources. They decided to buy some windmills, later ditching the textile business to focus on pioneering wind as an energy source. The Suzlon business was founded in Pune, which is in the western Indian state of Maharashtra. It was here that Enron built the giant ill-fated Dabhol gas-fired power plant to address India's power shortages and provide electricity to towns like Pune. In an ironic twist Suzlon has helped to address India's power shortages through a more modest solution: wind, a business model that has helped Suzlon expand internationally. Enron on the other hand, tried to go global with big projects such as Dabhol, but failed because its business model was ultimately flawed. 'The demand for wind power is driven more by shortages than by incentitives,' said Raghuraman Vaidhyanathan, an advisor to Suzlon.

Despite the growth in wind and other renewable energies – such as biomass which involves the burning of wood – collectively they still equate to about the same portion of the global energy pie as

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they did in the early 1970s, mainly because hydropower has remained static. Renewable energy needs not only government legislation, but also greater research and development to meet the future energy demands and lower greenhouse gases. In Denmark for example, the stimulation of renewable energy technology through government assisted programmes has resulted in wind energy accounting for 19 % of total electricity consumed in 2005. It's one of the few countries able to boast of economic expansion and falling greenhouse emissions, accomplished not only through the installation of wind turbines, but also through domestic energy efficiency measures, such as home insulation and better public transport.

One issue that has held back the wider adoption of wind or solar energy is that neither source is able to store power. This limits their ability to generate electricity to meet periods of peak demand. Wind does not blow at the exact moment when power is needed and the same goes for the sun – it shines during the day, but most solar power is actually needed when it gets dark and lights are switched on at home.

There are projects currently working on wind storage capacity. Just west of Des Moines, state capital of Iowa, amid the corn and soya bean fields, is the Iowa Stored Energy Park, which is using an underground aquifer as a test bed to store power from the wind farm located above. If successful it could radically change the dynamics of the wind power industry (and prove that Bob Dylan had a point when he sang, 'the answer is blowin' in the wind'). The project is backed by utilities in Iowa where wind power is becoming increasingly popular with farmers, who are installing wind farms as another potential revenue stream, selling electricity back to the power grid. But there's a long wait: demand for wind turbines is high. 'Worldwide there is such demand for wind turbines that prices have gone up significantly, and I will not be able to get them until 2009. I went out and bought ten turbines, but that is relatively small – manufacturers won't really work with you unless you are ordering 100 or 200 turbines,' said Philip Sundblad, a corn farmer and district director of Iowa Farm Bureau.

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California is also embracing wind power. Arnold Schwarzenegger, the state's governor, is writing into law that a third of the Golden State's electricity must come from renewable sources by 2020 (California Energy Commission, 2007). To achieve this goal California plans to spend $2.2 billion installing solar panels on the roofs of more than a million homes, including low-income and affordable housing projects, to ensure that solar is adopted across the board. California is the most visible of government and local authorities around the world to have taken a proactive stance on climate change and energy security, partly because it is run by a former bodybuilder turned Hollywood star who is married to a member of one of the most famous American families. But visit any city around the world and chances are that the local buses will run on hydrogen, biofuels or liquefied or compressed natural gas. These buses are expensive; but they offer an opportunity for the local authority to demonstrate its green credentials.

With more proactive legislation on renewable energy and higher energy prices, the money people in the San Francisco area who backed the computer, internet and telecommunications technology start-ups in the 1980s and 1990s are turning their attention and dollars to renewable energy and energy-efficient technologies such as longer-burning light bulbs and electric cars. With the combination of dollars and brains, the proponents of renewable energy – also known as clean energy – are hoping that technological advancements will be made in the areas of solar, wind and biofuels in the same way that a mobile phone was turned from the electronic brick of the 80s to a slimline device that can send emails, take pictures and play music. The innovations from Silicon Valley have also led to computers light enough to carry around without dislocating your shoulder, with enough power and software to make telephone calls, download documents, book airline tickets, watch a video or listen to any radio station in the world.

Clean energy venture capital converts are optimistic that what they were able to achieve in IT they can repeat in energy. Vinod Khosla is a founder of Sun-Microsystems and a partner in venture capital group Kleiner Perkins Caufield & Byers, which helped fund Google and teamed up in 2007 with Al Gore to seek clean and green technology investments. The Indian-born entrepreneur has his own investment firm, Khosla Partners, which has a portfolio of renewable energy investments from cellulosic ethanol to solar technology, plastics, building materials and electrical efficiency. Google founders Sergey Brin and Larry Page are investors in Nanosolar, a solar-film technology group, and are promoters of plug-in cars as well as trying to make the company carbon-neutral. PayPal founder Elon Musk, who sold his electronic payments company to Ebay for $1.5 billion, has become the major financier of Tesla, the electric sports car. Craig Venter, pioneer of the human genome that cracked the DNA code first, is applying the same technique to plants in an effort to make biofuels from plants more effectively.

The two educational institutions in California credited with nurturing the brains and talent that spurned the tech revolution, Stanford and Berkeley Universities, have also established their own clean energy research arms. 'Energy was never an area for venture capital before, because it was considered a large upfront cost to get in,' said Guy Caruso, Administrator of the Energy Information Administration (EIA), a statistical arm of the United States Department of Energy. The barrier to entry is now pretty small, almost anyone it seems can set up an ethanol plant. The big thing would be whether this capital would bring investment of the scale that is needed; you are talking about a few per cent, if it stimulates technology that leads to bigger things.

Terry Tamminen, energy adviser to governor Schwarzenegger, displays a typical Californian-style confidence when it comes to technological solutions for the energy challenge. Tamminen describes thin-films of solar that can cover windows and roofs in the home and on skyscraper buildings, absorbing heat and turning it into power. He speaks of more energy-efficient solar panels, and wider deployment of other energy-saving technology such as LED (light-emitting diodes) lighting – known as 'intelligent lighting' because it is computer controlled to provide greater control of the lighting systems in large buildings. The art deco Empire State Building in New York (best known for King Kong's last stand) has installed this type of system in an effort to reduce carbon emissions and power costs. More research is being carried out on motion sensors which trigger lights when somebody moves from room to room inside the house.

Total investment (that is not just venture capital) in 'clean' or low-carbon technology was $74bn in 2007, according to Michael Liebreich, founder of consultancy New Energy Finance (Harvey and Allison, 2007). A more ambitious renewable energy programme that puts the aspirations of California and its venture capitalists in the shade is the Space-based Solar Power programme, directed by the Pentagon-based US National Security Space Office (NSSO). Its aims are like something out of a science fiction film: the idea is to put large solar shields in space, that can beam solar rays back to Earth (National Security Space Office, 2007).[22] The NSSO justifies its pursuit of an improbable solution by saying that, 'Every energy resource opportunity, including those from space, must be fully explored to determine its ability to contribute toward solving mankind's looming energy supply and security dilemma.'

