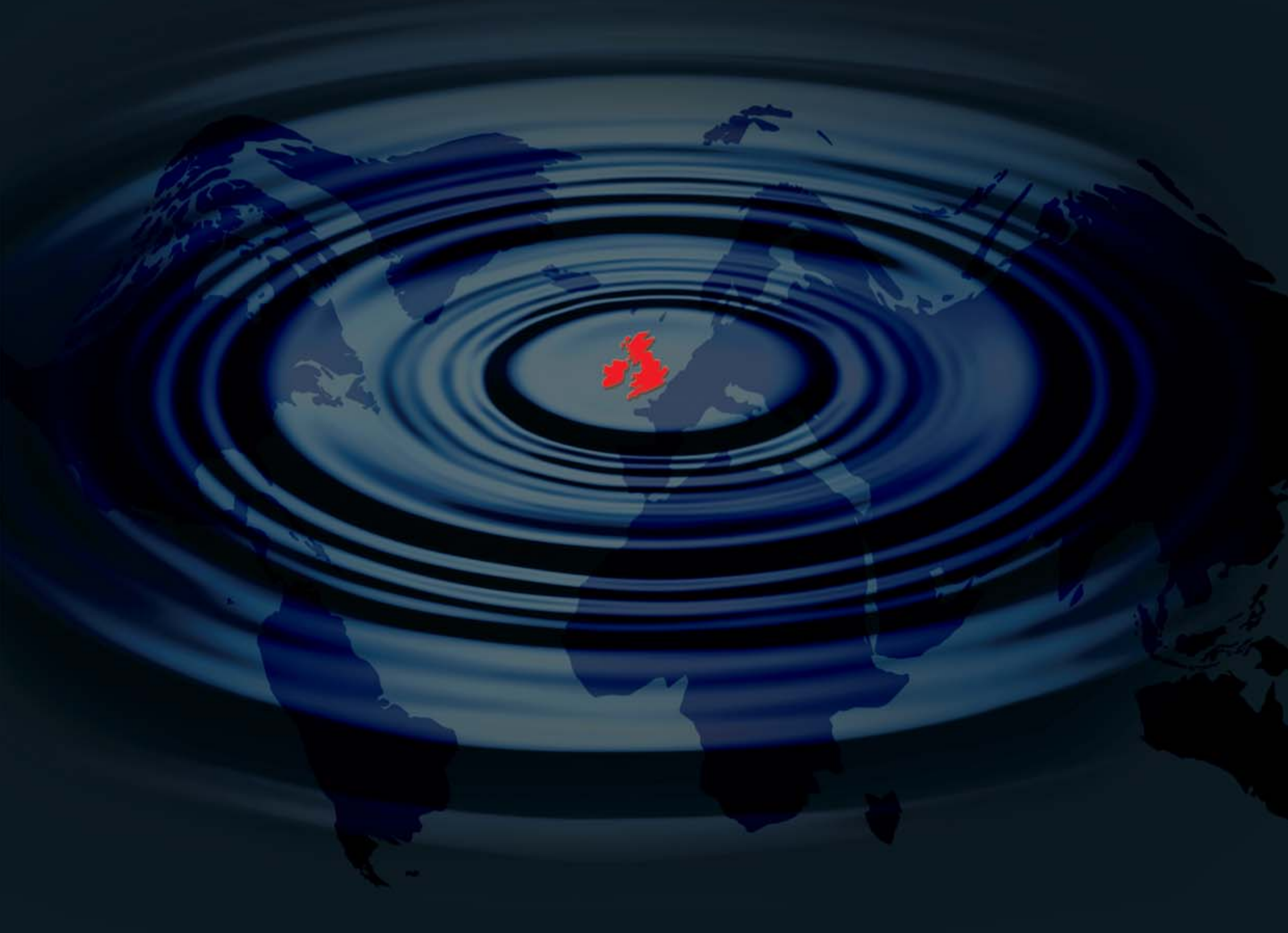
The Oil Crunch

Securing the UK's energy future

First report of the UK Industry Taskforce on Peak Oil & Energy Security (ITPOES)



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Note: References to the Department of Business, Enterprise and Regulatory Reform in this report were accurate at the time of writing. Subsequently, energy has become the remit of the new Department of Energy and Climate Change.

Industry Taskforce on Peak Oil & Energy Security

Taskforce member companies

Arup, FirstGroup, Foster and Partners, Scottish and Southern Energy, Solarcentury, Stagecoach Group, Virgin Group, Yahoo!.[1]

[1] The Chairman of the taskforce is Will Whitehorn of Virgin, and the editor of this report is Jeremy Leggett of Solarcentury. Contributors from the companies include John Miles and Simon Roberts (Arup), Paul Moore (FirstGroup), Stefan Behling and David Nelson (Foster and Partners), Ian Marchant and Rhys Stanwix (Scottish and Southern), Steven Stewart (Stagecoach Group), Alan Knight (Virgin) and Toby Coppel (Yahoo).

Foreword

Lord Ron Oxburgh
Former Chairman, Shell

There isn't any shortage of oil, but there is a real shortage of the cheap oil that for too long we have taken for granted. During the 20th century, cheap oil - $20 – 30/barrel in today's terms - allowed the internal combustion engine to replace the steam engine and sparked a transport revolution that fostered and fed the innate human desire to travel. We loved it.

By the middle of the century warning bells began to ring and some such as King Hubbert began to point out that world oil was a finite resource and furthermore that it was possible to estimate how much remained. At the time Hubbert was regarded by many as a crank and the industry line was that new discoveries would continue to replace what had been used. We now know differently.

A great deal more oil has been discovered since Hubbert's day but his basic thesis still holds. The difference is that today, with more exploration and more sophisticated exploration tools, we know the Earth much better and it is pretty clear that there is not much chance of finding any significant quantity of new cheap oil. Any new or unconventional oil is going to be expensive.

A more immediate concern is that today the world supply of oil is only just meeting demand and this is keeping the price very high. Earlier this year the price nearly hit $150/per barrel and even with the subsequent fall back below $100, the forward price is high. These prices partly reflect short term market jitters about political instabilities and vulnerability of supplies to natural or man-made disasters, but more fundamentally there is a concern that even though supplies may increase they may not increase as rapidly as the demand from large developing countries. It is this looming prospect of an early overhang of unsatisfied demand that is keeping forward prices high. All that could change this view of the future is a major world economic recession, and even the effects of that on demand have to be put in the context of a rapidly rising global population.

There is also another change from the past. Today around 80% of the world's oil and gas reserves are controlled by governments through national oil companies. This is in marked contrast to a couple of decades ago when international oil companies had the major influence. Disregarding the potential use of fuel supplies as political levers, it is entirely reasonable that national governments should have legitimate policies different from those of oil majors when it comes to exploiting the natural resources of their countries. They are starting to regard their shrinking oil and gas resources as something to be husbanded. King Abdullah of Saudi Arabia recently described his response to new finds: "No, leave it in the ground … our children need it." In other words, even those who have less expensive oil may wish to exploit it slowly and get the best possible price for it – a marked contrast with the past when oil was sold in a highly competitive market for little more than it cost to get it out of the ground.

Today's high prices are sending a message to the world that words alone have failed to convey, namely that not only are we leaving the era of cheap energy but that we have to wean ourselves off fossil fuels. For once what is right is also what is expedient - we know that we have to stop burning fossil fuels because of the irreversible environmental damage they cause, and now it may be cheaper to do so as well! The problem is that in the developed world our power and transport infrastructure is based almost entirely on fossil fuels. With the best will and the best technology in the world this will take decades to change.

In the pages that follow you will read the views of some of those closest to the oil industry. In the past these views might have been regarded as heretical. But they are not and their warnings are to be heeded.

Executive summary

Plentiful and growing supplies of oil have become essential to almost every sector of today's economies. It is easy to see why, when we consider that the energy locked into one barrel of oil is equivalent to that expended by five labourers working 12 hour days non stop for a year. The agricultural sector perhaps makes the case most starkly: modern food production is oil dependent across the entire value chain from the field to the delivered package. Within modern cities, for example, life in the suburbs will become extremely challenging without plentiful supplies of affordable oil. Yet in recent years, a growing number of people in and around the energy industry have been warning that global oil supply will soon fail to meet demand, even if the global demand drops, because the world is on or close to its peak of oil production. Peak oil production is the point at which the depletion of existing reserves can no longer be replaced by additions of new flow capacity. Conventional wisdom holds that the peak is many years in the future, allowing a timely transition to alternatives that can replace falling oil supply. However, the International Energy Agency has warned of an oil crunch by 2013. Other authoritative voices warn of severe problems earlier than this.

Being concerned about the implications of an early peak in global oil production for the UK economy, the companies contributing to this report have elected to conduct a risk assessment, from a collective UK industry perspective. Equally, aware of the commercial opportunities that are arising around the world in clean energy, we wanted to examine the opportunities. We asked ourselves three related questions: How big is the risk from peak oil? How big is the alternative-energy opportunity? How do the two conflate?

Risk analysis and the taskforce approach

We sought two opinions on oil-supply risk, one from an oil-industry expert known as a leading advocate of the early-peak scenario, and the second from Royal Dutch Shell, who we expected might advocate a more sanguine prognosis. In our first risk opinion, Peak Oil Consulting[2] presents an analysis pointing to a peak in global oil production in the period 2011-2013. His core argument is that the problem is not so much about reserves, as the timely bringing on stream of new flow capacity to replace the depletion of existing capacity. The "easy oil" that makes up most of existing capacity is declining fast, and the new capacity coming on stream – often from "not-so-easy" oil - will not be replacing it fast enough from 2011 onwards.

In our second risk opinion, Shell argues that we indeed face an "easy oil" supply gap, but should think not of "peak" production, rather "plateau" production, with accompanying tensions as the demand for energy continues to surge. The global supply of oil will flatten by 2015, in Shell's view, and if the oil industry globally is to maintain hydrocarbons supply on this plateau, very heavy investment will be required in ultra-deep water, pre-salt layers, tight gas, coal-bed methane,[3] in the Canadian tar sands and other areas of unconventional oil production.

We find it of great concern that both our risk opinion-providers agree that the age of "easy oil" is over. If so, fast-growing alternative energy supplies become imperative, even if production flattens in 2015 as Shell suggests.

We publish the taskforce's views, based on the two risk opinions and our own researches, as an interim report and an invitation-to-debate. Given the magnitude of our concerns about the challenges and opportunities we perceive in peak oil and related aspects of energy security, the taskforce companies have elected to continue working on the issue. We plan to produce an annual review of peak oil and energy security, and will prepare other reports, including on the vital issue of net energy in economies (the amount of energy needed to produce energy-generation technologies and services themselves, and the carbon implications thereof). We will seek to recruit other companies concerned about the issue, and we will endeavour to work synergistically with the UK government.

That said, we do not wish to detract from our immediate conclusions. We hope our work to date will act as a wake-up call for fellow companies, for government, and for consumers. For one is surely needed.

Reasons for concern

All is not well with the discovery and production of conventional oil - easy-flowing crude - as both the risk opinions in this report demonstrate. The production figures of all the five major international oil companies have been falling for five consecutive quarters. The steepest fall was in the last quarter, despite a collective $44bn profits in that three month period. Where the international oil companies now sit, the national oil companies – the largest oil companies in the world, controlling some 80% of global production - can easily follow. Old oilfields and provinces are showing today that local and regional oil production can descend very fast beyond peak-production, even where the best enhanced-oil-recovery techniques are applied. We conclude that global oil production may well descend fast too, once we reach the peak.

We are concerned that the industry is not discovering more giant fields, given that oil prices have been rising for four years now. We note the long lead times even when they do make a big discovery. We find it difficult to understand, given these long lead times, why the net flow-rate data presented in Opinion A, slowing as they do in 2011-13 and dropping thereafter, are not galvanising a response from governments and industry. Finally, we are worried by allegations that OPEC governments have been less than transparent about the size of their national reserves, since deciding to fix quotas based on the size of reserves in the 1980s. Some experts, including within OPEC itself, profess that at least 300 billion barrels out of the 1.2 trillion barrels of supposed global proved reserves may be overstated.

We are further concerned by the infrastructure problems, underskilling and underinvestment in the oil industry. Much of the current infrastructure (drilling rigs, pipelines, tankers, refineries etc) was built more than 30 years ago, and according to some insider experts its physical state would be a major problem area even were global supply not expected to grow. The average age of personnel in the oil industry is fully 49, with an average retirement age of 55. This will entail massive legacy problems. Despite the high profits of late, the industry's overall budget for exploration has actually fallen in real terms in recent years. We fear these issues will compound the peak oil crisis, and - as things stand - impair society's collective ability to respond.

"Plateau", "descent", or "collapse"?

The risk from premature peak oil can be thought of, globally, in terms of three qualitative scenarios. In a "plateau" scenario, like the one Shell foresees, global production will flatten around 2015 and remain on a plateau into the 2020s, propped up by expanding volumes of unconventional oil production because of the decline of conventional oil production. In a “descent” scenario, global production falls steadily as oilfield flows from newer projects fail to replace capacity declines from depletion in older existing fields. In a “collapse” scenario, the steady fall of the “descent” scenario is steepened appreciably by a serial collapse of production in some – possibly many – of the aged supergiant and giant fields that provide so much global production today. On balance, having reviewed the state of play in global oil production, the taskforce considers that the “descent” scenario is a highly probable global outcome. We also fear that a “collapse” scenario is possible.

The same three scenarios are also germane to a country-by-country analysis of oil supply, including imports. In the “collapse” scenario as it might apply to an individual oil-consuming nation, a major oil producing nation - or a group of them - decides that it has been over-optimistic in its assessment of reserves hitherto, that its domestic economic requirements for oil are growing, and it slows or even stops oil supply to nations it formerly exported to. In the UK’s case, the taskforce considers that the “descent” scenario is a highly probable outcome for future UK oil supply. As with the global situation, we also fear that the “collapse” scenario is possible. These risks may very well apply to gas as well as oil. Gazprom’s historical behaviour, and recent events in the Caucasus, add to this concern.

Energy policy in the UK: reversal of priorities?

Neither the government, nor the public, nor many companies, seem to be aware of the dangers the UK economy faces from imminent peak oil. Big as our current economic problems are, peak oil means a very high probability of worse problems to come. The risks to UK society from peak oil are far greater than those that tend to occupy the government’s risk-thinking, including terrorism.

Currently, it seems to us, the government places climate change as first priority for policymaking, followed by energy security, with peak oil (if it is viewed as a problem at all) in last place. In our view the more serious short-term climate-change impacts – substantial as they will be – will not be the first to wash over our economy. Peak-oil impacts are more likely to arrive first, with 2011-13 being a worryingly early candidate window based on the evidence in Opinion A. The core priorities we think the country faces are the reverse of the government’s current thinking. First we need to buy insurance for our national economy against peak oil. Next in line comes wider energy security, because our gas supplies are much at risk from geopolitics. We could in principle face the prospect of power shortages as soon as the coming winter, but on balance we believe a gas crunch is less likely to hit than peak oil before 2013. Climate change in this approach comes third not because it is less important, but because its severest impacts are further out than 2013.

That said, clearly the core policies needed to meet the challenges of peak oil and wider energy security are the very same as those needed if we are to achieve deep-enough cuts in greenhouse-gas emissions to abate climate risk. The key to all three threats, whenever they unfold upon us, is immediate and rapid acceleration in our use of non-fossil sources of energy, and reduction in the overall demand for energy.

A mandate for (low carbon) mobilisation

The UK government has been conferring with the energy industry regularly of late, given the nature of emerging energy imperatives such as fuel poverty. Some progress has been made as a result. For example, fresh short-term funding for energy efficiency is likely to be measured in hundreds of millions of pounds in the years ahead. Similarly, multilateral negotiations have increasingly involved energy. Many governments are desperate for an effective post-Kyoto deal on climate, so great do they perceive the risks of unabated global warming to be. Again, some progress has been made as a result. But when the full gravity of the oil crunch dawns on governments, we fear that there is scope for the peak oil threat to relegate the climate threat in policymakers’ eyes, both in the UK and internationally.

We anticipate proliferating calls for expansion of production in the tar sands, and for major coal-to-liquids programmes, whether or not carbon capture and storage (CCS) can be brought to bear as a means to deal with greenhouse-gas emissions. We are concerned that CCS technology is well over a decade away from the prospect of commercial deployment, and that there is no demonstration project today that shows industrial-scale deployment is even feasible, much less economic. We consider it imperative, therefore, that policy decisions on the response to peak oil (pro-active or retro-active) should be carbon-constrained.

Nuclear power holds the potential to cut emissions in the longer term, provided its own economics can be made to work in a world of rising construction costs. Much of the automobile industry has aligned behind electricity as the ground-transport fuel of the future of late. This will play to the advantage of nuclear power in the long term. Many renewables advocates profess that their family of technologies can do the job quicker, and ultimately more economically. Equally, many energy analysts profess that we need both renewable and nuclear technologies.

Alternatives and opportunities

Peak oil affects every aspect of energy use. Transportation may dominate in many views of the problem, being 99% oil-dependent. However, oil has many other uses, and transportation of other fuels, notably coal, depends on oil. Furthermore, the price of gas is closely linked to that of oil. Any strategy for tackling premature peak oil must therefore address the entire energy sector. The use of oil, gas, and coal (fossil fuels) must be cut across the board.

Encouragingly, when it comes to non-fossil-fuel energy, investors have begun to talk over the last year or so of a new industrial revolution in the making in the field of “cleantech.” Similarly, architects and city planners have begun to execute designs for cities of the future in much different, low-carbon, ways. In Silicon Valley, which seems to be in the process of transforming itself from the centre of the digital world to the centre of an emerging cleantech world, dozens of families of demand-side and supply-side clean-energy technologies are attracting interest and investment. They span the entire energy spectrum from transportation to generation, to use, smart grid-integration and building design. Automobile manufacturers are in the process of rapid systemic change in manufacturing, favouring electricity as the fuel of the future. This emerging trend is being driven primarily by current high oil prices.

The 2007 global energy investment figures for renewable energy give a flavour of the wider revolution underway. Almost $150 billion was invested in renewables of all types in 2007, out of a global total of some $1,300 billion invested in all forms of energy. This means that well over 10% of all energy investment is going into a sector that currently meets only a few percent of world primary energy, notwithstanding its fast growth rate. This incipient revolution is being driven by technical advances in concert with energy-security concerns and climate-change concerns, and has yet to feel the acceleration that peak oil will add to the equation.

Many of the broad family of cleantech energy technologies in the process of being commercialised around the world are classically disruptive, meaning that they can displace traditional energy markets very fast: far faster than many people probably realise. Given the developments in cleantech of late, out-of-the-box thinking on ambitious targets for replacing oil and other fossil fuels are eminently feasible. There is a silver lining to the challenges: mobilising to deal with peak-oil risk can greatly accelerate the global policy response to climate-change risk.

Speed of mobilisation

To stimulate our discussion of alternative-energy opportunities, we asked researchers from two respected teams to provide opinions for us on the potential for alternative energy supply. A team from the Energy Saving Trust provided a view for our consideration on the demand side (Annex 1). A team from the Open University and the Centre for Alternative Technology provided an opinion on the supply side (Annex 2).

In terms of risk abatement policy, the implications of the two UK peak-oil scenarios of concern can be summarised as follows.

	Climate-change policy-response scenario	Peak-oil "descent" scenario	Peak-oil "collapse" scenario
End goal for UK replacement of oil use	Within 42 years	Within < 20 years	Within < 10 years
Annual rates of oil replacement with respect to 2008 levels	2.38%	c 5%	> 10% p.a.
Applicability of policy measures in Annex 1, demand-management	Many but not all needed	All needed	Insufficient
Applicability of policy measures in Annex 2, renewable supply	Many but not all needed	All needed	Insufficient

By 2020, the combined impact of the aggressive renewables deployments mapped for the taskforce's consideration in Annex 2, added to a suite of wide-ranging multi-sectoral efficiency measures of the kind described in Annex 1, cut UK oil use by 46%, coal use by 79%, gas use by 29%, from 2007 levels. National CO_2 emissions drop by 47% from 2007 levels. A cut of c 20% CO_2 by 2020 would put the UK on track with existing climate goals. In the scenario mapped, oil use drops at 5% per year, and gas by 2%. We emphasise that the scenario is just one of many possible scenarios, and certainly not a forecast. Our main point is this. The speed with which the UK would need to mobilise for a "descent" peak oil scenario, much less a "collapse" scenario, exceeds anything that has yet been considered in the climate-change policy-response arena. Formulating a plan for either the "collapse" or the "descent" scenarios will require an entirely new framework for energy thinking in the UK.

Failure to act would entail major social and economic problems for government, industry and consumers alike, should either the "descent" or "collapse" scenarios materialise. Acting without taking a total-energy approach could lead to bad decisions involving little net-energy gain for the national economy, and deleterious impacts on our balance of payments. We will consider this vital topic in a later report.

Recommendations

National:

- 1. We call on the UK government, and other companies operating in the UK market, to join us in an effort to appraise the risk from premature peak oil, and plan proactive and reactive strategies - local and national - for facing up to the problem.
- 2. A UK national energy plan to deal with the peak-oil threat needs to have four core themes. First, exploration for and production of conventional oil and gas needs to be expanded. Second, energy conservation and energy efficiency need to be maximised. Third, investment in renewable energy and sustainable renewable fuels must be accelerated. Fourth, a national skills programme is needed to address the dangerous shortfalls in skills and manpower evident in all areas of the energy industry.
- 3. Given the gravity of the risks we have described, there is no time to wait in drawing up and implementing a new national energy mobilisation plan. The policy measures in a national energy plan should include, but not be limited to, the following:

  - Development and implementation of a long term sustainable transport policy, with renewable transport at its heart. This should include measures to increase transport fuelled by sustainable bio-liquids and electricity, and measures to reduce the amount of fossil-fuel-based road transport. If we are to significantly reduce oil consumption, the current measures being proposed in the renewable transport arena must be just the start, and measures well in excess of those proposed will be required.

  - Policies in the current Renewable Energy Strategy process must go beyond the EU targets for renewable energy (20% of the EU-wide energy mix by 2020). The renewables industry is confident that 100% renewables energy supply is possible in 20-40 years, according to the overwhelming consensus of participants at the Tenth Forum on Sustainable Energy, held in Barcelona in April. They should be given the opportunity to prove it.[4]

  - Nuclear decisions should be taken rapidly, and government should ensure that uncertainties over the nuclear renaissance should not act as barriers to the mobilisation of energy efficiency and renewables. Mass markets will be needed in these technologies whether we have a nuclear segment in the energy mix or not.

International:

- 1. We call on oil companies and governments generally to be more transparent about oil reserves. OPEC governments could address concerns about the state of their reserves, as summarised in this report, with a minimal programme of verification by a small United Nations team of suitably qualified experts. Such a confidence-building measure has been proposed by the G-8 governments.

It could ultimately be beneficial for the global economy whatever the findings. If its results show the fears expressed in this report to be groundless, oil prices would surely fall. If the programme confirmed reasons for concern, governments could work together with urgency to accelerate sustainable energy alternatives. In the meantime any resultant rise in the oil price would itself stimulate greater efficiency and renewables investment.

- 2. We urge all governments to combine efforts to deal with oil depletion and climate change in the multi-lateral post-Kyoto climate negotiations, and significantly to improve their level of co-operation in that forum. There is ample scope for the UK government to lead by example domestically in this respect. Such leadership could include ensuring rapid trialing of CCS, and rapid national nuclear decision-making so as to give investors clarity on their energy options. Unconventional oil should not be exploited if its net carbon footprint is higher than that of conventional oil.
- 3. All governments should draw up their own national responses to peak oil. National energy mobilisation plans should aim to accelerate the green industrial revolution already underway.

[2] Author: consulting editor of Petroleum Review Chris Skrebowski.

[3] Ultra-deep water is water more than around 2 km deep, wherein drilling has only recently become possible. Pre-salt layers are sedimentary strata below the layers of salt to be found deep in the rock column in many sedimentary basins. Tight gas is gas confined in sedimentary layers that wouldn't have been drillable without recent technical advances. Coal-bed methane, as the name suggests, is methane gas trapped in coal layers.

[4] "Positive outlook," Godfrey Boyle, Energy Engineering, August 2008.

Background

The UK Industry Taskforce on Peak Oil and Energy Security (ITPOES) is a group of British companies, variously concerned that threats to energy security are not receiving the attention they merit. The aim of this, our first report, is to engage government more proactively on the peak oil threat, and also to alert the public to the problem. We aim to encourage collaborative contingency planning by government, industry, and communities on measures that can be taken to accelerate independent energy supply within the UK. In preparing this report, we asked ourselves three related questions: How big is the risk from peak oil? How big is the alternative-energy opportunity? How do the two conflate?

Most if not all aspects of a modern economy have become oil dependent. The agricultural sector, for example, is oil dependent across the entire value chain from the field to the delivered package. Oil is very energy dense. The energy locked into one barrel is equivalent to that expended by five labourers working 12 hour days non stop for a year, and to grow one cow in the United States, for example - from conception to plate - requires the direct and indirect use of around six barrels of oil.[5] Yet corporate and ministerial plans, in the UK and other countries, have long been geared to the assumption that despite current high prices, supplies of oil will continue growing, continue to meet rising demand, and do so at generally affordable prices. Recently, however, as oil prices have soared, that premise has come into question.

Increasingly, in their explanations of why the price is increasing, analysts mention peak oil. Peak oil is the point where further expansion of global oil production becomes impossible because new production coming onstream is fully offset by production declines. Beyond this point, the world will face shrinking supplies of increasingly expensive oil. That is a manageable proposition if the peak is several decades away, as is the general assumption. But if the peak is imminent, oil-intensive modern economies face major problems.

The International Energy Agency (IEA) has been dismissive of peak oil for many years, but in its 2006 World Energy Outlook, it voiced strong doubts for the first time.[6] Non-OPEC oil production will peak within a few years, the IEA concluded, and then the world's ability to match growing demand with supply will depend on three countries lifting their production significantly: Saudi Arabia, Iran and Iraq. This conclusion means that no debate on oil supply risk is complete without consideration of geopolitical risk.

In July 2007, the IEA spelt their assessment out even more clearly, and predicted an oil crunch by 2013. "Oil looks extremely tight in five years time" said the IEA Mid-Term Market Report, and there are "prospects of even tighter natural gas markets at the turn of the decade". The IEA forecasts OPEC crude capacity at 38.4 million billion barrels in 2012, up from an estimated 34.4 million b/d in 2007 but below OPEC's own estimates of near 40 million b/d for 2010. This warning prompted an alarming headline in the Financial Times: "World will face oil crunch 'in five years'."[7]

These warnings, and others like them (relayed in Part Two of this report) are clearly strong enough that it behoves industry to take a view on the risk, and the risk-abatement / management scenarios on offer. That is the reason the taskforce has come together. We have sought to engage the government, but the Department of Business and Regulatory Reform - responsible for energy - has not been responsive.[8] At the most recent annual Energy Institute meeting on oil depletion, in November 2007, all in attendance were frustrated by the low engagement by BERR. BERR's representative attended only for her own presentation, avoiding any discussion. The current Number 10 website offers the following thought on peak oil: "proven reserves are already larger than the cumulative production needed to meet rising demand until at least 2030."[9] In Part One of our report, we will see whether our two risk-opinion providers agree with this assessment.

5 "The price of steak", National Geographic, June 2004, p. 98. The article cites a 1,250 lb steer requiring 283 gallons. 1 barrel = 42 US gallons, 6 barrels = 252 gallons.

6 "World Energy Outlook 2006," International Energy Agency, 2006, 596 pages.

7 "World will face oil crunch 'in five years'," Javier Blas, Financial Times, 9 July 2007. The IEA's World Energy Outlook is due out in November 2008.

8 Industry members of the Renewables Advisory Board proposed the creation of a taskforce in 2006, and DTI did not action the proposal. Jeremy Leggett of Solarcentury revisited the proposal with BERR energy officials in December 2007 and was told there was no need for contingency planning by government and industry.

9 www.number10.gov.uk/Page16833

Part 1:

Risk from oil depletion

1. Opinion A: Peak Oil Consulting[10]

1. Introduction

Since February 2005 global oil supplies have been essentially flat. The much discussed production growth since December 2007 has only raised production 1.4% above the three year average (Figure 1). The consequence has been that oil prices have risen very sharply in order to reconcile supply and demand. Prices doubled in the last year alone and are now running at around four times the levels of the early 2000s (Figure 2). Already economies and businesses are being negatively impacted by high oil prices. Given there has been no major supply disruption this begs the question: are we experiencing the early stages of the peaking of oil supplies?

The peaking of oil supplies, or "Peak Oil", is by its very nature a "Grey Swan" event. That is to say that although it is a predictable event - because very few people doubt that oil is finite - on the basis of historic experience it is seen by many as an unlikely event. This goes some way to explain the widespread resistance to the idea despite the fact that there is now considerable evidence that it is imminent.