The lack of widespread penetration by wind and solar energy because of the storage issues and the need for lower emissions has also led to the re-emergence of nuclear this decade.

The Nuclear Quandary

The nuclear industry has rebranded itself as an emissions-clean alternative to fossil fuels, without the energy security issues that dog oil and gas. One of the best examples of the changing political landscape for the nuclear industry was the reversal in the British government's position on nuclear. When the UK government, then led by Prime Minister Tony Blair, unveiled its energy white paper in 2003, the government had maintained its line from the previous decade on the decommissioning of nuclear energy plants. Within three years the government had released another long-term strategic review of its energy industry, putting the nuclear industry back in the frame.[23] This backtracking

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has been repeated around the world. Many countries that have been averse to nuclear in the past are reconsidering the nuclear option. Proponents of nuclear energy argue that the world would not be emitting so many greenhouse gases had nuclear continued on its trajectory of expansion in the 1960s.

In the 1950s nuclear was touted as the fuel of the future. A fuel that would be so cheap it did not need metering. President Eisenhower gave the go-ahead to commercialize nuclear energy in the wake of his 'Atoms for Peace' speech in 1953. Initially, there were optimistic predictions made about the technology, such as nuclear-fuelled cars, but a spate of catastrophic accidents beginning in the 1970s – culminating in the Chernobyl disaster in Ukraine in April 1984 – halted any further expansion of the nuclear energy industry. For almost 20 years nobody wanted to take the risk of building a nuclear plant for fear of further accidents and concerns about the storage of nuclear waste, which remains one of the biggest impediments to the growth of nuclear energy.

To overcome this negative perception, the nuclear industry maintains that it can still play a key role in reducing carbon emissions. Nuclear power stations around the world avoid what would otherwise be about 2 billion tonnes of carbon dioxide emissions each year.[24] Actual carbon savings, though, vary from country to country. Nuclear is not totally carbon-free, but comparable to the emissions from renewables such as wind power. Plus nuclear does not have the same security issues that confront oil and gas. Uranium – the metallic element that is turned into nuclear power – comes largely from politically stable countries such as Canada and Australia. Relatively little uranium is required to create the nuclear power that, in turn, produces electricity, therefore the volume of uranium required for the future is nowhere near the vast quantity of fossil fuels required. Like other commodity markets, it is the demand from China[25] and India that is really changing the dynamics of the nuclear industry.

The world's electricity capacity from nuclear power is expected to expand by about a fifth by 2030, according to the IEA (International Energy Agency, 2007). Most of that will be in China and India, with only a handful of other countries – the US, Russia, Japan and South Korea – also set to expand nuclear capacity. Over the next 20 years existing facilities built in the 1970s and 1980s will have to be replaced, since most nuclear plants have a lifespan of 40 years. New nuclear plants are estimated to cost more than double coal-fired power stations, and the industry relies to a certain extent on government tax breaks. Nuclear has received one of the biggest shares in research and development funding from the US government, which committed itself in 2003 to an ambitious research programme to develop nuclear fusion (the holy grail of nuclear technology) as it potentially eliminates the issue of waste management. The project funded through the International Thermonuclear Experimental Reactor (ITER) will see the construction of a pilot plant in southern France.[26]

The rate of nuclear expansion for electricity (as opposed to nuclear weapons) will substantially increase the demand for uranium.

Uranium-101

The World Nuclear Association estimates that the demand for uranium for the purposes of electricity generation will increase by 70 % from 2006 to 2030 (World Nuclear Association, 2007). In 2007 Canada and Australia produced more than half of the world's uranium, though Kazakhstan could challenge both countries as the world's biggest producer; the central Asian country has been rapidly expanding its output. The revival of the nuclear sector has prompted a worldwide search for new sources of uranium, after decades of negligible exploration activity (following a glut in supply from the uranium-mining boom of the 1970s). In the past five years more than 450 companies have listed their shares on stock exchanges in Australia, Canada, the United Kingdom and the US, promising to find uranium from all corners of the globe.

Uranium is actually a very common element on the Earth's surface.[27] It is mined like a metal, but unlike other metals, no objects or mechanical structures are made from it. Although it was used for the manufacture of ceramics and glass in the early 20th century (US

Geological Survey, 2001). Like other metals it also has to go through several stages of processing before it can be used. It's made up of different elements but only one very small element – uranium-235 – can be turned into a power source. Uranium-235 makes up only 0.7 % of all the uranium that is mined, and therefore it needs to be enriched to make it more commercially viable to use in power generation. Given that such a tiny proportion of the ore contains usable uranium from such a large volume of rock taken from the mine, the milling of the uranium from the rock is done close to the mine. It would be uneconomic to transport the ore away for processing. After milling it is turned into uranium oxide U3O8 – better known as yellowcake. The vast majority – around 99.3 % – of uranium ore is not used to generate nuclear power.

Making uranium into a more commercial fuel involves turning uranium into a gas – uranium hexafluoride UF6 – and then converting it back into an element again. The uranium now has an energy concentration of 4 %. Finally the uranium is burned into ceramic pellets and placed in fuel rods, which make up the fuel assembly that goes into the nuclear reactor. Like other mineral processing, the large volume of poor grade uranium left over is uneconomic to process unless the uranium price is high.

A tenth of the world's uranium supply has so far come from the plutonium (processed uranium) in decommissioned US and Russian nuclear warheads dismantled under the Megatons to Megawatts programme.[28] Lack of new supply combined with uncertainty over the future of the US–Russia pact means that the uranium price has more than quadrupled in recent years. Such is the demand for uranium that it has created tightness in the supply and demand equation.

There have been several previous attempts to commoditize the uranium market. In the 1980s and 1990s, Oren Benton (through his flagship company Nuexco Trading Corporation) bought Russian uranium and sold it into Western markets. The profits he made from uranium trading were used to build a business empire that included a controlling interest in the Colorado Rockies baseball team before the business imploded under a $500 million debt in 1996. Benton's legacy though, was that he created a spot market in uranium, previously dominated by long-term contracts. Given the fluctuations in prices, more uranium is being traded on the spot market now.