Figure 1: Production data Jan 2004 to June 2008 for global crude production (dark), natural gas plant liquids production (mid) and other liquids production (light) in thousands of barrels a day

Source: Energy Information Agency (EIA)

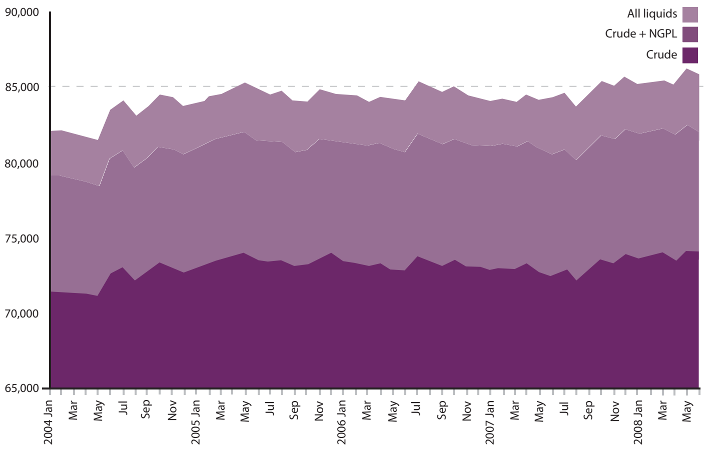
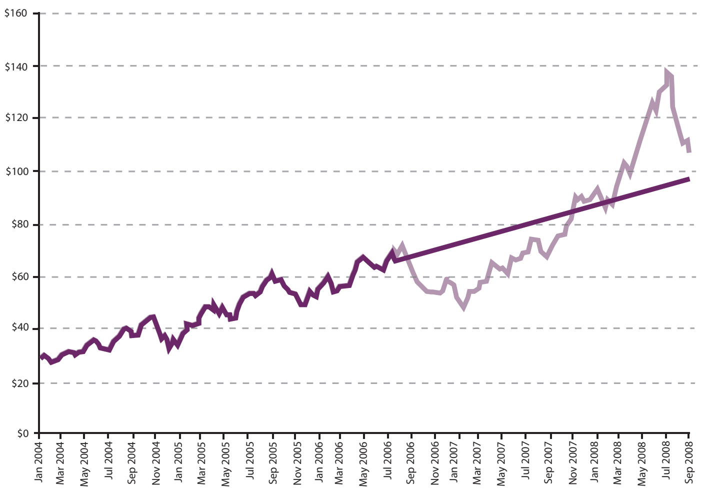


Figure 2: The price of oil 2004 - present. All countries spot price weighted by estimated export volumes ($/per barrel)

Source: Energy Information Agency (EIA), extrapolation by Peak Oil Consulting



Much coverage has been given to the idea that "peak oil" is solely a geologically driven phenomenon. This is incorrect: the peaking of oil supplies is coming about because of an interaction of geological, economic and political influences all ultimately driven by the fact that the world is running out of low-cost, free-flowing, easy to develop oil. This in turn is driving negative political actions by producer governments: expropriation, higher taxes, extortion, denial of access to international companies and output restrictions.

It is important to stress that the world is not running out of oil. Peak oil occurs when the flows of oil can no longer be expanded. Crucially this will occur whilst oil is still being discovered and developed. It will occur because the loss of capacity due to depletion exceeds the volumes of new flows entering the system.

The problem is that the remaining oil is in extreme environments, is technically challenging to develop or is difficult to refine. These more technically challenging resources are difficult to mobilise at anything like the rate that would offset the loss of capacity to depletion and the rate that world demand is increasing. These two pressures - depletion and demand - have already combined to produce the price increases we have observed over recent years.

Political uncertainties (expropriation and conflict) have combined with rapid inflation in all oilfield costs to slow and complicate investment in new production. The best known price index of exploration and development costs, the CERA oilfield costs index, has more than doubled since 2005. The continuing shortfalls in the flow of new capacity means that existing capacity is being worked harder and depleted faster than might have been the case if more new capacity was coming onstream.

A further pressure is that in most of the oil producing countries cheap oil products are seen as a birthright and low consumer prices are being achieved by government subsidy. The effect is to stimulate rapid oil product demand growth. High oil prices mean that subsidies are generally not an excessive burden on producer government finances. One result is that the price of gasoline around the world ranges from 20-40 cents/US gallon in the Middle East and Venezuela to nearly $4/US gallon in the US and up to $8-9/US gallon in Europe. Different consumers are seeing very different price signals for virtually all oil products. The point has now been reached where oil demand has fallen for the last three years in the OECD countries as a result of the high consumer prices. In contrast in the Middle East, India, China and the Far East demand is growing by 5-7%/year on a combination of rapid demand growth and government subsidy. Growth of oil production is having great difficulty keeping up with global demand growth outside the OECD countries and crude prices are rising strongly as a consequence.

2. Forces and feedback loops

It is this combination of forces and a series of feedback loops that is producing the peaking of oil supplies. However, once global production starts to decline it is likely to be virtually impossible to reverse as discovery size and new project size is generally declining while the large-volume unconventional oil resources - tar sands, heavy oils, shale oil – are either proving difficult to mobilise rapidly at useful volumes, or have so far proved uneconomic (shale oil). In addition the perception of increasing scarcity will lead some producers to reduce or curtail production to "save it for later generations."

The oil companies have acted rationally and in line with economic theory by developing the largest fields first, exploiting those that are easiest to access and those in countries with the most attractive investment conditions. The challenge now is that essentially all the "easy oil" has been found and exploited. Only the hard-to-find remains and all too often is found in the most challenging environments and the least attractive countries. While the "easy oil" can readily be turned into large production flows to meet demand, the difficult, unconventional oils can only be mobilised slowly and expensively. The world now needs high and rising prices to ensure these difficult future flows can be mobilised at all.

No oil company would drill in ultra-deep water, or through thick salt deposits, or in the high Arctic, or deal with regimes who unilaterally change contract terms, if there was anywhere easier to go to find oil. The increase in oil prices has been so rapid that contractor and construction capacity has failed to adapt rapidly enough, which has meant that the significant expansion of exploration and development expenditures over recent years have inflated costs rather than delivering new capacity. A similar inflation can be seen with alternative energy investments. This project cost inflation combined with commodity inflation, notably for steel, means that oil industry investment has been notably less productive over recent years. This means continuing high oil prices will be needed to deliver even existing planned projects.

3. The reserves myth

There is considerable confusion both inside and outside the oil industry about the importance of reserves. The world actually wants production flows but for many years reserves were a convenient proxy for future production flows. More recently as the easily accessible free-flowing reserves were used up people failed to recognise that slow-to-flow reserves didn't guarantee future production flows. Not all reserve barrels are equal. Some can be mobilised rapidly others only slowly.

Company accounts treat all reserve barrels as equal even though they can have very different implications for production flows. Reserve growth in old fields will usually ensure the fields are in production for longer. Only very rarely does reserve growth support faster flows from the older fields.

It is no coincidence that the companies under greatest financial pressure to increase their reserves are making the largest investments in the Canadian tar sands. The high cost of tar sands investments and their low production rate means they will almost certainly be less profitable investments than investing in a conventional oilfield. The fact that enormous sums are being invested confirms that the companies lack more profitable investment opportunities and need this capacity to try to maintain or enhance their production flows. The latest estimate from Christophe de Margerie CEO of Total is that new Canadian tar sands investment requires an oil price of over \$80/barrel. As Canadian tar sands supplies are the marginal supply this implies oil now has an effective floor price of \$80/barrel.

4. Economics isn't working as hoped

To date the widely anticipated economic response of high prices stimulating supply and depressing demand has not manifested itself. High prices have not produced a significant increase in exploration and development spending largely because rapid inflation in oilfield costs have pre-empted virtually all the additional spending by companies. A recent IMF report suggests that two-thirds of all incremental investment in the period 1999-2006 was lost to inflation. In addition exploration success has remained limited with the industry discovering only around one barrel of oil for every three the world consumes. The recent much publicised exploration success in Brazil barely alters the overall global discovery/consumption ratio.

Exploration and development costs have more than doubled in the last three years. Capacity constraints are to be seen in all sectors and even with investment these bottlenecks will take years to clear. The biggest single bottleneck is skilled manpower and particularly specialist engineers. Training and giving experience to new recruits means this bottleneck could persist for up to 10 years: in all probability well beyond the point at which oil supplies are likely to peak.

Oil companies have so far had great difficulty in increasing oil supplies even though they are still developing a portfolio or storehouse of existing discoveries. The immediate outlook improves to produce large capacity and potentially output gains in 2008 and 2009, although project delays and depletion may erode this. However, as we move into the next decade the companies will predominantly be developing the discoveries made around seven to ten years earlier as the storehouse of existing discoveries will be largely depleted. These discoveries of around nine billion barrels/year are already known. Even if fully developed they will not even offset current depletion rates let alone supply a demand increase.

Declining production is inevitable in the next decade. There is now little stock of known but undeveloped discoveries so the world is moving to the point where development will be of recent discoveries only.

To date the demand side has been equally unresponsive to high prices largely because oil demand continues to be very price inelastic. Experience from the 1970s oil crises indicates that demand is only impacted after some sort of yield point when recession or worse destroys demand. The other key learning from the 1970s is that adaptive responses – new technology, new equipment – take about six to eight years before there is any substantial impact.

Since the 1970s all the easy substitutions of oil products have largely been made. Compared with the 1970s little fuel oil is now used for power generation or by industry. Use of kerosene and gas oil for home and commercial heating has been massively reduced. Further substitutions away from oil will now be much harder.

The conclusion is that oil prices can move in quite wide ranges with only limited supply and demand responses although there is undoubtedly a yield point at which economic activity and oil demand collapses. For example individuals will continue to drive to work and consume fuel until the point where they lose their jobs and their fuel consumption then decreases. No one knows where the yield point is although it is clearly lower in poorer economies than in richer ones.

5. Future production flows analysis

Analysis and prediction of peak oil falls into two schools. The first analyses reserves and discovery trends and is based on the observation that oil production in a region or basin tends to decline once 50% of the reserves have been produced. The major challenge faced by this type of analysis is the variable quality of reserves data and the fact that the best data is held on expensive and/or confidential databases. While there is a broad measure of agreement about non-OPEC reserves, the large and unexplained upward reserve revisions by OPEC members in the 1980s remains a major cause of debate and uncertainty. Do we really believe that Saudi Arabia has discovered each year as many barrels as it has produced and that their claimed reserves are unchanged? But how do we assess Saudi or OPEC reserves figures given that there are no independent audits or systematic data release?

The alternative analytical route relies on an accurate tabulation and predictive analysis of future production flows. This is the route followed by a number of companies in the financial sector, some consultants and the IEA. Exact methods and the databases used are generally confidential or have restricted access.

"Flow analysis" is an effective tool because the oil industry is very much an "old economy" industry with long investment horizons. It moves slowly and predictably and is able to change direction only very slowly, rather like the supertankers employed to transport crude. For example the time between the announcement of a major new oil discovery and the first production flows currently averages six and a half years. It is therefore possible to predict maximum future production flows with some accuracy. Some key areas of new production are taking even longer. Major offshore discoveries in Nigeria have averaged nine years from discovery to first oil. Kashagan, the largest oilfield discovery in the last 30 years is now expected to start up in 2013. This much delayed development will have taken 12 years since discovery despite going more or less straight into development.

Since 2003, first Petroleum Review and latterly Peak Oil Consulting (POC) have[11] been refining a "future production flows" analysis based around an accurate listing of future projects. The "Megaprojects database" currently itemises 258 projects due onstream between January 2008 and end 2016. In a supply constrained world the question to be answered is, going forward, how much net supply is potentially available. This is calculated by determining the gross new capacity additions in each year. This is then added to existing capacity deflated by an assessment of the loss of capacity to depletion. This calculation then enables future capacity to be determined. Project delays effectively reduce new capacity in the short term. Varying the assumptions and adjustment factors gives an idea of the most probable range of production outcomes.

The nature of the analysis is that it is highly accurate for the next six/seven years but it still gives clear indications of outcomes beyond 2016. The conclusion of the analysis is that there will be no net increases in oil flows after 2011 even if all planned projects come onstream more or less on time and achieve the anticipated production flows. That everything should go to plan is, on the basis of recent experience, a distinctly optimistic assumption but it does define an outer boundary, the best possible outcome that could theoretically be achieved.

The immediate conclusion from the analysis is that the peaking of oil supplies is imminent and will occur in the window 2011-2013.

In planning terms 2011-2013 is effectively tomorrow. This means the crisis is already upon us and companies and individuals need to be planning their response now.

Before taking a more detailed look at the flows-based analysis it is worth examining how global production has been developing over recent years and how the largest quoted companies have been faring in terms of their production.

6. Current production flows

The latest "All liquids" data is reproduced below. According to the EIA, all world liquids production peaked in 2005. The amount of new capacity coming onstream suggests that this should be a temporary peak and not the final peaking. However, in practical terms production has been on a plateau for the last three years at 84.6mn b/d. In the first half of 2008 this has increased to 85.5mn b/d or 1% above the previous three year plateau. This minimal production gain is remarkable given the sheer volume of investment over that period.

The other major source of production data is the IEA – the International Energy Agency. This was set up after the oil crises of the 1970s to allocate production in the event of a production cutback. The IEA tabulates a broadly defined all liquids production which it subdivides into OPEC oil, OPEC NGLs and non-OPEC production. See Table 1 below which also includes EIA world liquids production for comparison.

Table 1: IEA and EIA all-liquids production figures contrasted, figures in million of barrels per day

Year	IEA OPEC oil	IEA OPEC NGLs	IEA Non-OPEC	IEA World Liquids	EIA World Liquids
2000	27.80	3.20	46.10	77.10	77.76
2001	27.20	3.30	46.80	77.30	77.68
2002	25.40	3.50	48.10	77.00	77.00
2003	27.10	3.70	49.10	79.80	79.62
2004	28.90	4.20	50.10	83.20	83.12
2005	29.70	4.50	50.20	84.40	84.63
2006	29.71	4.63	51.08	85.42	84.60
2007	30.66	4.81	50.10	85.57	84.60
2008 1st Half	32.24	4.95	49.74	86.93	85.50

If we compare the two series for "All liquids" we find that the IEA figures were lower than the EIA ones in 2000, 2001 and 2005 but were effectively identical in 2002. They were slightly higher in 2004. In 2006 and 2007 the IEA figures were significantly higher than the EIA numbers although beyond an upward revision in processing gains the cause of the discrepancy is not clear.

In addition to its monthly reports the IEA produces an annual Medium Term oil report. The latest (2008) clearly indicates that despite large downward revisions to anticipated global demand by 2011/12 there will be little or no OPEC spare capacity. They have also revised down their estimates of non-OPEC capacity. They also note that in addition to the general market tightness, lack of refinery upgrading capacity may further tighten the market and strengthen prices.

7. Production of 21 largest producers

It is worth examining the current status of the world's 21 largest oil producers as this gives a clear indication of the difficulty in expanding global production. The 21 producers individually produced at least 1mn b/d although Indonesia has just declined to under 1mn b/d while Azerbaijan is just reaching 1mn b/d. Collectively the 21 produced 68.9mn b/d in 2007 or 84% of the 2007 global total of 81.5mn b/d.

This clearly shows just how concentrated the oil industry is and just how few hands control the bulk of the world's production capacity. Producers are arranged by whether their production is expanding or contracting and by whether this is happening quickly or slowly.

In 2007 the situation was: (Figures in million b/d. Source: BP statistical Review of World Energy June 2008).

Table 2: 2007 production in million b/d of the world's 21 largest oil producers grouped by rate of change in production
Source: BP Statistical Review 2008, presentation Peak Oil Consulting

Slow Expansion (28.3mn b/d)	Potential for Fast Expansion (8.0mn b/d)
Saudi Arabia (10.4)	Iraq (2.1)
China (3.7)	Brazil (1.8)
Canada (3.3)	Angola (1.7)
UAE (2.9)	Kazakhstan (1.5)
Kuwait (2.6)	Azerbaijan (0.9)
Nigeria (2.4)	
Libya (1.8)	
Qatar (1.2)	
Rapid Decline (8.7mn b/d)	Gentle decline (23.9mn b/d)
Mexico (3.5)	Russia (10.0)
Norway (2.6)	USA (6.9)
UK (1.6)	Iran **(4.4)
Indonesia (1.0)	Venezuela (2.6)
** Production essentially flat	

Just 10 years earlier in 1997 the situation was very different with no countries in rapid decline. In 1997 the 21 producers' output was 61.4mn b/d out of the world total of 72.1mn b/d or 85% of the total.

Table 3: 1997 production in million b/d of the world's 21 largest oil producers grouped by rate of change in production
Source: BP Statistical Review 2008, presentation Peak Oil Consulting

Slow Expansion (37.6mn b/d)	Potential for Fast Expansion (8.5mn b/d)
Saudi Arabia (9.5)	Brazil (0.9)
Iran (3.8)	Angola (0.7)
Mexico (3.4)	Kazakhstan (0.5)
Norway (3.3)	Azerbaijan (0.2)
China (3.2)	Russia (6.2)
UK (2.7)	
Canada (2.6)	
UAE (2.5)	
Nigeria (2.3)	
Kuwait (2.1)	
Libya (1.5)	
Qatar (0.7)	
Rapid Decline	Gentle decline (15.3mn b/d)
	USA (8.3)
	Venezuela**(3.3)
	Iraq** (2.1)
	Indonesia (1.6)
** Production essentially flat	

In summary, in 1997 46.1mn b/d was expanding and only 15.3mn b/d was contracting. By 2007 36.3mn b/d was expanding but 36.6mn b/d was in decline. In other words we have now reached the point where approaching half of the output from the 21 largest producers is coming from countries where production is declining.

8. Oil company production peaking

There is now clear evidence that the large publicly quoted oil companies – the Megamajors and the Majors – are having increasing difficulty in expanding their oil production. Examining the quarterly and annual production of the 23 largest quoted companies reveals the difficulties the companies are already having expanding production despite the fact that they are free to go to many different countries and locations. The five Megamajors are all now experiencing declining oil production. Collectively their production peaked in 2004. Individually: Chevron peaked in 2002, Royal Dutch Shell in 2003, Total in 2004, BP in 2005 and ExxonMobil in 2006.

Of the 11 largest quoted companies (the Megamajors plus ConocoPhillips, Eni, Petrobras, Petrochina, Repsol-YPF and StatoilHydro) - all with production of over 1mn b/d - the collective peak output was in 2006 with only Petrobras and Petrochina still expanding output in 2007.

For all 23 quoted companies their output peak was also in 2006. However seven additional companies were still expanding production in 2007 although their collective production was under 1.2mn b/d.

In the second quarter of 2008 the Big Five – ExxonMobil, Shell, BP, Chevron and ConocoPhillips - experienced a 614,000 b/d (6%) production decline versus year-earlier levels. This confirms the view that the largest oil companies are experiencing considerable difficulties in trying to maintain production flows let alone expand them.

While it is theoretically possible for companies with declining production to turn the situation around it becomes harder with every passing year. However, it is worth noting that some of the smaller companies still appear to find capacity expansion possible.

9. Megaprojects analysis

By itemising the number of projects with a peak flow of over 40,000 b/d in each year, separating them into OPEC and non-OPEC and listing the gross new capacity we find there is a clear bulge in new projects and capacity in 2008 and 2009 and a rather lower level from 2010 to 2013 and the real step down thereafter. This is tabulated in Table 4 below.

Table 4: Number of new OPEC and non-OPEC megaprojects (peak flows of over 40,000 b/d) and gross new capacity added by year to 2016
Source: Peak Oil Consulting

Year	OPEC Projects	Non-OPEC Projects	Total projects	Gross New Capacity
2007	10	13	23	3.3mn b/d
2008	33	38	71	5.2mn b/d
2009	20	20	40	7.2mn b/d
2010	18	20	38	4.4 mn b/d
2011	10	17	27	3.8mn b/d
2012	20	24	44	4.7mn b/d
2013	6	18	24	4.5mn b/d
2014	2	3	5	2.3mn b/d
2015	2	5	7	1.1mn b/d
2016	1	1	2	0.8mn b/d

A widely accepted assessment of depletion is that it accounts for 4.0%-4.5% of current production. CERA (Cambridge Energy Research Associates), which is probably the most optimistic of the consultancies about future production growth, believes depletion is running at 4.5%. Current production is around 87mn b/d giving a depletion rate of 3.48-3.92mn b/d/year. This level is confirmed by the 2008 Medium Term Oil Market Report from the IEA which assesses the global depletion rate at 3.5-3.7mn b/d per year. Depletion volumes are generally thought to be rising gently but there is some evidence that rates are accelerating. On top of this comes incremental project slippage (over and above the slippage already announced by the oil companies), which will deflate the gross additions. When all this is allowed for, depletion will probably wipe out the gross production gains from all the major projects in all years except 2008, 2009 and possibly 2012. In addition, peak flows cannot be maintained consistently because shutdowns are needed from time to time for operational/maintenance reasons. This necessitates a further reduction to estimations of gross additions.

Additional new capacity, of course, is to be found in all the small infill projects and minor investments that never get recorded as individual projects (those producing less than 40,000 b/d). The size of this can be estimated by backcasting (i.e. using historical records of the contribution of small projects alongside megaprojects) and then trending this forward on a gentle decline to take account of the reducing opportunities as fields around the world are increasingly fully drilled up.

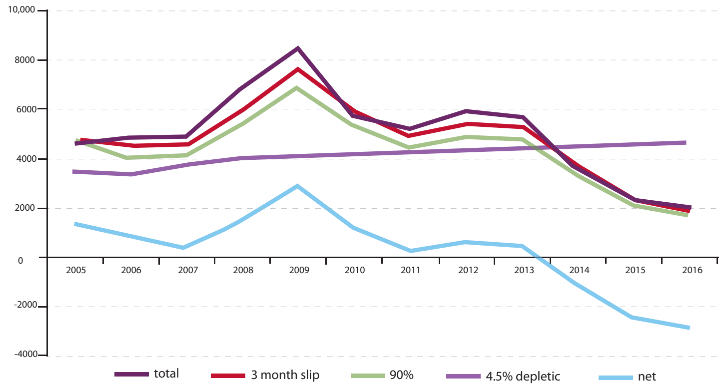
It is certain that all non-OPEC capacity will be fully utilised as will all non-OPEC capacity expansions. In contrast OPEC will probably utilise new capacity, but doesn't have to. OPEC projects appear to be suffering project delays and cost inflation like non-OPEC projects, but start-ups are poorly documented and flow rates rarely revealed.

By putting all the data together and then using various depletion rates the likely volumes of new capacity for each year going forward can be established. In Peak Oil Consulting's analysis (Figure 3 above right), net new capacity falls to low levels after 2011 but peak oil - or no net new capacity - would not occur until 2013. It can also be seen that if the depletion rate (purple line) rises peak oil will move back to 2011.

The blue line represents gross new capacity including all the very small projects. The red line represents the impact of an additional three month slippage over and above announced slippages. The green line is 90% of the red line to account for the fact that maintenance and operational requirements reduce average flows from announced peak flows by 10%. The purple line represents the loss to depletion allowing the lighter blue line to represent the available additional flows in each year. This represents the best possible outcome on the basis that all planned capacity expansions will come onstream and be fully utilised. It should therefore be seen as a best case: defining the best outcome that can realistically be anticipated.

Figure 3: Oil supply from megaprojects due to come on stream, minus assumed slippage, showing net additions of capacity (in thousand barrels/day). For further explanation see text.

Source: Peak Oil Consulting



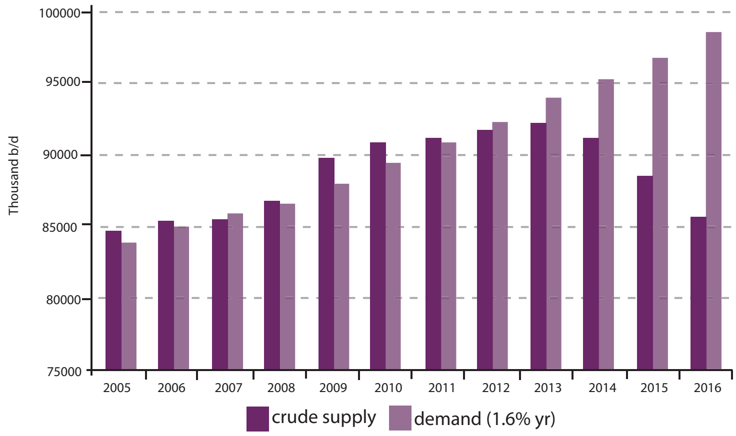
It is now possible to compare the most probable production outcomes with the most likely demand requirements. In terms of demand growth, the latest IEA projection is for annual growth of 1.6%/year. Plotting these best estimates of supply and demand gives us Figure 4 below. Supply and demand figures to 2008 are actual figures as reported by the IEA. Thereafter they are projections.

This graph shows that supply is likely to exceed demand in 2009 and 2010, leading to a possible price weakening, but that from 2012 demand will consistently exceed supply. It is notable that production is likely to be on an effective plateau between 2009 and 2014. However from 2012 onwards the shortfall versus likely demand will lead to a rapid price escalation as higher prices will be needed to reconcile demand to the available supply.

The final conclusion must be that from 2012 onwards business-as-usual is likely to be virtually impossible. Unless both business and government start actively planning for the shortfall in oil supply there is likely to be a very disruptive period in which supply and demand for oil are only reconciled by high and escalating oil prices with all the consequences this would entail.

Figure 4: Global oil supply versus projected demand in a best-case analysis

Source: Peak Oil Consulting



Source: Peak Oil Consulting

10. The UK North Sea as a Peak Oil exemplar

The development and exploitation of the UK sector of the North Sea clearly demonstrates both the best of oil industry practise and the impact of geologically driven depletion. The exploration, development and production of North Sea oil and gas resources has been a truly stunning achievement that has provided employment, income and tax income to the country. However, the very success of North Sea exploitation has led to a widespread reluctance to face up to the reality that production of both oil and gas are now in irreversible decline. A decline that has been only partially mitigated by the aggressive exploitation of the large number of small accumulations not yet brought into production.

For the oil and gas companies, the UK sector of the North Sea offers an almost perfect operating environment, apart from the harsh climatic/environmental conditions. The exploitation of the UK North Sea has not been constrained by any government output restrictions (there never have been any), lack of access (there has always been more acreage allocated than immediately required), excessively burdensome taxation (although the industry would always prefer lower taxes) or even by excessively bureaucratic permitting procedures (field development permitting is one of the fastest if not the fastest in the world). It is therefore safe to conclude that it is lack of exploitable resources that is now driving the inexorable decline in North Sea oil and gas production.

It is probably fair to say the UK North Sea is the one oil and gas province in the world where the only "above ground" constraint on development is the harsh operating environment in terms of waves and weather. This means production decline is overwhelmingly the result of "below ground" constraints – the lack of economically exploitable resources.

According to a recent presentation by Mike Tholen, Economics Director for Oil & Gas UK (the industry lobbying body and successor to UKOOA, the UK Offshore Operators Association), the North Sea industry will invest £5bn in 2008/09 and could pay up to £15bn to the UK Exchequer if oil prices average $110/barrel. (Over the last three years oil and taxation has contributed nearly £9 billion/year). In addition, Tholen claimed that direct and indirect employment amounted to 450,000 people in North Sea related jobs.

However, Tholen's presentation also showed that UK oil and gas production declined by 7.5%/year between 2002 and 2007, with production projected to reach just 0.5mn barrels of oil equivalent per day (boed) by 2020 on the basis of exploiting the 7bn barrels of oil equivalent (boe) of known reserves.

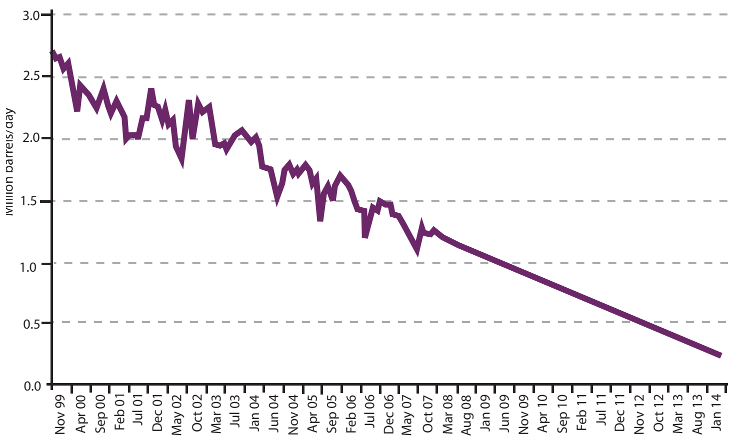
The hope expressed by Oil & Gas UK and BERR is that the decline rate can be slowed to 4-6% with the discovery and recovery of an additional 15-18bn boe of exploitable oil and gas reserves over time. Were this to be achieved, production in 2020 would be about 1.4mn boed rather than 0.5mn boed.

This appears extremely optimistic and we believe anyone addressing the challenges posed by the peaking of oil supplies would be most unwise to bank on the hopes of an industry lobbying body, albeit one whose conclusions are endorsed by BERR. The reason for this caution about future oil and gas production are sixfold.

1. The previous "Pilot" initiative from Oil & Gas UK's predecessor UKOOA aimed to get production to 3mn boed by 2010. By the start of 2008 production was at 2.5mn boed having fallen from 2.8mn boed at the start of 2007.
2. The irreducible cost of any small North Sea development is the cost of a well, the wellhead and the pipeline to link to the existing infrastructure of platforms and pipelines. The cost of wells and pipe has been rising quite rapidly and rig availability remains constrained. Deep water rig rates were costing about $400,000/day in 2007 but are expected to average nearer $600,000/day in 2008 and industry insiders believe rates may reach $700,000/day by end 2008/early 2009.