The New York Mercantile Exchange (Nymex), the world's largest energy futures exchange, launched a cash-settled uranium contract in 2007, but a physical uranium market is also emerging where utilities, producers and investors will be able to buy and sell uranium. They won't be able to physically move the material though. It's tightly controlled under an intergovernmental arrangement to stop uranium ending up in the hands of renegades who want to make nuclear weapons. What investors can buy and sell are the rights to hold the uranium, which is kept in registered warehouses. This is similar to the conditions for trading in base metals on the London Metal Exchange. There is growing demand from new players who want to make money from trading uranium. If this market takes off it will ensure enough trading volumes in the market for participants to buy and sell quickly, key to all successful financial and commodity markets (Raghavjee, 2006).

In the long term though, the potential of nuclear power is dependent upon the uranium resources available. Various studies have been done, some estimating up to 100 years of supply based on consumption levels seen this decade. Uranium, like other commodities we will examine in this book, is open to substitution if the price is high enough. Nuclear fuels can be made from thorium, another radioactive metallic element. It's similar to uranium but it doesn't have the waste issues associated with used uranium. Thorium was discovered in 1828 by the Swedish chemist Jons Jakob Berzelius, who named it after Thor, the Norse god of thunder. It can be found in small amounts in most rocks and soils, and it is about three times more abundant in the Earth's crust than uranium.

Thorium is also more energy efficient than uranium. Mined thorium is potentially usable in a reactor before it is enriched (compared with the 0.7 % of natural uranium). Thorium versus uranium is a bit like the betamax versus VHS debate that raged in the new era of video in the 1980s: VHS won out, but there are many who still argue today that Betamax was a better technology. Thorium-based nuclear reactors are a different technology to uranium, so unfortunately it is not a simple case of feeding a nuclear reactor in Europe or the US with thorium rather than uranium. A nuclear energy industry around thorium would involve an entirely new layer of infrastructure.

Burning the Midnight Oil

Of all the fossil fuels the role of oil in the global economy is the most vital. The world's primary modes of transportation are fuelled by petroleum products derived from oil, gasoline (petrol), diesel, jet fuel and bunker fuel. Without these liquids it would be impossible to travel by plane or boat or drive most cars. The fear about secure supply has triggered a race for viable alternatives to oil, such as hydrogen, liquid fuel from coal and gas and biofuels. The latter have gained much attention (and will be explored further in the second chapter). The search is now on for the second generation of biofuels, made from the backbone of plants and trees rather than from the fruit or seeds they bear. The desire for energy security has become more and more apparent. The demand for oil has not slowed down, in fact if anything it has accelerated with the unprecedented growth of China. The increase in demand comes at a time when oil supply from traditional sources in the North Sea and the Gulf of Mexico is declining – a trend that appears irreversible – leaving the world more reliant on oil supplies from the Middle East, Russia, central Asia and West Africa.

Most of the world's oil will come from supplies held by the Opec cartel, the group of oil producers whose de facto leader is the oil kingdom of Saudi Arabia, the world's largest producer.[29] Opec has been a major beneficiary of high oil prices this decade, recording record export receipts that have been used by some Gulf countries to acquire overseas assets to diversify their economies away from oil dependency. Other Opec members, such as Venezuela, have spent the dividends on large social programmes and a significant slice of Iran's oil earnings have been spent on importing refined oil products and subsidizing gasoline for its fast-expanding population. It is little wonder that both Iran and Venezuela have become the most vocal supporters of higher oil prices. Their oil production profile remains static, due to a lack of adequate reinvestment in the industry that provides both nations with their relative wealth.

Higher oil prices and increased demand have given Opec more leverage when it comes to its oil-production policies. Opec behaves more consistently like a cartel now than at any other time in its near 50-year history. When it was founded in 1960 most of the oil in the member countries was produced by Western oil companies. This arrangement changed through the nationalization of the respective oil sectors in Opec countries during the 1960s and early 1970s, which resulted in government-owned oil companies controlling supplies. The shift in ownership occurred around the same time as the Arab oil embargo in 1973, when oil-producing countries first exercised their power. The change in power and cohesion was relatively brief: two Opec members, Iran and Iraq, after the Islamic revolution in Iran in 1979, sent oil prices higher, only for them to collapse as oil demand fell due to the arrival of new supplies from the North Sea and the Gulf of Mexico, and the switch from oil power generation to alternative sources such as gas and coal.

In the 1990s the world faced an oil glut as Venezuela ramped up its oil production to increase its global oil market share. This policy of increasing market share was reversed when Hugo Chavez was elected in 1998. The election of the former army colonel marked a turning point in the oil price, which bottomed to less than $10 a barrel, leading *The Economist* magazine to predict in March 1999, a $10 barrel forever. The collapse in oil price hit the oil dependent economies of Opec hard. They responded by cutting oil supplies and adopting a more vigilant oil-production policy, meeting more regularly and fine-tuning supplies to ensure that consuming nations could not build up their oil inventories to the same levels again. Opec has been further aided by the succession of Vladimir Putin in Russia in December 1999, who became a de facto friend of Opec (Russia now has observer status at Opec meetings). Putin has also wrestled for control of oil production in Russia, which is the second largest exporter after Saudi Arabia. It is now back under state control following the privatization of the sector under President Yeltsin in the 1990s. The move to state control has coincided with a slowdown in Russian oil production growth.

Politicians from oil-importing countries have blamed Opec for high oil prices, but it is not that simple. If European politicians were really concerned about high oil prices, they could cut the taxes which make up about three-quarters of the retail price of petroleum products, and in the US, driving more fuel-efficient cars would go some way to reducing the country's demand for oil.[30] But that is not to let Opec totally off the hook; its members are increasingly addicted to higher oil prices to balance the government budgets. Some of the oil revenues subsidize telephone calls, water usage, and low or no personal income tax rates for local citizens, as well as financing the increasing cost of investment in new oil production. Opec oil ministers consistently talk down the cartel's importance in the oil market by blaming high oil prices on other factors such as a lack of refining capacity, the weaker dollar and competition from biofuels and speculators in oil markets. The first two reasons may have merit, but the latter two don't stand up under closer scrutiny, and will be discussed in Chapters 2 and 5 respectively.

For the oil-importing countries – the US, China, India, Japan and Europe – the increasing influence of Opec and Russia is a cause for concern on two fronts. Firstly, political risk: the troubles in the Middle East are well known – the Israel–Palestine issue, the rising influence of Hezbollah in Lebanon and the repercussions in terms of political stability, the rise of Sunni militant extremists across the Islamic world borne out of the puritanical ideology of Wahhabism in Saudi Arabia, the war in Iraq, the nuclear ambitions of Iran, the confrontation between Turkish troops and Kurds and the political instability of Pakistan, not forgetting the dynamics of Shia–Sunni relations in many countries of the Islamic world. These political issues are not going to disappear in the foreseeable future.