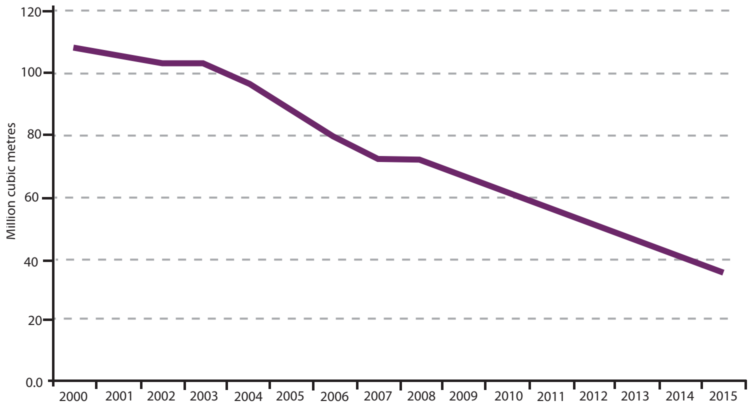
   By the time these bottlenecks are resolved and costs start to ease back it will be well into the next decade. This would more or less coincide with the point where increasing amounts of time-expired infrastructure is to be removed from the North Sea. Any small accumulation of oil or gas that has not been developed before the infrastructure has been removed is likely to be rendered uneconomic to develop. Once significant amounts of infrastructure have been removed only very large discoveries will be economic to develop. These larger discoveries are becoming increasingly rare.
3. While the actual discovery in any one year varies, the overall trend to smaller discoveries is well established and continuing. Average discovery size is now down to around 20mn barrels. Quite rapid depletion is required to make small accumulations economic which means that production lives can be a little as 3-5 years for these small fields. The BERR website provides a listing of all the "significant" discoveries made on the UK continental shelf since the first gas discoveries in late 1965. There are 505 of these. Fields in production, or about to come onstream, account for 359. A further 22 are named discoveries that are probable developments. There are a further 18 finds that have been named and 106 that have not. The unnamed finds are generally thought unlikely to be developed, although there will probably be a few. Many of the remaining 18 named finds will be developed. Given that all the undeveloped accumulations are small it is clear that production volumes from new development to mitigate decline are now small. The flow of recent discoveries is slightly more encouraging with nearly 10 significant discoveries in the last three years compared with slightly over six in 2000-2004. It is notable that of the 61 significant discoveries made since 2000 no less than 18 are either already in production or under development.
4. UK liquids production is made up of two elements: crude production, which hit an all time peak of 2.6mn b/d in November 1999 and has been in sustained decline since that date, and NGLs, whose production has remained remarkably stable throughout the period at 200,000-220,000 b/d. While it is true that the start up of the Buzzard field in 2007 meant that 2006 and 2007 production were almost identical, it is nevertheless also true that a simple straight line trending of monthly crude production since November 1999 has proved a remarkably accurate predictor of future crude production levels. Figure 5 opposite plots actual crude production levels from November 1999 until January 2008 and extrapolated to end 2013. It should be noted that the 200,000-220,000 b/d of NGL's production needs to be added to divulge total liquids production. Simple extrapolation gives likely output levels that are well below those projected by BERR or Oil & Gas UK.

Figure 5: UK continental shelf crude oil production Nov 1999 – Jan 2008 and extrapolation to 2014
Source: Royal Bank of Scotland monthly Oil and Gas Index, extrapolation by Peak Oil Consulting



5. A similar methodology can also be followed for UK gas production. However, because gas production and demand is highly seasonal a useful trend can only be established using annual data. UK sector gas production peaked in 2000 and has been extrapolated to 2015.

Figure 6: UK continental shelf gas production 2000-2008 and extrapolation to 2015
Source: BP Statistical Review 2008, extrapolation Peak Oil Consulting



6. The flow of recent development (Table 5) is considerable but the impact on slowing production decline is minimal, as can be seen in Figures 5 and 6.

Table 5: North Sea start-up developments 2004-10
Source: Petroleum Review September 2008.

Year	Oil	Gas & Condensate
2004	7	7
2005	8	6
2006	6	7
2007	10	11
2008	11	11
2009	7	7
2010	9	8

[10] Chris Skrebowski, Managing Director of Peak Oil Consulting, also Consulting Editor, Petroleum Review.
[11] The company was set up after the author stepped down as Editor of Petroleum Review in 2008.

Throughout the 2004-2007 period both oil and gas production declined, apart from 2006-2007 when oil production held steady as the result of the large 550mn b Buzzard field coming onstream. Currently the only known large undeveloped oilfield is the 200-400mn b Rosebank/ Lochnagar field to the west of Shetland that is unlikely to come onstream until early in the next decade. After 2010 there will still be around 30 probable oil and gas developments and another 40 long shots, plus anything that has been discovered in the intervening period. Even if the rate of recent and planned development is sustained it seems unlikely that there will be any significant new development activity by 2015. In the absence of even limited new development, depletion rates for oil and gas will accelerate, making even straight line extrapolations optimistic.

The UK North Sea continues to play a highly important economic role in terms of employment, taxation and energy supply. The rapid production declines for both oil and gas have important social, economic and budgetary impacts. There remains a dangerous reluctance to face up to the consequences on the part of both the industry and government. Only by recognising what is happening and the speed of the declines will it be possible to limit the impact and disruption to the UK economy.

11. Conclusion

There is considerable evidence that global oil supplies are becoming extremely difficult to expand and that the peaking of production is very close. Oil production capacity is currently being eroded by depletion at up to 4mn b/d each year. Increasing supply capacity coming onstream in 2008 and 2009 appears sufficient to meet demand in those two years without significant increases in the oil price.

Various capacity constraints – lack of rigs, of construction capacity, of skilled manpower – are currently ensuring that all the risks to new capacity coming onstream are on the downside. These constraints are the major cause of project delays. It is reasonable to expect that these will ease over time but they are unlikely to ease significantly in less than five to seven years by which time, peak oil will have been reached.

After 2010 meeting any incremental oil demand will be very difficult as the incremental supply is insufficient. After 2010, prices are likely to rise strongly to reconcile available supply and demand.

The extended time required to develop oilfields means that future capacity out to 2015 can be predicted with a high degree of confidence. By mid-decade oil supply is likely to be in sustained decline. Barring catastrophic economic collapse, oil prices will continue to rise to reconcile diminishing supply and demand requirements.

Adaptive responses to high oil prices will be relatively slow because the easy oil substitutions have already been made. Capacity to change fuels is generally limited and requires associated investments. More fuel efficient vehicles take time to develop and there is a delay until they form a significant proportion of the fleet.

The urgency of the situation means that it now vital to have a co-ordinated national policy to encourage and facilitate adaptive responses and the maximum availability of alternative fuels so as to minimise the disruptive impact on the UK economy.

Part 1:

Risk from oil depletion

2. Opinion B: Royal Dutch Shell

"I think that easy oil and easy gas - that is, fuels that are relatively cheap to produce and very easy to get to the market - will peak somewhere in the coming ten years."[12]

Jeroen van der Veer, Chief Executive, Royal Dutch Shell plc

Easy oil is past – what's vital now?[13]

Jeremy Bentham, Vice-President Global Business Environment, Royal Dutch Shell plc

When Chinese motorists queue for scarce petrol, angry Spanish truckers put up blockades because of high diesel prices, and US carmakers slow production of petrol-guzzling sports utility vehicles, it is hard to imagine that oil was cheap less than a decade ago. In 1999 a barrel of oil cost only 10 dollars. In a story titled "Drowning in oil", the Economist magazine famously argued the price might drop to five dollars. Since 1999, surging demand and tight supplies have pushed up the oil price by more than 1,000%, and there are fears of an oil and gas supply shortage.

1. Supply and demand

Yesterday's cheap oil is partly responsible for today's expensive oil. It encouraged energy consumption and at the same time discouraged investment in new upstream projects by the industry. International oil and gas companies, faced with a collapsing oil market, drastically cut costs and fired tens of thousands of oil workers. By the time it became apparent that demand in the developing world was racing ahead, the oil & gas industry was in no position to respond quickly. But is the industry's underinvestment in the cheap oil era the only reason for today's tight supplies and high prices? Or is the world simply running out of hydrocarbon resources to produce? Have we reached a peak in global oil production?

This paper argues that the debate on what is now called "peak oil" needs reframing. Inherent in the term "peak" is the notion that both the ascent to a production maximum and the subsequent descent will be steep. To paint the supply picture that way is unrealistic, since increases and decreases in hydrocarbon production will be gradual. The term "peak" also contributes to a sense of panic among governments and consumers. Worse, it does little to promote the actions societies need to take to secure a sustainable energy future, because it draws attention to only a single element on the supply side of the energy equation rather than the combination of supply, demand, and environmental issues that can only be addressed together. Urgent attention is required, but it needs to be directed across a broader front.

The bigger story is that society is entering a transition period of many decades, where it is shifting from a heavy reliance on oil, natural gas and coal to a much broader mix of energy. But new, low-carbon dioxide energy technologies will need time to mature.

The big challenge, therefore, is how to maintain a sufficiently high production "plateau" long enough to enable us to increase the share of complementary energy sources in the global energy mix, while moderating the flight into coal and reducing greenhouse gas emissions.

2. Peak or Plateau?

In simple terms oil is a finite resource, as is gas, iron, copper or any other commodity. There will inevitably come a point in time when production reaches a maximum. For "easy oil" it could come as early as the next decade.

Shell's "Scramble" and "Blueprints" scenarios suggest that the world should be able to maintain production of oil and natural gas at between 120 and 170 million barrels of oil equivalent a day until at least 2050. Today's oil and gas production stands at around 135 million. These outlooks remain well within the limits of geological potential. They also take into account a broad range of political, macroeconomic, technological and environmental influences that will variously slow or accelerate the development of fossil fuels or their alternatives.

The physical "peaking" of oil is just one factor in a rich cocktail of energy and climate dynamics. A peak in production might be caused by hitting a geological barrier, but economic, geopolitical or environmental barriers could be more significant and would surely happen earlier.

At Shell, we think of this complex energy and climate challenge as a set of three hard truths. The first hard truth is that surging energy demand will continue for decades; the second that supplies of "easy oil" cannot grow at the same pace as overall energy demand growth; and, third, that increased use of energy means rising greenhouse gas emissions at a time when climate change looms large as a critical issue.

These hard truths make structural change in the energy system both necessary and inevitable. Equally, they place limits on the scale and the speed of change. The three hard truths need to be addressed in an integrated way.

3. The surge in demand

Zooming in on the first hard truth, we see that demand for primary energy has continued to surge since 2004, at an average of 3.5% per year for the last three years. This is a rate not seen since the 1970s, and that was from a much smaller base. By 2050, we will probably use at least double the amount of energy we do today - that is, if we keep on doing things the way we always have.

An important driver behind surging energy demand is population growth, with 75 million people – the equivalent of Turkey's population - being added each year. By 2050 there could be over nine billion people in the world, up from 6.7 billion today. This means there will be more than three times as many consumers in the global economy as in the 1950s.

Many of these new consumers will be richer than their parents. The commercial engine is bringing hundreds of millions of people out of material poverty. The other important driver of energy demand is the industrialisation that goes with economic growth in developing countries. As an example, let's look at what is happening with China, which accounts for one fifth of the world's population.

Until recently, the Chinese economy grew faster than China's energy consumption. Between 1990 and today, Chinese citizens on average doubled their income while increasing their energy consumption only 15%. But now China is entering the energy-intensive phase of its development. Since 2001, energy demand growth has been in line with GDP-growth, despite the government's emphasis on energy efficiency. According to Xinhua press agency, China in 2007 added 91 gigawatts of capacity in the power sector, more than the total capacity of the UK. Of that new capacity, more than three quarters is coal-fired.

Energy demand is spurred by China's still expanding heavy industry, its rapid urbanisation – with roughly 20 million people moving from rural areas to cities every year – and, now increasingly by the transport sector. In China today there are 40 million cars on the road, or three cars for every 100 inhabitants. By 2020 there could be 150 million.
This is still only 12 per 100 people, well below the American or European average. But fuelling those cars would require an additional 2-3 million barrels of oil per day – equivalent to the current demand of Germany.

This unprecedented demand for energy is the main reason for high oil prices and cost inflation, resulting in pressures on supply.

In principle, a high oil price is attractive for upstream companies. And investment levels have indeed quadrupled since the oil price bottomed out in 1999. But, despite the best efforts of the industry, the costs have also risen and supply tightness continues. This brings into focus the second hard truth.

4. Supply challenges

The second hard truth is that by 2015 growth in supplies of "easy oil and gas" – or conventional oil and gas that are relatively easy to extract - will no longer match the pace with which demand for hydrocarbons is growing.

At a time when demand for energy is surging, more and more of the world's conventional oilfields are going into decline. Many of the traditional heartlands for the industry are running out of potential. The North Sea is a good example, with the UK's crude production falling since 1999. Really substantive supply growth needs to come from technologically complex projects and new regions that challenge the industry's ability to respond in terms of technology and cost.

Many billions of dollars are being invested, but big projects take years to come on-stream. Moreover, research by CERA shows that the cost of building these projects has doubled since 2002, as surging demand also affects building materials and people with skills. This has forced companies to postpone final investment decisions on some large new projects, which only adds to the stresses in the energy system.

Today, there is little spare capacity in the system – few idle rigs and no glut of unemployed but experienced workers. Everything is flat out.

Meanwhile, the market is nervous and sensitive to any potential disruption, from hostile weather to acts of terrorism. This pushes prices up further.

Political limitations on access and increases in taxation in resource-holding countries also add to the pressure, as do security issues in Nigeria, and local opposition to exploration and production in places like Alaska and Canada.

The problem of limited access to resources applies all over the world, including in North America. For instance, 85% of the Outer Continental Shelf of the United States is off limits to oil and gas producers. What little exploration has been done there dates back 30 years – when the industry had no deep-water drilling capability, no super computers, no submarine robots and no four-dimensional seismic models.

This is not to suggest that such resources would be large enough, or could be produced quickly enough, to stop the decline in US domestic oil and natural gas production, but they could help to slow it down and buy the USA more time to bring other sources of energy into its energy mix.

A similar argument applies at the global level: to gain the time that is necessary to diversify the world's energy mix, we need to keep up supplies of oil and gas for many years yet. This will require us to open up new resources and enhance recovery rates.

While peak oil theorists argue that major OPEC members in the Middle East have been overstating their proven reserves since the mid-1980s, others counter that recovery rates have improved since then thanks to new technology. As a result, proved reserves may be larger than previously assumed.

New technology can indeed help to improve recovery rates in both old and new fields. If we increased what we expect to recover from reservoirs globally by a very conservative 1%, it could perhaps yield 20-30 billion barrels of additional oil. That's more than the North Sea's remaining reserves.

Brazil's recent deep water discoveries show that new technology can help the industry to make discoveries that would not have been possible before.

However, even if we manage to increase reserves and open up new resources, the demand growth is likely to continue to stretch the system. Apart from the availability of capital and hydrocarbon resources, what matters is the rate at which they can be found, produced, refined and transported. The world now produces roughly 130 million barrels oil equivalent a day of oil and natural gas. We can raise that number, but in light of the demand increase, we would have to do that much faster than we used to and even then we cannot push up production levels indefinitely.

OPEC's likely future contribution to the growth of conventional supplies in the period up to 2030 illustrates the point. The International Energy Agency assumed in its 2007 reference scenario an average annual growth of oil production of 1.3% to 2030 for the world as a whole. At first sight, this seems a reasonable estimate. During the past 25 years, the average annual rate of production growth of oil indeed was around 1%. However, this average was reached because non-OPEC production grew at 1.1%. OPEC's production growth rate was only 0.9%. By using the 1.3% growth rate for the coming 25 years, despite non-OPEC production levelling off, the IEA seems to assume a growth rate for OPEC production that is double or more the rate we saw in the past 25 years.

This is not likely to happen. At the summit of producers and consumers in Jeddah in June 2008, Saudi Arabia promised to raise its production to 12.5 million barrels. And it was announced that a massive investment programme could help to raise production by an additional 2.5 million barrels if needed.

Even if Saudi Arabia could produce 12.5 to 15 million barrels a day over a sustained period of time, surging demand would keep eating away at OPEC's spare production capacity. Moreover, assuming producer countries were technically able to increase their production even further, they will act according to how they see their sovereign interests, and will grow their industries at a rate that matches those interests. That rate may well be different to the pace of development of importing nations. There may come a time when producer countries feel they no longer have an economic incentive to grow production, given that the natural resources they own are finite. They may calculate that a barrel left in the ground today will be worth more to them tomorrow, or they may want to preserve resources for their own country for as long as possible at the expense of exports.

Not surprisingly, the IEA in its most recent Medium-Term Oil Market Report made downward revisions to both OPEC and non-OPEC supply capacity growth after 2011.

Unconventional oil and natural gas, while abundantly available, can only partly make up for an "easy oil" supply gap. Unconventionals take longer to produce due to higher technical complexity and lower flow rates than light crudes. On the positive side, since depletion of unconventional resources proceeds more slowly, they could help the world to maintain a hydrocarbons production plateau for a long time.

And so the key challenge is to determine at which level the world can achieve and sustain a production plateau that both producers and consumers consider economically fair and can be maintained for at least half a century. This should give us and future generations the time to broaden the energy mix in a responsible way, while reducing the CO_2 in the fossil energy chain and continuing to supply the energy the world needs to grow and prosper.

5. The CO_2 challenge

Some would argue that the world should not seek to reach a hydrocarbons production plateau at all, given the need to reduce greenhouse gas emissions and mitigate climate risk. Instead, they say, we should redouble our efforts to boost the growth of complementary energy sources like wind, solar and nuclear.

It is true that we cannot solve the supply challenge in a business-as-usual fashion. Unless we take drastic steps, CO_2 emissions from energy could outpace the growth in energy demand. So what steps do we need to take to prevent such a scenario from unfolding?

- First, we need to improve energy efficiency.
- Second, we need to boost complementary energy sources.
- Third, we need to deploy CO_2 capture and storage technology to enable clean power from coal.

By the time new energy technology will have matured, greenhouse gas concentrations in the atmosphere may already have risen to levels scientists consider dangerous. That is why we urgently need to capture and store underground the emissions that are inevitably produced in the fossil energy chain, especially in coal-based power plants.

Burning coal poses a huge environmental challenge. It generates about twice as much CO_2 as burning natural gas. According to the International Energy Agency, coal became the biggest single source of world CO_2 emissions in 2004, accounting for 40% of overall emissions.

Rather than burning coal directly, we should gasify coal together with biomass, capture the CO_2 and then store it underground. Coal gasification technology generates a concentrated stream of CO_2 before combustion that is more easily captured than it is from exhaust gases after coal is burned.

6. Conclusion

It is right to have concerns about the way something as important as our global energy system will develop, and to recognise that urgent steps are required to shape better outcomes over the decades ahead. Given the natural timescales of energy-using and energy-producing facilities, it takes time to increase energy efficiency, boost complementary energy sources and deploy capture and storage technology.

To give us that time, we must keep supplies of oil and natural gas at a high level in the coming decades. Our scenario outlooks indicate that the maximum production of easily accessible oil could come as early as the coming decade. And maintaining a production plateau for all oil and natural gas will become a serious challenge in the 2020s. Sustaining such a plateau during the first part of this century is vital if we want to slow the global flight into conventional, dirty coal, with all the environmental consequences that implies.

Fossil fuels are ultimately finite, but they are far from becoming the fossils of the world's energy system. Innovation will change that system. There will be both evolution and revolution, but even the revolutionary changes will take decades to grow to the scale of global significance. In the meantime, cleaner fossil fuels are a vital intermediate step on the road towards a low-carbon future, a step we cannot afford to miss.

[12] The Globalist, "Oil's futures and beyond", 9 June 2008, www.theglobalist.com

[13] In this article, the author makes use of the insights gained from the work on Shell's long-term energy scenarios, Blueprints and Scramble, published in the spring of 2008. In addition, references can be found to publications by third parties, such as the International Energy Agency and the U.S. Energy Information Agency. To find out more about Shell's views of the energy system, please read Shell's long-term energy scenarios on www.shell.com

Part 2:

The ITPOES view of risk and mitigation options

1. The differences of opinion in the peak oil debate

1.1 A common view: peak oil nowhere in sight

ExxonMobil took out national newspaper advertisements in March 2006 suggesting that "peak (oil) production is nowhere in sight." ExxonMobil's view is that global oil production can carry on rising for several decades to come. The majority view certainly holds that reserves are sufficient for supply to keep rising for many years. UK government, Energy Minister Malcolm Wicks, for example, said in May 2008 that:

> "global oil reserves are sufficient to prevent total global oil production peaking in the foreseeable future provided sufficient investment in both upstream and downstream is forthcoming in order for production to keep pace with the growing global oil demand. This is consistent with the assessment made by the International Energy Agency (IEA) in its 2007 World Energy Outlook (WEO)."[14]

A recent posting by the government on the Number 10 website goes further, offering the same form of words as Mr Wicks and adding that the 2007 WEO "concludes that proven reserves are already larger than the cumulative production needed to meet rising demand until at least 2030."[15] This opinion overlooks the flow-rate considerations highlighted in Opinion A, and a number other concerns that this taskforce harbours about reserves, as we explain below.

1.2 The IEA's evolving opinion

We find the UK government view puzzling, because when the IEA released their 2007 report they warned of an oil crunch within five years, as we observed in our Background section. In Opinion B above, Shell also alludes to the unmeetable assumptions the IEA has to make if the world is to rely on Saudi Arabia for supply to keep meeting demand.

Shortly after Mr. Wicks offered his view, the IEA gave another warning. The organisation is currently in the middle of its first global assessment field-by-field in the top 400 fields (comprising two-thirds of global production). They intend to publish the results in November 2008. Ahead of publication, the agency fears that aging fields and under-investment will mean a peak below 100 million barrels a day. Fatih Birol, the IEA's chief economist and the leader of the 25-member team doing the study, told the Wall Street Journal: "The oil investments required may be much, much higher than what people assume. This is a dangerous situation." ...."We are of the opinion that the public isn't aware of the role of the decline rate of existing fields in the energy supply balance, and that this rate will accelerate in the future."[16]

1.3 The peak-oil risk as analysed in Part One

Oil industry insiders are warning, in growing numbers, that oil supply cannot meet demand for much longer. The risk opinions commissioned for this report present the main reasons for concern. In Opinion A, Chris Skrebowski, Consulting Editor of Petroleum Review, presents evidence that total global oil production will begin declining somewhere in the period 2011 - 2013. His main argument is that new capacity flows coming onstream from discoveries made over the preceding decade will begin dropping at that time. This problem will be compounded by other issues, including accelerating depletion of the many old oilfields propping up much of global oil production today, exaggeration by OPEC of reserves, and failure of the "price-mechanism" assumption that higher prices will lead to increased exploration and expanding discoveries. In Opinion B, Royal Dutch Shell presents a view that although the era of "easy" oil will be over around 2015, global production can be maintained beyond on a plateau extending into the 2020s by resorting to unconventional oil resources.

We can fairly categorise these views respectively as a "descent" scenario and a "plateau" scenario. Both present problems for the British economy. This is because the government and the business world tend to assume that global oil supply will continue to grow: that as our North Sea oil and gas production falls - as it has by 7.5% per year since the peak of oil production in 1999 - we will be able to meet demand by importing ever more oil and gas each year.

We note that the Shell opinion concludes "we cannot solve the supply challenge in a business-as-usual fashion," and that "unconventional oil and natural gas, while abundantly available, can only partly make up for an 'easy oil' supply gap." In other words, both opinions contend that the cheap oil era has gone and will not return, that meeting future energy demand in general - and oil and gas demand in particular - will be very challenging, with unconventional oil and gas only a partial answer. Necessarily the future is going to require a radical change in the way our economies are fuelled. Business as usual as we currently know it will not be possible.

The taskforce believes that human effort and ingenuity will rise to the challenge of the peaking of (cheap) oil supplies but will only be able to do so, in a timely and not too disruptive manner, if a critical mass of stakeholders is made aware of the urgency of the situation. For the business community, information about the future oil and gas supply challenge is vital if timely and appropriate investment decisions are to be made.

We are thoughtful about some of the arguments in the Shell analysis. Unconventional oil and alternatives have so far failed to achieve significant output levels in relation to current world liquids demand of around 86 million b/d. Current biofuels production is around 1.4 million b/d (1.6%), Canadian tar sands around 1.4 million b/d (1.6%) while Orinoco heavy oil capacity is 0.6 million b/d (0.7%). This gives a current combined total of 3.4 million b/d (3.9%). With political backing for biofuels waning, President Chavez reluctant to allow additional investment, and Canadian tar sands investment critically dependent on the relationship between the price of gas and the price of transport fuels, it appears to us optimistic to believe that production of the difficult oils and alternatives can be expanded rapidly. We further explore this, and other arguments made by Shell, below.

2. The state of play in easy oil

2.1 Production in old oilfields and provinces

Nearly a quarter of the world's oil is pumped from the 20 biggest fields and most of these were discovered decades ago. Production in several of the top 20 is falling fast. Today only four oilfields anywhere produce at more than a million barrels a day. These are Ghawar (Saudi Arabia), Greater Burgan (Kuwait), Cantarell (offshore Mexico) and Daqing (China). The latter three are all in decline. Cantarell, once the world's third biggest oilfield, reached a peak production of 2.1 million barrels a day four years ago. It was then providing some 60% of Mexico's oil. Production had fallen to just over 1 mn b/d in April 2008, half the capacity at its peak. Mexico's production has fallen every month of 2007 and 2008 as a result.[17]

Such rapid decline rates can be seen not just in individual giant fields[18] but in whole provinces - nested groups of oilfields set in one contiguous geological structure. The North Sea was the last oil province to be discovered anywhere in the world, back in the 1960s. Production peaked there in 1999 (UK) and 2000 (North Sea as a whole). Output of oil and gas has been falling at a combined average of 7.5% since 2002, and the province is now one of the fastest-declining in the world. The UK government has had to revise down its once lofty expectations of North Sea production: its target now is simply reducing the depletion rate to 5%, if it can. (A common view of baseline global oil depletion is in the range 4.0 - 4.5%). Oil and Gas UK, the UK oil industry's professional body, is warning that without heavy investment and new-field development there would effectively be no industry by 2020[19], and certainly not the 0.8 million barrels a day of production envisaged by the Department of Business (BERR).[20]

When it comes to maintaining production in the world's giant fields, much will depend on performance in the Arabian Gulf. Worryingly, Sadad al-Husseini – former head of exploration and production at Saudi Aramco - calculates that the Gulf's giants are an average of 41% depleted.[21]

The fact that old oilfields tend to collapse fast would not be a problem if we were finding plenty of giant oilfields to replace them. But it seems we are not. Recent Brazilian deep water discoveries are a very welcome addition. In 2006 and possibly 2007 they effectively doubled the global discovery rate from 10 billion barrels/year to 20 billion barrels/year. But this simply means in 2006 and 2007 the world discovered two barrels for every three used rather than the one barrel for every three used earlier in the decade.

2.2 New discoveries, and the delays in bringing them onstream

Both Opinions A & B make it clear that the oil industry is not discovering enough fresh reserves of easy oil. In the hundred year-plus history of oil exploration, only 507 giant fields have been found. We call them giant because they hold 500 million barrels or more. That sounds a lot, but it is less than a week's global supply at current demand levels. The 507 world's giants make up 1% of the total numbers of fields ever found but in 2005, these contributed around 45% of the global production and represented 60-70% of the global ultimate recoverable reserves of oil.[22]

The peak of discovery of oilfields, giants or otherwise, was in the 1960s. The vast majority of the giants were discovered before the peak of discovery. They are old. The discovery rate of giants this century tells the story: 16 were discovered in 2000, nine in 2001, two in 2002, one in 2003, two in 2004, two in 2005, one in 2006, one in 2007. With the high oil prices since 2004, it is not as though the industry has been hard up for cash to finance its exploration programmes. It is looking, and not finding. Or rather, it hopes to find elephants and generally finds mice. The average size of oilfields discovered since 2000 is a mere 50 million barrels, 10% of a giant, well under a day's global oil supply.

The biggest discovery in the last 30 years was Kashagan, an oilfield in Kazakhstan. As much as 13 billion barrels may be recoverable from the field, making it a super-giant. But after its discovery in 2000, development of Kashagan has involved repeated delays, as we read in Opinion A. Meanwhile, initial cost estimates have doubled, enraging the Kazakh government, who seek $10 billion in damages from the main developer, ENI.[23] The oil is deep, it is rich in highly toxic hydrogen sulphide, and profitable and sustained recovery in the face of a hostile environment and a hostile government is going to be far from easy.

Even where the fields are in "friendly" waters, other problems crop up. BP's Thunder Horse discovery in 1999, in deep water off New Orleans, was the biggest-ever find in the Gulf of Mexico, booked at 1.5 billion barrels. After delays caused by high pressure at the well head, and a capsized drilling platform after Hurricane Katrina, it is now not expected onstream before the end of 2008.[24]

2.3 Uncertainties about existing reserves of easy oil

Both opinions in Part One alluded to a potential problem with quoted proved reserves in the Middle East. Oil reserves, being defined as the amount of oil economically extractable - from a field, region or nation - tend to be in the eye of the beholder. When the oil price goes up appreciably, it might be reasonable to argue that the amount of oil extractable economically increases with it. The Securities and Exchange Commission does what it can to define and apply rules for the calculation of reserves, at least for oil companies quoted on the New York Stock Exchange. In the OPEC nations, where the national oil companies tend not to be quoted on stock exchanges, there are no such rules. In the 1980s, many OPEC nations announced that they had much bigger reserves than they had earlier declared. They did this at a time of low oil prices, which ought if anything to have been shrinking reserves. Many experts believe that this mass inflation of the figures happened not because they found more oil, but because OPEC began in 1983 to link its production quotas to the size of national reserves. As a result of this political game, the world's supposedly proved reserves of 1,200 billion barrels are probably overstated by at least 300 billion barrels.

Kuwait was the first country to decide it had bigger reserves than it had earlier calculated. From 1980 to 1984, Kuwait declared 64-65 billion barrels of proved reserves each year. In 1985, it declared 90. It has announced "proved" reserves of 92-100 billion barrels each year ever since. The jump in 1985 was the subject of a certain amount of sceptical speculation, unsurprisingly, and in January 2006, Petroleum Intelligence Week reported that it had seen national oil company documents suggesting that Kuwait has been overstating its proved reserves by more than half. In May 2007, after much vacillation, a Kuwaiti oil minister confirmed the revelation, and announced that the nation's proved reserves would have to be written down, from 100 billion barrels to 48 billion.[25]

It is clear that Kuwait hasn't been alone in playing the political-oil game. No less a figure than Sadad al-Husseini, who retired from the board of Saudi Aramco in 2004, is now on record as saying that global proved reserves are overstated by 300 billion barrels.[26] This is a lot of oil: 10 North Seas, 10 years of production at today's rate.