The second area of concern for consuming countries is longevity of supplies: the estimation of oil reserves is an opaque art that few outside the oil world understand. There is no global standard to measure oil reserves, nor is there any independent scrutiny. It comes down to the estimates by the oil host countries and the blind trust of the

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consuming nations that the guesswork is correct. This relationship is not a strong foundation for oil consumers to secure long term supplies of oil. Consuming nations are making alternative arrangements by looking at other energy sources. This ambiguity about global oil reserves has given rise to the peak oil theory.

Based on the number of recent large oil discoveries (not many), and the age of many of the existing oil fields in the Middle East (pretty old), the peak oil theorists may have a point. But the restrictions enforced by oil-producing nations on foreign companies and a desire not to maximize output has, for the short term at least, blurred the issue on peak oil. In his book *Twilight in the Desert,* Matthew Simmons, a Houston-based investment banker, warned that Saudi Arabian oil reserves – estimated to make up about a quarter of global oil reserves – could face serious and irreversible decline (Simmons, 2005). This prompted an angry response from Saudi Aramco, which dismissed Simmons's assertion. Nevertheless, concerns about the sustainability of high oil supplies linger.

Mehdi Varzi, the independent oil consultant who formerly headed energy research at Dresdner Kleinwort bank, wrote a report for them on Opec production. It took eight months to write and analyses supply field by field in each of the countries. Some of the fields were discovered 50 years ago, and Varzi found many were on their way to depletion. 'Opec production is depleting by 5 % a year, which means it has to find an additional 1.5 million barrels a day just to stay still,' he said, though he added that each Opec country has its own individual set of problems surrounding production and reserves. Whether the predictions about oil and other resource peaks are correct, we probably won't know until after the event. Right now, a higher oil price has resulted in exploration of other oil-containing resources, such as the oil sand deposits of Canada.

Catch 22

The wealth in oil-producing countries has provided more money to a rapidly growing population to spend on more and bigger vehicles. The Middle East is one of the fastest growing regions for oil demand, putting it just behind China and India. Iran's expanding population and its generous fuel subsidy programme has led to a rise in domestic oil consumption rates from less than 700 000 barrels a day in 1976 (when it was producing close to 6 million barrels a day) to more than 1.5 million barrels a day now (when it is actually struggling to produce more than 4 million barrels a day). This growing demand of course leaves less for export. In fact, Iran is importing more petroleum products from places like India, because of the lack of domestic refinery capacity to process its own oil (with Iranian drivers not paying much more than 42 US cents a gallon at the pump, it is little wonder they behave like racing car drivers on the wide roads of Tehran!)[31] The oil consumption and production trends for Iran pose a huge challenge for the country and for the global oil market, because they could lead to tighter oil supplies for importing countries.

Part of the reason Iran's oil production has not regained the levels last seen in the Shah's era is because some of its oilfields were bombed by Saddam Hussein during the eight-year war between the two neighbours. Rather naively, I first went to Iran during this period. Although I never saw any sign of conflict, hundreds of black and white photos of young men posted along the main roads of small towns and villages acted as a poignant reminder of who had died in the war. One of my memories of Iran at the time is the prevalence of Hillman Hunters on the roads. The Hillman was renamed the Paykan in Iran after the Shah government bought the rights to it and continued to mass-produce the car well after they disappeared from British roads. I travelled through war-torn Iran for five days on a bus, but the first time during this period that I saw a gun being fired was when we crossed the border into Pakistan and the border guard in his remote hut in the Baluchistan desert, got out his Enfield .303 rifle and challenged our bus driver to a target contest.

The unpredictability of the Middle East and large parts of south Asia has prompted energy-importing governments to respond. Energy policies now have the lofty aim of reducing their oil dependency from unstable suppliers and energy efficiency research programmes and alternative clean energy sources are being developed, as energy policy becomes entwined with climate change.

The difference between now and the 1970s is that there are no new conventional North Sea oil fields coming on, and the promises of the new supply from the Caspian Sea and central Asia have consistently failed to live up to expectations. At the same time demand for oil – predominately for transportation – remains strong due to the emerging mobile classes in China and India. The cost of cars is coming down, too. Tata Motors, the Indian carmaker, intends to sell its new Tata Nano for $2500 each, or about half the cost of the next cheapest car.

Today's equivalent of the North Sea oil fields – that is, oil supply from a politically stable region – is the Canadian tar sands, also known as oil sands. These are a combination of clay, sand, water and bitumen in a rock formation. Unlike conventional oil, which is drilled, tar sands near the surface are mined using open pit techniques, a common method normally used for large metal deposits. Once the rock is removed from the ground, the oil content, which is bitumen, has to be separated, from the clay, water and sand. The bitumen, a rather thick, gooey substance, is processed to make it more viscous so that it can be refined and turned into a liquid for use in our cars.

The extra processes required to extract and refine tar sand compared with conventional oil add significantly to its cost. Only in recent years has it been economic to commercially exploit the deposits of tar and oil sands, found mainly in Canada and Venezuela. The rise in Canadian petroleum production from oil sands has created an oil rush in the state of Alberta, which has become the Saudi Arabia of unconventional oil, and tar sands provide a new source of supply for American drivers. The US imports more oil from Canada than any other country. Given their political and geographical proximity, this is probably as close as the US may get to energy independence. Canadian oil sands production is estimated to account for most of the net increase in oil production from countries outside of the Opec grouping. By 2030, Canada is projected to produce as much oil as Iran does today. But it is a more energy intensive and costly process. It requires a lot of gas, another fossil fuel Canada exports to its southern neighbour; about 85 % of the US gas imports come from Canada. The oil sands sector is consuming so much gas that Canada predicts

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it will become a net gas importer in 20 year's time (National Energy Board, 2007), a fact that brings a whole new meaning to energy security, since most of the world's gas reserves are in the Middle East and Russia. At present the US and Canada account for more than a quarter of global gas demand.[32]

Not only do oil sands require a lot of gas for processing, but they are a big polluter. Oil sands production is estimated to release more than double the emissions of conventional oil, a major factor in emissions growth in Canada. Yet the Canadian government has signed up to the Kyoto Protocol, a pact to reduce emissions. Another factor contributing to the release of emissions from oil sands mining is deforestation in the area (which is bigger than the state of Florida) containing the oil sands deposits. The Alberta state government said that its greenhouse gas emissions from all sources have risen by 37 % since 1990, far more than the national average of 25 % for all of Canada. Although power generation remains the largest source for Canada's greenhouse emissions, oil sands and heavy oil production make up more than a quarter of all of the country's emissions, and more than 40 % of Alberta's (Alberta Government, 2007).

The US has its own unconventional oil resource, in the form of shale oil. This generally refers to any sedimentary rock containing a material called kerogen, which is like fossilized algae and was formed millions of years ago. Most of the US shale oil deposits are in the Rocky Mountain region.[33] Back in the oil crisis of the 1970s, Exxon embarked on developing shale oil, spending about $1 billion at the time on the Colony Project. After oil prices fell in the 1980s and the cost of extracting shale oil continued to rise, Exxon abandoned its plan (Yergin, 1991).

Even now, the commercialization of this resource is decades away according to the National Petroleum Council, headed by former ExxonMobil chairman Lee Raymond. Oil prices around $100 a barrel, it is still hard for shale oil to be economic. One of the factors inhibiting the exploitation of shale oil is the amount of water required to extract it – an estimated 1.2 barrels of water for each barrel of shale oil. The US shale deposits are in dry areas where rainfall is minimal.

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Developers of oil shale projects would therefore need to buy water rights – a complicated affair in Colorado, and the demand for water is becoming even more competitive with the expanding population in the Rocky Mountain region.

US energy researchers have also experimented with the live form of algae. The US department of energy spent 20 years researching the prospect of turning algae into biodiesel, but found that it cost twice as much as making gasoline from crude oil (National Renewable Energy Laboratary, 1998). Large investments in the production of oil from natural gas have failed expectations. Qatar pulled the plug on one of the most ambitious gas-to-liquid programmes because of escalating costs.

The search for oil above all other fossil fuels can be explained by the fact that it is one of the most efficient. When discussing energy it is worth assessing the energy value for each source – it becomes clear why oil stands out among all fossil fuels and why it is going to be a tough job replacing it.

Here Comes the Science

Energy is measured in units called joules. A joule is a minuscule amount of energy, far smaller than the energy we expend drinking a drop of liquid or lifting a lettuce leaf. When people speak of joules they normally refer to them by the millions or billions: that is, megajoules (MJ) or gigajoules (GJ). Energy can be measured by its physical characteristics – weight, volume – or in its nature – whether it is a solid, liquid or gas. Coal, for instance, has fewer joules per kilogram than the same weight in oil, making oil the favourite in terms of what you're going to get out of the effort of finding and producing it. In fact, oil is superior to all other fossil fuels, which is why it is the most strategic of all energy. The weight of oil is 43 MJ per kilogram compared with 25.5 MJ for ethanol from grain, 24 MJ for coal, 18 MJ for wood and 4.4 MJ for oil shale (the small content of energy power contained in oil shale is one of the factors that have limited its commercial viability).

In terms of volume, a cubic metre of oil contains 35 000 MJ of energy, a cubic metre of coal around 27 500 MJ, ethanol about 20 000 MJ, and a cubic metre of gas only 35 MJ. Another point in oil's favour is that it is a liquid, so it's easier to transport and store.

Shrinking Big Oil

As their conventional oil reserve bases shrink, the large Western oil companies have become major investors in projects like the Canadian oil sands, gas to liquids, shale oil and strategies for producing hydrogen. Back in the 1970s, US oil companies were also diversifying out of conventional oil and bought production, reserves and milling capacity in the uranium industry. In 1970, seventeen oil companies, including Exxon, controlled about 48 % of the known US low-cost uranium reserves (Ruttenberg and Associates, Inc., 1973).[34]

A major problem faced by the energy industry is a lack of skilled personnel who can develop large-scale oil and gas projects. The 1980s and 1990s saw fewer petroleum engineers coming out of universities – the industry was perceived as dirty and did not have the glamour of the technology, finance or communications sectors. Nearly half the personnel in the US energy industries will be eligible for retirement within the next ten years and a 'demographic cliff' is looming in all areas of energy industry employment. An American Petroleum Institute survey in 2004 indicated that by 2009 there would be a 38 % shortage of engineers and geoscientists and a 28 % shortage of instrumentation and electrical workers in the US oil and gas industry (National Petroleum Council, 2007).

The high price of oil today is blamed on the wastefulness of the finite resource when prices were cheap. The gains made in fuel engine efficiency in the wake of tighter standards in the aftermath of the 1970s energy crisis have largely been lost in the US through the sale of bigger cars; the increased weight and horsepower have meant that fuel economy levels have been flat for the past two decades (National Petroleum Council, 2007). 'You had a period of 25 years where the American public had a declining share of their personal income that would go to personal mobility and they chose to spend that gain in personal disposable income on heavier vehicles and higher horsepower,' said Guy Caruso from the EIA.'The fall in energy prices through the 1980s and 1990s has meant that energy costs for the household budget fell from 14 % in the early 1980s to about 7 % earlier this decade,' said Mr Caruso, who is in charge of one of the most comprehensive energy data-gathering bodies in the world and has been analysing energy markets for the past 30 years. Gains in energy efficiency in both residential and commercial buildings have been offset by the increase in the size of the average US home. The trend is mirrored in household appliances such as the refrigerator, where an increase in size has negated the gains made in energy-efficient design. 'The big difference with this energy challenge is that this is really driven by very strong economic growth,' said Mr Caruso, who told me that energy prices, particularly oil, are likely to remain high, which would underwrite the investment needed to commercialize cleaner and more sustainable energy sources.

On The Road

Terry Tamminen explained how California is gearing up for hydrogen cars and how the car industry is responding. Just days prior to meeting Tamminen near his Santa Monica office, Honda unveiled its fuel cell car at the November 2007 Los Angeles Motor Show. The Japanese car maker said a limited number of the FCX Clarity would be ready in the summer of 2008 in southern California at a cost comparable to the conventional car (based over the lifespan of the car when running costs and maintenance are factored into the equation). At the same show, General Motors announced that its Chevrolet Silverado hybrid pick-up truck would be available in late 2008. The truck will be one of its first passenger vehicles to go hybrid – long after its Japanese rivals Toyota and Honda launched their respective hybrids: the Prius and Civic have become market leaders in hybrid cars.

The unveiling of a clean energy car in a city noted for its traffic jams and pollution is welcome. The Pico Boulevard from the beachside

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suburb in Santa Monica to the convention centre in downtown LA is always clogged with traffic and introducing less-polluting cars will help clear the air (though it may not do much about the traffic jams). 'We will have 200 hydrogen stations by 2010, with thousands of vehicles, and we are in talks with governments up and down the coast from British Columbia to Baja (in Mexico) so that you can drive all the way in a hydrogen car,' said Tamminen, sporting a blue jacket with a logo for California's hydrogen highway.