The optimists in the oil companies remind us of their well-known ability to lift production in existing fields with a variety of enhanced oil recovery techniques, and in Opinion B, Shell is no exception. These techniques range from pumping fluids or gases underground to ease the movement of oil through the pores of a reservoir, or drilling horizontally. They can lift ultimate recovery from a field dramatically, sometimes from 30% to 70% or more. But most of these techniques are already deployed in most of the areas the international oil companies (IOCs) have access to today. Even if they could secure access to the choicest remaining easy oil in areas controlled by national oil companies, we have the example of the United States to consider. Here, in and around Houston, many of the techniques of enhanced oil recovery were invented, tested and first applied. Production in the USA peaked in 1970, and has fallen steeply ever since, despite every effort to throw reserves-enhancement techniques at slowing the collapse. Can we be sure that EOR would make such a major difference to the global pattern of depletion? The taskforce concludes that we cannot rely on this.

Shell points out that a 1% increase in recovery rates adds 20-30 billion barrels of oil to reserves, which is impressive compared to current global consumption is 31.4 billion barrels/year. It is also true that increased recovery comes out as low flow rates and the end of a field's life. It is flow rates that should concern us more than ultimately recoverable reserves, as Opinion A and to some extent even Opinion B demonstrate.

3. Unconventional oil and conflation of the peak oil and climate change threats

3.1 Tar sands

There are vast amounts of oil locked up in the tar sands, and certainly hundreds of billions of barrels of it are accessible in principle. But as Shell is careful to emphasise in Opinion B, the oil is difficult to extract. It is solid, not liquid, and has to be melted, mostly underground. That requires significant quantities of gas and water. Even then, progress is glacial. The oil industry has invested $25 billion to date, and after decades of effort has a production capacity of 1.3-1.4 million barrels a day as of August 2008. Industry estimates now put production in 2015 at little more than 2.5 million barrels a day.[27] It is difficult to see how that can that make much difference if the easy-oil depletion rate is around c 3.5-3.9 mn b/d/year (4 - 4.5% a year) today, as we heard in Opinion A. By 2015, what will the depletion rate be in conventional oil, we ask?

Well over $100 billion of new investment would be needed to ramp up the tar sands production to the levels the industry foresees in 2015. In the face of these challenges, at least one oil company, Talisman, has lost faith in the tar sands proposition and pulled out.

The oil shales of Wyoming and Colorado are also held up by some as a considerable hope for the future. In this type of unconventional oil, organic matter has yet to be cooked to the level where it forms either crude or tar. As in the case of the tar sands, there is plenty of "oil" there in oil shales, if it can be cooked underground. But how to cook it? Whether there is any realistic technique for doing so, or if so on what timescale, remain open questions. One proposal involves drilling wells into the shale and installing electric heaters to raise the bulk temperature to the level needed for reactions that produce light crude: 370°C. Another, from a US government engineer, involves installing nuclear reactors underground. But as US government officials asked at one recent closed door industry-and-government conference: "where are you going to get the water, and the permits?"[28]

3.2 Coal from liquids

Nazi Germany, hard up for fuel in the Second World War, resorted to extracting liquid oil from coal. This can be done by pulverising the coal, and passing gases across it at high temperatures. This is such an energy intensive process that since the war only oil-strapped Apartheid-era South Africa has followed the Nazi example with any seriousness of intent, until recently. China's biggest coal company, Shenhua, launched a coal-to-liquids (CTL) programme with Shell and Sasol in 2006. The plan at the time was to build eight liquefaction plants by 2020, producing 0.6 million barrels a day.[29] The IEA reports that similar coal-to-liquids plants are planned in Japan, the USA, Australia, NZ, India, Indonesia, Botswana and the Philippines.

Converting and burning the liquid from coal emits twice the greenhouse gas of diesel, meaning that there is a considerable environmental toll from CTL. In June 2007, China reportedly considered halting coal-to-oil projects due to worries about energy, expense, and water requirements. The official Xinhua News Agency reported an official of the country's top economic planning agency, the National Development and Reform Commission, as saying that China "may put an end to projects which are designed to produce petroleum by liquefying coal." In August 2008 they did: the Chinese government ordered a halt in all coal to liquids plants in order to conserve coal supplies for power generation. The National Development and Reform Commission decree excepted only Shenhua's plants in Inner Mongolia and Ningxia. Sasol immediately confirmed it is dropping one of the two projects it has underway in its joint venture with Shenhua. China, it should be noted, is struggling through a sixth year of power shortages because of insufficient coal supplies. Coal shortages caused the mothballing of almost 3% of China's coal-fired generating capacity in July, according to the State Grid Corporation.[30]

Faced with this evidence of environmental and resource constraints, and only small flow rates projected far in the future, it seems difficult to imagine that CTL – like tar sands – can contribute significantly to closing the easy-oil depletion gap, even if environmental considerations are ignored. And such constraints, of course, should not be ignored.

3.3 The vital importance of conflating the climate-change and peak oil threats

Little we have written so far considers climate change. Yet this problem is viewed by many people, and organisations, to be the single biggest of all the threats to a viable future for global human civilisation, acting as it will in concert with population growth. Growing numbers of companies are responding with leadership measures of different kinds. Many executives believe that within a few years carbon consciousness will be written into the DNA of boardrooms across every sector of the global economy. Governments too are responding, though not generally with the seriousness-of-intent of some of the corporate action.

Against this backdrop, it is a safe bet that any oil companies intent on ignoring the carbon implications of plundering the tar sands, or seeking to produce liquids from coal, are going to experience pressure from stakeholders. The writing may already be on the wall. The Conservative Canadian administration announced in April 2007 that its greenhouse target was 20% emissions cuts by 2020. As part of this, John Baird, environment minister, announced new rules in March 2008 that will apply to all big industry, including tar sands operations and power plants: they must capture carbon from 2012 onwards.[31] This will be an incredibly tall order for the tar sands operators. Big as that problem is, there are carbon troubles coming the other way across the border too. A new US law, the Energy Independence and Security Act of 2007, could put a halt to American tar sands imports. It stipulates that federal agencies can't buy alternative fuels if the carbon emissions involved their production and use amount to more than those of regular oil. Canada's tar sands exceed the emissions of regular oil by three times or thereabouts. For the moment, the border will doubtless remain open to tar-sands oil shipments. But if a Republican administration can contemplate putting limitations on carbon-intensity of alternative fuels, oil industry planners certainly have to fear what a Democrat one might do.[32]

Where does the global-warming danger threshold lie? One view, shared by the governments of the European Union among many others, is that we dare not go above a 2^{o}C rise in average global temperature. According to leading climate scientists at Germany's Potsdam Institute, no more than 400 billion tonnes of carbon can be emitted this century if we are to have at least a 50:50 chance of staying below that threshold. That places the long-term utilisation of coal and tar sands without carbon capture and storage firmly out of bounds, because the energy industry estimates that several thousand billion tonnes of carbon remain below ground in coal resources waiting to be extracted and burned. Including accessible areas of tar sands, the total amount of carbon left in un-utilised oil resources is in excess of 700 billion tonnes. Even allowing for early peak-oil advocates being correct, staying below the 2^{o}C threshold of extreme danger entails the vast majority of coal and tar sands staying below ground.

Much is made by coal advocates of their ability to make use "clean coal" technologies, including - in the case of greenhouse emissions - the capture of carbon emissions in power plants, and the sequestration of the gases underground.

3.4 Carbon capture and storage (CCS)

The idea is behind CCS is to trap the escaping carbon dioxide gas at the coal-fired plant, pump it long distance to the coast, then offshore to oil and gas fields. There, it is pumped down into an old oil or gas reservoir, boosting production of oil in so doing. But former US Energy Secretary James Schlesinger is prominent among those who take the view that this notion has a timing problem. "It will take 15-20 years to introduce carbon capture and storage, if then," he warns. The languor with which policymakers set their carbon capture and storage (CCS) goals would seem to support such a lengthy timeframe. Proposed EU legislation envisages all coal-fired power stations built in the EU having CCS: after 2020. EU leaders expect to commit to 12 large-scale pilot CCS projects: by 2015.

In May 2007, BP dropped its first plan for a CCS power station, citing lack of governmental enthusiasm to share costs. In June 2007, Shell dropped its first CCS project because it and partner Statoil had found CO_2 sequestration didn't enhance oil flow enough to make the project economically viable. Shell is currently still involved in developing a number of CCS projects, including the public-private research project CO2SINK in Germany, which began pumping small amounts of CO_2 into the ground earlier this year. A flagship American CCS project collapsed in January 2008 when the US Department of Energy pulled out. The FutureGen Alliance was a coalition of power and coal companies that joined with the US DoE in 2005 to announce it would build a virtually zero emissions coal plant. The chosen site for the $1.8 billion, 275-megawatt prototype zero-emissions power plant was Mattoon in Illinois. The DOE, signed up to cover three-quarters of the financing, became frustrated as costs almost doubled. Illinois lawmakers have expressed an intention to take the DoE to court over this.[33]

There is also the question of whether or not CCS will work, even if it proves ultimately deployable at industrial scale for the 2,000 plus power plants that will be built or revamped by 2020 on current trends. In the UK, the government appears likely soon to licence the first British coal plant to be built for 30 years, at Kingsnorth in Kent, provided it is made "CCS ready." However, tellingly, the Department of Business will not require plant operator E.ON to fit CCS by a target date. The reason given for this by the energy minister is that he fears E.ON won't go ahead with the plant if the government sets a cut-off date for CCS operation "when we do not know 100% that CCS is going to work, the engineering has not been tested and no-one is fully aware of what the costs might be."[34] This approach speaks volumes for the practicability of the CCS option, and suggests – at minimum – that few risk-abatement eggs should be put in this basket, and certainly not at the expense of market-ready energy solutions.

3.5 Nuclear power and climate change

The nuclear industry has also argued strongly that it can help substantively with the quest to cut greenhouse-gas emissions. The strengths of this case are that the industry's operations have a low carbon footprint once a plant is running, 40 years of operational experience can be called on in designing and operating a safer and more efficient next generation (third) of reactors, and the industry has built a substantial body of support in industry and government for a re-start to mass reactor building.

On the weakness side of the equation, the industry admits that it cannot build and bring on stream the next generation of power plants in less than 10 years. That isn't fast enough to make a difference either to the oil depletion problem, if the early peakists are correct, or the climate-change problem, if the great majority of the IPCC's scientists are correct. In 2018, the first nuclear plants would be coming on stream in the UK a minimum of five years after the most peak oil crisis dawns on the world, if Opinion A in Part One is accurate. Then, they would be replacing a bare minority of the 429 nuclear reactors active in the world today, many of which are already near or past their supposed decommissioning dates.

It should also be noted that the first European nuclear plant to be given a go-ahead in 10 years was the Finnish Olkiluoto 3 plant, in 2002.

Then, it had a projected completion in 2009 on a budget of €3 billion. Completion is now estimated not sooner than 2011, and at an unquantified but vast cost over-run. A big factor in this over-optimism has been the difficulty of bringing sub-contractors up to the level of work required. As with the oil industry (see section 4 below), the nuclear branch of the energy industry has a severe skills shortage, largely based on the age-imbalance of its core skilled workforce.

4. The oil industry's internal problems

4.1 Risk from legacy infrastructure

Crude oil is a corrosive substance and the majority of oil industry infrastructure is now more than a quarter of a century old, having been installed during the last period of high oil prices at the beginning of the 1980s. Houston investment banker Matt Simmons, who built a successful bank on investment in oil services, has warned that BP's recent problems with pipeline corrosion, and the lethal 2005 Texas City refinery fire, could point to endemic problems in the wider industry. "We've kind of let the industry rust away," he has told Bloomberg News, pointing to the age of the current fleet of 600 offshore drilling rigs: 80% are in the 24-27 year age group. The pipeline infrastructure is also too old. The problem could be oil's "Pearl Harbour," he believes. Simmons says oil output can now only decline, in part because oil rigs are working flat out - as Shell also points out Opinion B - and older ones are retiring faster than new ones are entering service.

Matt Simmons, it should be noted, holds the view that crude oil probably peaked in 2005. He echoes the view of Opinion A, observing that for the last three years crude has struggled to stay on an undulating plateau at 73-74 million barrels per day. The rest comes from LNG, refining processing gains, and tapping inventories. Major new projects occasionally coming online may nudge the total crude production higher than 74 mn b/d, he professes, but the odds of going higher are low.[35]

4.2 Risk from underinvestment

Estimating investment requirements for meeting rising oil demand, the IEA has calculated that more than $4 trillion is needed if the oil industry is to meet projected oil demand by 2030. It is far from certain that this investment will actually occur, the IEA warned in 2006: recent absolute increases in investment by oil companies are "illusory", in relative terms, because of inflation in drilling costs.[36] Worryingly, in real terms most international oil companies actually cut exploration spending between 1998 and 2006, in spite of the rise in oil prices. ExxonMobil, BP, Chevron, and ConocoPhillips used more than half of their increased operating cash flow not on exploration but share buybacks and the payment of dividends to shareholders.[37]

For the national oil companies there are different pressures on investment. OPEC ministers pointed out that President Bush's 2007 assertion that the US is "addicted to oil" could impact OPEC plans to invest in new production. They fear a return to the 1970s and 1980s when they invested billions only to see the oil price fall.

4.3 Risk from skills shortage

The average age of people working in the oil industry is a staggering 49. The average age at retirement is 55. Oil consultancy CERA reports that 50% or more of the experienced workforce will be retired by 2015.[38] The problem is worldwide, but particularly acute in the Middle East. The legacy problems are going to be immense. The oil industry faces soaring costs, and mounting health-and-safety pressures. Its increasingly inexperienced workforce seems set for a struggle in the years ahead.

5. The oil industry's external problems

5.1 Resource nationalism

Some 80% of global oil reserves are controlled by national oil companies (NOCs). Whilst it may be true that enhanced recovery offers a route to a lot more oil in these countries, given that many NOCs don't have the technological capabilities of the international oil companies (IOCs), most of their governments are not about to let the IOCs in. They forced them out more than a quarter of a century ago, in a wave of nationalisation, and most OPEC governments want them to remain out if at all possible.

A renewed phase of oil nationalism in 2007 - in Russia, Venezuela, and other countries - is shutting down options for the IOCs still further. The new resource nationalism began in 2006 at Shell's Sakhalin 2 project in Russia, a four billion barrel-equivalent oil and gas field. In the hostile environment of coastal eastern Siberia, Shell experienced the same kind of delays and cost over-runs as the operators of Kashagan. They attempted to hand part of the bill on to the Kremlin as a reimbursable cost. The result was that President Putin's men first threatened Shell executives with jail for environmental damage, and then effectively nationalised the project by giving a majority stake to Gazprom. In 2007, BP, ExxonMobil, and Total were subjected to similar Russian tactics, which have reached new heights recently with the denial of visas to BP specialists employed by the 50:50 joint venture TNK-BP, and the hounding from office of its ex-BP CEO.