The hydrogen initiative by California may represent just one of the 50 US states, but with 30 million motor vehicles, California is one of the world's top ten car markets. There are concerns about hydrogen storage at filling stations near residential areas. Hydrogen is highly flammable and the size of the storage tank in the car leaves little room for luggage in some prototype designs. California, though, has long been a supporter of cleaner energy cars. It supported the first modern electric car, which was built by General Motors and named EV1, short for Electric Vehicle 1. There were high hopes for the vehicle following California's well-intended Zero Emissions Vehicle (ZEV) mandate, but the project was abandoned after other car companies sued the state because they did not want to be mandated to produce electric cars, and the ZEV was subsequently dropped. The energy cleanliness of electric cars is also open to debate, since the vehicle is plugged into a network where electricity is generated from coal fired power stations. Toyota is looking to launch a plug-in Prius this year, which may stimulate more activity in the electric vehicle market.

America has become one of the largest markets for the sale of the Toyota Prius, which runs on a combination of electric motor (the part that gets the car started and powers the vehicle for low speeds) and the conventional combustion engine (the part that kicks in at higher speeds). Car companies have been designing more fuel-efficient gasoline and diesel cars as lower emissions and running costs become a key selling feature. That said, the era of cheap gasoline that Americans have enjoyed has led to more cars on the road. Getting millions of Americans to drive smaller, fuel-efficient cars will be key to determining the success of environmentally friendly cars.

Tamminen's view is that Americans have had subsidied oil for too long, as the true cost of oil is not factored into its price. A life-long environmentalist, he said it is not just the carbon cost which is increasingly becoming part of the energy market. 'People need to look at the true cost of oil, in terms of the war in Iraq and health care costs. Once people internalize that, then things start to change,' said Tamminen, who wrote a book on the subject: *Lives Per Gallon*. Tamminen is also a director of Vantage Partners in the San Francisco Bay area, which is investing in cellulosic technology to make the second generation biofuels. Proponents promise these will eventually be cheaper than the current biofuels made from sugar, corn and oilseeds.

Biofuels: The Next Generation

President Bush likes biofuels. He has boosted the emerging industry with generous tax breaks and frequently talked about them; most notably during his 2006 State of the Union speech, when he said: 'We'll also fund additional research in cutting-edge methods of producing ethanol, not just from corn, but from wood chips and stalks, or switch grass. Our goal is to make this new kind of ethanol practical and competitive within six years.' It's a timeframe that most energy experts consider optimistic.

Robert Brown, head of Biorenewables at Iowa University, said that there are four goals of the so-called 'second generation' biofuels, and economics is not one of them. The goals are: reduce US dependence on imported petroleum; reduce greenhouse gas emissions; increase opportunities for rural development in places such as Iowa; and increase and provide new opportunities for agriculture. Brown, who has worked on chemical lasers under the Reagan Star Wars Programme and on research projects to convert biomass into gas, acknowledges that cellulosic biomass is not the best material in the world to work with: it has moisture in it and therefore it has to be dried, and it is a solid material and not a more transportable liquid. It also has a lot of oxygen in it. One of the problems with making biofuels from woody

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or plant material, Brown explained to me, is how to break down nature's structure. It is a bit like the conventional oil production process versus the oil sands production process, in that there are a lot more costly steps involved.

All plants have an energy source, known as sugars. They're different to the one we put in our cup of tea, but they form the cellulose of the plant. This cellulose is bonded to the lignin, which is like the human equivalent of bones in the plant structure. Therein lies the problem: the separation of the two. Cellulose can be turned into ethanol, but lignin cannot and it makes up about a quarter of the biomass. Enzymes are used to break down these biological barriers to create an alcoholic liquid. The lignin cannot be fermented, but it does hold value in that it can be used as a binder for asphalt to build roads. Depending on the different processes, up to 70 % of the biomass could be converted into cellulosic ethanol. This biomass could be the native American grasses that once graced the prairies before European settlement, or the residue from corn plants, known as corn stover or wood waste. 'I don't think biofuels will be cheaper than gasoline was in its heyday, but there are other factors besides the selling price that will determine the success of cellulosic ethanol, such as cleaner or more secure fuel,' said Brown.

Brown believes that more money should be invested in cellulosic ethanol. 'When you think that the new Superman movie, which was made in Iowa, cost $350 million, and all we can put in is $500m (the budget of the US Department of Energy for cellulosic, biobuthanol research in 2007), there is room to do more,' he said. At the same time he warned that too much money could also create a problem. The US government has a mixed record on funding of energy research and development programmes. 'If we toss too much money at a problem, it won't be spent wisely, the same as what happened on the Manhattan project and the race to the Moon, so we have to be careful here.'

Not all are convinced about the take-up of cellulosic ethanol though, including Brown's colleagues at Iowa State University. Bruce Babcock, Head of Research at the Center for Agricultural and Rural Research Development at Iowa State University, said money would

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still determine the success of cellulosic ethanol. 'Each year the farmer in the Midwest has to decide whether to plant corn or soya beans, or a mix of the two depending on their selling price. But if he switches to grass or one of the other perennial grasses, then there is no need for all the farmers and the infrastructure that supports the corn industry, from the seed distributor to the John Deere dealership. These guys support the small towns across the Midwest – do you think all that is going to be given up for cellulosic ethanol?' said Babcock, who admitted that his views do not make him popular with energy policymakers. Babcock said the subsidies would need to be substantial in order for cellulosic ethanol to work. 'They are politically not palatable, and they are unaffordable,' he said.

Nevertheless, ConocoPhilips, the US oil company, has put $22.5 million into the Iowa Biorenewables wing. BP, one of the few other oil majors that is investing in biofuels, has put its money in a different pot. BP has teamed up with D1 Oils, a UK-based biodiesel producer. D1 is not using the traditional plants for biodiesel: it is using a non-food plant called jatropha. Together, BP and D1 have 200 000 acres of jatropha plantations across India, China, southeast Asia and Africa. Daimler also has a jatropha plantation in India.

Jatropha is not, strictly speaking, a second-generation fuel like cellulosic ethanol; it is a non-edible toxic oilseed that is part of the next stage of biofuels research. It moves biofuels away from the direct food versus fuel debate. Jatropha is thought to have originally come from Central America and is therefore suited to tropical environments. Since Portuguese traders took the plant to other parts of the world in the 16th century, it has been used mainly for medicinal purposes. Its potential as a biofuel was discovered only recently.

In comparison to other feedstocks for biofuels such as corn and sugar, relatively little research has gone into the plant. Yet many, including Goldman Sachs, the International Monetary Fund and the US government, are touting it as the next major biofuel that could be a cheaper replacement for biodiesel than existing feedstocks of soya oil, rapeseed oil and palm oil. What interests the plant breeders, biofuel promoters, governments and investors is the plant's ability to produce seeds with a high oil content of around 40 % (double the amount contained in a soya bean plant) and the fact that it can grow more plants per acre than soya beans. It is also seen as a plant that can be grown on dry marginal land in developing countries, thereby offering farmers an alternative crop to grow and a chance to cash in on the global biofuel boom.

Promoters say that jatropha does not compete with food crops because it can be grown on land that is not used for food production. However, for the plant to boost its yield it needs cultivation and that often involves using irrigation. If water is used for growing biofuel crops, critics will ask why it's not being used for growing food crops. There is little knowledge of growing jatropha for commercial purposes and therefore there are a great number of unknowns. Left to the wild, jatropha grows tall and leafy, and it grows with little maintenance, but plant breeders prefer a smaller, stocky jatropha plant that is full of seeds and to get it in this optimal condition it requires attention.

A factor which has prompted investment in jatropha is that it has good fatty acid properties that are necessary for transfercation (refining) into biodiesel. The research is very much a work in progress and there is no commercial production yet. All this is expected to change by the end of the decade. India is fast becoming a leading player in this emerging fuel. It not only faces a growing import bill for oil, but has one of the largest rural populations in the world, with the majority of its populace dependent on farming for their income. Because of the importance of farming, India has a large agricultural science research community, and, like the US, a desire to be energy independent.

Dr Jaap Vromans, a plant biologist who worked for D1 as a consultant, is one of the alchemists charged with turning this toxic weed into a fuel fit to power your car. He is based in Coimbatore in the southern Indian state of Tamil Nadu, the second largest in the state after Chennai, formerly Madras. The city is dotted with water tanks spouting like giant mushrooms above the palm trees that provide a welcome shade to the busy streets of this bustling town, better known for its textiles and automotive parts. Its links to the textile trade have given the town the title 'the Manchester of South India.' (though Manchester's link to the world of cotton is now ancient history).

Coimbatore makes an unlikely setting for the new frontier in the oil industry.

The D1 Oils' Product Development Centre can be found on the outskirts of Coimbatore. The centre is one of its key research centres for jatropha, with similar ones set up in Swaziland and Thailand, covering Africa and southeast Asia respectively. The centre has visitors from the biofuels and agricultural world. Jim Bolger, the former prime minister of New Zealand (who now heads up the World Agricultural Forum, a St Louis-based non-government organization) had visited the centre a few months before my arrival. 'We get lots of people coming to see what we are doing. Almost every week we have a visitor. Whether they are from D1 Oils or from government, agriculture or biofuels, they are all here to see and learn what we are doing with jatropha,' said Vromans, who is finding that his role is quickly becoming part tour guide, part educator.

Anyone hoping that there will be large-scale commercial biodiesel production from jatropha in the short term will be disappointed; Dr Vromans predicts that it will take five to six years for the tree to develop. The goal is to have about three kilograms of oil per tree, and 2000 trees per hectare, making 6000 kg per ha. The oil content per seed is about 30 to 37 % and the rest of the seed weight is the seed cake, which can be used for fertilizer to grow the crop or to go into animal feed, even though it is toxic. It could even go into biomass to use for power generation. But it could be another ten years before there is a track record with the seeds consistently producing the desired oil and before the breeding techniques for the plant are fine-tuned around the world.

The Energy and Resource Institute (Teri), the New Delhi-based research group headed by Dr Rajendra K. Pachauri, the chairman of the Intergovernmental Panel on Climate Change, is also conducting research on jatropha. 'We should not be debating whether there is land for fuel or land for food, we should debate what areas are suitable for non-edible crops,' said Dr Adholeya, director of biotechnology and management in Teri's bioresources division. His office was prone to intermittent power cuts during our discussions, a regular occurrence across India due to prolonged power shortages. Indians are used to the lights going out while they are at work; which is why India has an ambitious, programme to electrify the country. When added to China's ambitions, it creates an enormous energy challenge for a generation. Meeting this challenge will require energy to come from more varied sources. In effect it is more democratic because the world will not be reliant on one source. As Tamminen put it, 'It is the democratization of our economy by the democratization of the fuel that drives the economy. There is nothing democratic about an oil baron or a coal baron. It is totally democratic to get wind power or solar power because everyone has access to the sun and wind.'

Avoiding the Inevitable

To avoid the type of environmental catastrophe experts are warning about, significant changes in behaviour and habits will be needed. Swapping to energy-efficient light bulbs is one step, but more needs to be done in terms of government policies at local, regional and national levels. When energy prices hit the hip pockets, public awareness is greater and consumers will start to modify their energy consumption.

While energy prices are high, money will be attracted to finding more energy sustainable solutions. The expansion in global coal supplies will divide traditional government allies. Coal miners and farmers in the US and Australia will battle with each other over the expansion of coal mines into farming areas and the use of local water supplies. Forrest E. Mars Jr, whose family owns Mars Inc., the confectionery company, is fighting against the development of coal and gas in the Powder River basin near his Montana ranch, while Australian farmers in the upper Hunter Valley, home to some of the country's richest farmland, are concerned about plans to develop coal deposits in the region so it can be shipped to China to burn in power stations.

Right now we are heading into a phase of greater take-up of renewable energy, but it is still not enough to offset the increase in greenhouse gas emissions. The next chapter will look more closely at the growing link between agriculture, energy and greenhouse gases.

Notes

1. Kynge (2006) wrote that the Chinese economy in 1400 was larger than Western Europe based on 1985 dollars.
2. The IEA estimated that China had 37 million cars at the end of 2006, almost a seven-fold increase since 1990. China surpassed Germany in 2004 as the world's third largest car market.
3. The IEA estimates that China will build 750 gigawatts of power in the period to 2015.
4. Some 105 gigawatts of new power plants, almost all of which are coal-fired, were built in 2006 alone – a rate of increase for which there is no precedent worldwide (International Energy Agency, 2007).
5. The IEA says one of the most popular Chinese refrigerators with a volume of 220 litres uses on average 1.2–1.3 kWh per day, compared with around 0.8 kWh per day in Europe.
6. The EIA estimates that by 1885, coal had overtaken wood as the major fuel in the US (Energy Information Administration, 2006).
7. Coal supplied almost half of US energy demand by 1945, and oil was less than a third (Energy Information Administration, 2006).
8. The Gas Exporting Countries Forum (GECF) was set up in 2001 as a forum for gas producers. Its members include Algeria, Bolivia, Brunei, Egypt, Indonesia, Iran, Libya, Malaysia, Nigeria, Norway (as an observer), Oman, Qatar, Russia, Trinidad and Tobago, the United Arab Emirates and Venezuela. Collectively, these countries account for 73 % of the world's gas reserves and 42 % of production.
9. Jaccard (2006) estimates that coal-fired power stations have increased from 1 MW to 800 MW and stations as large as 1500 MW have been built.
10. Between 1950 and 2000, the world's population rose by about 140 %, fossil fuel consumption rose by almost 400 %.
11. The United Nations International Panel of Climate Change (IPCC) has said that stabilizing the global temperature increase at no more than 2 °C above the pre-industrial level is expected to prevent irreversible and potentially catastrophic changes in the global climate.
12. The IEA estimated that the energy embedded in China's domestic production of goods for export was 452 million tonnes of emissions (Mtoe)

in 2004, or 28 % of the country's total energy consumption. In 2001, the amount of energy embedded in exported goods was only 197 Mtoe, or 18 % of total energy use.

13. The United States, China, Russia and India contribute two-thirds of the projected increase in global emissions from 26.6 to 41.9 gigatonnes between 2005 and 2030. From 1900 to 2005, the United States and the EU countries combined accounted for just over half of cumulative global emissions. China accounted for only 8 % and India 2 %. China's share of emissions from 1900 to 2030 rises to 16 % compared with 25 % for the United States and 18 % for the European Union.
14. Freese (2003) wrote that these quotes were attributable to Fred Palmer who was head of Western Fuels, a lobby group set up by the coal and utility industry. She wrote that Palmer later joined Peabody Energy, one of the biggest coal producers in the US.
15. The National Energy Policy Development Group (2001) said that since 1989, electricity sales to consumers had increased by 2.1 % annually, yet transmission capacity had risen by 0.8 % annually, which created the need for more power stations. The President's energy taskforce recommended that the government spend $2 billion over ten years in clean coal technologies.
16. President George W. Bush said in his speech that 'When I ran for President in 2000, I promised to invest – or asked the Congress to invest – $2 billion over ten years to promote clean coal technology. So far, working with the United States Congress, we've provided more than $1.3 billion for research in the innovative ways to improve today's coal plants and to help us build even cleaner coal plants in the future. And the bill I sign today authorizes new funding for clean coal technology so we can move closer to our goal of building the world's first zero emission coal-fired power plant.'
17. California filed a lawsuit against the Environmental Protection Agency (EPA) over its refusal to allow the state to set its own vehicle-emissions standards. California's law would require vehicle emissions to be cut by a third by 2016 to 36.8 miles per gallon (mpg), which is tougher than the Bush inspired Federal plan to improve vehicle fuel-efficency standards to 35 mpg by 2020, four years after the Californian plan.

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18. Ruttenberg and Associates Inc. (1973) said that of the proposed expenditure of $120 million between 1971 and 1975, the bulk was given to four research projects, which are to be 'concentrated in three firms whose relationship to the oil industry might be interpreted as something less than arms-length.'
19. United States General Accounting Office, Testimony Before the Subcommittee on Energy, Committee on Science, House of Representatives, *Fossil Fuel R&D Lessons Learned in the Clean Coal Technology Program*, Statement of Jim Wells, Director, Natural Resources and Environment, June 12, 2001.
20. The cost of constructing coal-fired power plants using new coal gasification technologies is about 20 % more than conventional coal-fired plants, and they carry higher perceived investment risk as new technologies according to the US Department of Energy (2006).
21. 'Given the scale of the energy challenge facing the world, a substantial increase is called for in public and private funding for energy technology research, development and demonstration, which remains well below levels reached in the early 1980s. The financial burden of supporting research efforts will continue to fall largely on IEA countries' (International Energy Agency, 2007).
22. The National Security Space Office in 2007 said that NASA and the Department of Energy have collectively spent $80 million over the last three decades in sporadic efforts studying this concept and, by comparison, the US Government has spent approximately $21 billion over the last 50 years pursuing nuclear fusion.
23. British ministers backed plans for a new generation of nuclear power stations on January 8, 2008.
24. A report by the World Nuclear Association (2007) says that US nuclear electricity avoids almost 700 m tonnes of CO_2, 1.1 m tonnes of nitrogen oxide and 3.3 m tonnes of sulphur dioxide.
25. The WNA estimates that China has the equivalent of 3170 megawatts under construction.
26. The ITER team includes the European Union (represented by EURATOM), Japan, the People's Republic of China, India, the Republic of Korea, the Russian Federation and the US. ITER will be constructed in Europe, at Cadarache in the south of France.

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27. Uranium is more common than tin, about 40 times more common than silver and 500 times more common than gold. From Cameco website – http://www.cameco.com/uranium_101/.
28. In the 1980s, the markets were driven by liquidation of government and commercial stocks. The Megatons to Megawatts programme refers to a 1993 agreement between the US and Russia. This is an agreement to convert highly enriched uranium (HEU) taken from dismantled Russian and American nuclear warheads into low-enriched uranium fuel, which is suitable for civilian reactors. The future of this agreement after 2013 is uncertain.
29. The International Energy Agency forecast in its World Energy Outlook that Opec's global share of oil output would rise from about 42 % to 52 % by 2030.
30. Sport utility vehicles (SUVs), which are classified as light trucks and are deemed to be work vehicles, although the majority are driven by urban dwellers, are exempt from fuel efficiency standards and their popularity has negated any improvement in US fuel efficiency standards. A 2008 Ford Escape 4WD has a range of 11 to 13 miles to the gallon (MPG). The 2008 Toyota Prius hybrid car has a range of 35 to 56, more than three times the range. See http://www.fueleconomy.gov for further fuel efficiency comparisons.
31. According to FACTS Global Energy, the cost of Iran's oil imports is expected to reach $6 billion in 2007, more than double the level from 2005. According to PFC Energy, car ownership in Iran grew by 250 % between 1990 and 2006. The International Monetary Fund (IMF) estimated that energy subsidies accounted for 12 % of Iran's GDP, the highest rate in the world according to an International Energy Agency (IEA) study.
32. By 2028, Canadian domestic gas consumption is estimated to be equivalent to Canadian domestic gas production and Canada's position as a net gas exporter would potentially come to an end.
33. A US Geological Survey report showed that the global oil shale resource base is believed to contain about 2.8 trillion barrels, of which the vast majority, about 2 trillion barrels, is located within the United States. The most economically attractive deposits, containing an estimated 1.2 to 1.8 trillion barrels (with an oil content of more than 10 gallons/tonne), are found in the Green River Formation of Colorado in Piceance

Basin, in Uinta Basin, Utah and the Green River and Washakie Basins, Wyoming.

34. Ruttenberg and Association, Inc. (1973) said, that in 1970, seventeen oil companies, including Exxon, accounted for about 55 % of the drilling and controlled about 48 % of the known US low-cost uranium reserves, with about 28 % of the uranium ore-processing capacity.