5.2 Civil unrest

In Opinion B, Shell referred to its problems with civil unrest in Nigeria. Recently these reached new heights when armed rebels on powerboats attacked a Shell platform in Nigeria 100 km out at sea. Shell shut the Bonga platform, one of Africa's largest fields, losing 200,000 barrels a day in the process. While production restarted within the space of a few weeks, the industry had been warned that even deep water projects would henceforth be vulnerable to terrorism.[39]

In April 2008, a Shell report to the Nigerian government had warned that Nigeria's oil output could fall by a third by 2015 without massive investment. The investment has to be in joint ventures with foreign companies.[40] Clearly, the higher the degree the civil unrest, the less likely the investment.

6.1 Oil exporters' domestic oil demand

A July 2008 report by the Royal Institution for International Affairs has suggested that dependence of oil producing countries on oil revenues is increasing so much that it threatens their ability to export. The RIIA study analysed twelve oil-exporting nations, and assessed how they have been investing their post-2003 surge in petrodollars domestically.[41] As a result of an equation combining depletion with soaring domestic demand for oil as oil-dependent infrastructure programmes roll out, even Saudi Arabia must plan for export decline. Some countries might also rationally choose to keep oil in the ground, even at over $100 a barrel, the report concludes. The authors cite the same comment by King Abdullah that Lord Oxburgh does in the Foreword to this taskforce report: "I keep no secret from you that, when there were some new finds, I told them 'No, leave it in the ground, with grace from god, our children need it."[42]

This is an area that fundamentally impacts national security in consumer nations, as we explore further below. First, though, it is expedient briefly to consider the relationship between oil and gas.

6.2 The relationship between oil and gas

Natural gas production has depletion- and geopolitics problems of its own: to what extent can it be substituted for oil to close the easy-oil depletion gap, and to what extent might its own continuing depletion deepen the coming global energy crisis?

There is every indication that gas, rather than coming to the rescue of oil, will compound the global energy crisis. In 2007 an American oil company CEO warned that "the world has a natural gas problem." ConocoPhilips CEO Jim Mulva thinks we face "serious future gas shortages."[43] As with oil, a growing chorus of insiders have recently joined him in speaking out. In the Gulf states, above some of the biggest oil reserves in the world, emerging gas shortages are threatening economic development in all countries today except for Qatar. Qatar, with the third biggest reserves in the world, has put LNG projects on hold until at least 2010 while it assesses reservoir difficulties in the world's largest gas field. The UAE, a country with the fifth largest gas reserves in the world, is importing gas from Qatar. Even Saudi Arabia, with the fourth largest reserves, is considering imports.[44] Meanwhile, in Russia, ex senior government officials warn that the Russian industry is in danger of not meeting export agreements because of underinvestment in developing gas fields. Senator Gennady Olenik alleges that private companies, since being created in the early 1990s, have not been prospecting in the oil-and-gas rich north because no incentives have been made available for doing so. In other words, as RIA Novosti puts it, "for the last 15 years Russia has done practically nothing to reproduce its mineral wealth, but has been scattering the inheritance it received from the previous generations." A former Soviet Minister of Geology has backed this up. The Ministry and Natural Resources is urgently drafting proposals to boost stagnant investment.[45]

We accept that much of this concern is anecdotal, and that undiscovered gas resources may be very large. But on the other hand, we note that half the world's supposedly proved reserves are in two countries: Russia and Iran.

6.3 Emerging evidence that exporters will increasingly look to retain oil and gas production

A particular concern is that if the early peak oil analysis proves correct, recent history in Kuwait, Iran and Russia suggests that as the new realities dawn on exporters, the news might not be good for oil importers, just as the RIIA report suggests. The reaction in Kuwait to January 2006 press reports in the West that the nation might have only half the oil reserves it declares each year is instructive. The Kuwait parliament, elected in June 2006, refused a request from the ruling family barely a month later for funds to lift oil production. The parliament professed that if the reports are true that the nation has fewer reserves than assumed, Kuwait should retain its oil resource for the purposes of growing its own economy.[46]

In Iran, fears emerged in 2007 that domestic oil consumption has become so unconstrained the nation's status as an exporter is coming under threat. The aged and neglected infrastructure combines with the problem of demand growing at up to 10% per year to suggest, in one estimate by analysts, that as soon as 2015 Iran will no longer be an exporter.[47] In June 2007 the Iranian government brought in fuel rationing as a reaction to shortages caused by long-run domestic under-investment in refining. Riots resulted, and in a foretaste of what awaits governments who fail to meet domestic expectations of oil supply, Iranians set fire to petrol filling stations.[48] It will be difficult indeed for a government to export in the face of this kind of pressure at home, if domestic demand cannot be met.

In Russia, oil production from February 2006 to February 2007 increased by over 400,000 barrels per day, whereas exports remained flat. The excess was needed at home, where Russian car production and sales grew prodigiously in 2006.[49] The Russian use of gas as an instrument of economic blackmail of its neighbours since 2006 shows clearly the kind of treatment states dependent on its fossil fuel exports can expect from the Kremlin, should a global energy crisis materialise. Ominously, Russian oil production has fallen in recent months after years of steady increase.[50]

Meanwhile in the UK, as domestic oil and gas production in the North Sea falls rapidly, we will be forced to look increasingly to imports. Britain imports only 5% of its energy now, but this requirement is likely to rise to something more like 50% in five years, much of it gas. The government appears sanguine about this, pointing to the growth of domestic infrastructure for liquefied natural gas (LNG) and pipelines from Norway, the Netherlands, and Belgium. But in 2007 imports of LNG into the UK actually fell. As for the pipelines, in May 2008 Thor Otto Lohne, executive vice-president of the Norwegian pipeline company Gassco, warned an energy seminar that long-term contracts with continental European companies meant that: "the UK is a secondary priority. Like it or not, that is a fact."[51]

In August 2008, further major delays to LNG projects increased the concern. A cumulative 100 million tons of supply by 2013 (138 billion cubic metres, 868 million barrels of oil equivalent) disappeared as a result of Exxon and Chevron postponing or shelving projects in Australia, Nigeria and the Baltics. This quantity is larger than the combined 2007 imports to S. Korea and Japan, the two largest importers in the world. Wood Mackenzie, reporting the setback, notes this will mean spot LNG prices at a premium to oil.[52]

7. Oil-production and supply scenarios

7.1 Global scenarios

We can distinguish four possible qualitative scenarios to capture the range of possible evolutions of global oil production. We emphasise that these are scenarios, not predictions or forecasts.

- *Global "growth" scenario*

  This scenario is the one actively espoused by ExxonMobil and oil-industry consultancies like Cambridge Energy Research Associates, in which global oil production continues to grow well beyond 100 million barrels a day. In its latest reference scenario, for example, the US Department of Energy (Energy Information Administration), expects global production to be 112 million barrels a day in 2030.

- *Global "plateau" scenario*

  Shell posits this scenario in Opinion B of this report, arguing that global production will flatten around 2015 and remain on a plateau into the 2020s propped up by expanding volumes of unconventional oil production because of the decline of conventional oil production.

- *Global "descent" scenario*

  This scenario, as described in Opinion A of this report, involves a fall off of global production as oilfield flows from the newer projects fail to replace capacity declines from depletion in older existing fields.

- *Global "collapse" scenario*

  There is another, very worrying, scenario, wherein the steady fall of the descent scenario is steepened appreciably by a serial collapse of production in some - possibly many – of the aged supergiant and giant fields that provide so much global production today.

  On balance, having reviewed the state of play in global oil production, the taskforce considers that the "descent" scenario is a highly probable global outcome. We also fear that a "collapse" scenario is possible, albeit less likely.

7.2 UK oil-supply scenarios in the light of global peak oil

The aforementioned four scenarios can be translated into a UK context as follows.

- *UK "growth" scenario*

  To keep oil supply growing after global peak oil, given that North Sea oil peaked in 1999 and production has now fallen to almost half what it was in that peak year, the UK would have to persuade a number of oil-producing nations to favour British interests over others, and to a significant but difficult-to-quantify degree. Russia would be high on the list that would need to be persuaded.

- *UK "plateau" scenario*

  Similarly, to keep oil supply steady year-on-year, the UK would have to persuade oil producing nations to favour it over others.

- *UK "descent" scenario*

  For UK oil supply to decline at the same annual rate as the global decline, the UK would still have to persuade oil producing nations to favour it with a growing quota of imports. This is because North Sea oil production will continue to decline, at a best-case rate of 5% (the government's objective) but more likely at the higher rates seen in recent years, or even higher if UK Oil and Gas's gloomy warning of an extinct industry by 2020 proves correct.

- *UK "collapse" scenario*

  In this scenario, a major oil producing nations - or a group of them - decides that it has been over-optimistic in its assessment of reserves hitherto, that its domestic economic requirements for oil are growing, and slows or even stops oil supply to the UK.

  In the UK's case, the taskforce considers that the "descent" scenario is a highly probable outcome for future UK oil supply. We also fear that the "collapse" scenario is possible. These risks may very well apply to gas as well as oil. Gazprom's historical behaviour, and recent events in the Caucasus, add to this concern.

8. Mobilising the UK for peak oil: challenges

The implications of the two UK peak-oil scenarios of concern can be summarised as follows, in terms of energy policy challenges. For comparison, we add a "Climate-change policy-response" scenario. This simply posits a nation acting on climate-change (carbon) risk, but not on peak-oil risk. We set out the rationale for each box in sections 8.1 to 8.3.

Table 6

	Climate-change policy-response scenario	Peak-oil "descent" scenario	Peak-oil "collapse" scenario
End goal for UK replacement of oil use	Within 42 years	Within < 20 years	Within < 10 years
Annual rates of oil replacement with respect to 2008 levels	2.38%	c 5%	> 10% p.a.
Applicability of policy measures in Annex 1, demand-management	Many but not all needed	All needed	Insufficient
Applicability of policy measures in Annex 2, renewable supply	Many but not all needed	All needed	Insufficient

8.1 UK "climate-change policy response" scenario

The most recent prognosis from the UK government's most senior advisors on climate change is that the global target for atmospheric greenhouse-gas concentrations has to be less than 450 ppm of carbon dioxide equivalent, and that to achieve this, at least 80% cuts will be needed in global greenhouse-gas emissions by 2050. Because some emissions from food production are inevitable, and because the developed countries will have to cut deeper and quicker than the developing countries on the principle of equity, this means that the UK has to target zero emissions from the energy sector by 2050. This gives us 42 years to replace oil, plus the other two fossil fuels, unless CCS can be proved as a technology and deployed - at industrial scale - at a sterling cost cheaper than alternative energy, and at an energy-cost involving less net carbon emissions. A target of 42 years involves a reduction from 2008 consumption levels of 2.38% annually. Note, however, that the Tyndall Centre has pointed out that initial reductions probably have to be higher than this: as high as 6-7%, they say. This is both to instigate the momentum needed in market change, and because fears about the potency of climate change are growing.

Though a target in excess of 2% a year may sound taxing at first pass, cutting emissions by a few percent year-on-year for four decades ought to be eminently feasible in a carbon-aware society conscious of the damage climate change can do to its economy. Doing so would certainly be a sensible investment. Lord Stern, former chief economist to the World Bank and the Treasury, recently told business leaders that decarbonisation of the global economy could be achieved by investing 2% of GDP, and would save 20% of GDP or more in climate damages.[53] Many business leaders approve of such levels of investment, as we will see when the Prince of Wales Corporate Leaders Group on Climate Change Communique to the Poznan Climate Summit is published in December.[54]

In terms of UK precedent for cuts in demand for oil, note that the highest ever annual UK consumption was 1,802 thousand barrels a day in 2005. Consumption fell to 1,785 thousand barrels a day in 2006 and again to 1,696 thousand barrels a day in 2007, which is an average drop of 2.9%. The drop between 2006 and 2007 was actually 5%.[55] A 2.38% reduction of 2007 consumption is 43,000 barrels a day.[56]

Annexes 1 and 2 give a sense of how such rates of reduction can be achieved - for all the fossil fuels, as the climate-change imperative requires. Annex 2 shows how a multi-technology programme of renewables deployment more aggressive than the programme proposed in the government's 2008 Renewables Consultation can reduce oil consumption in 2020 by 46% from 2007 levels by 2020. Coal reduces 79% and gas 29% in the same period, which is enough in total to cut UK CO_2 emissions by 47%. Renewables in this scenario are 22% of the UK delivered energy mix, and 53% of the electricity mix. In its Renewables Consultation, the government target is 15% renewables in the UK primary energy mix by 2020. (Note that the EU-wide target is 20%). 15% of UK energy entails a renewables quota in the UK electricity mix of in excess of 40%.[57] In the scenario mapped, oil use drops at 5% per year, and gas by 2%. We emphasise that the scenario is just one scenario of many possible scenarios, and not a forecast.

It is a safe bet that with renewables industries developing at the kind of speed that will be needed to hit a 20% renewables target in the UK energy mix by 2020 (up from 3% in 2008), much deeper penetration of fossil-fuel markets will be feasible beyond. We examine this contention in more detail in the next section, on opportunities.

8.2 UK peak oil "descent" scenario

For a country like the UK, facing the prospect of an annual reduction in oil demand of 5% or more over two decades – as described above – policy action to replace oil at something faster than the arithmetic decline would appear sensible. Simple arithmetic suggests that a 5% annual decline would give us 20 years to replace all oil use. But there would be no margin for error in such a calculation. The decline rate could easily steepen along the way, either for geological reasons, or geopolitical reasons, or both. Oil use would need to be replaced in less than 20 years.

Annexes 1 and 2, tough as some would consider their efficiency- and renewables-deployment assumptions to be, cannot easily achieve 5% per year reduction in oil use.

8.3 UK peak oil "collapse" scenario

How quickly could oil be replaced, in a worst-case analysis scenario with parameters as described in the "collapse" scenario? We leave this as an open question, because we know of no study that has addressed the question. Certainly the policy scenarios in our annexes, ambitious as some would consider them to be, do not come close.

We do not necessarily pose the open question gloomily. We consider the inspiring programme of mobilisation associated with the Apollo Programme. We note that in the 1940s America, Britain, Australia and Canada mobilised the construction of warplanes and tanks at formidable speed, once presented with no choice. We conflate these thoughts with the observations on the state of the emerging clean-tech revolution, which we describe in the next section, and we come to the conclusion that the peak oil problem may yet bring out the full potential for adaptability and capacity for change in the British economy.

That said, a 2005 study of peak oil for the US government shows how urgent the need for proactive action is. The Hirsch Report, a US Department of Energy commissioned-analysis, concluded that global peak oil was a clear and present danger, without drawing conclusions on a specific year. One of its most important conclusions was as follows: "Viable mitigation options exist on both the supply and demand sides, but to have substantial impact, they must be initiated more than a decade in advance of peaking."[58] Clearly, if Opinion A in Part One is correct in its analysis, we do not have a decade. But that should be no excuse for not taking urgent, proactive, precautionary action.

9. Mobilising for peak oil: opportunities

9.1 Coincidence with the first days of an energy revolution

A decline or collapse of oil supply would hit every sector of the economy, triggering rapid change right across transport and power generation. Fortunately, given the magnitude of such a wide-ranging challenge, the world seems to be at the inflexion point of a clean-energy revolution, spanning all aspects of energy, just as the peak oil problem is unfolding. Venture capital and private equity investment firms are directing many billions of dollars at cleantech, from new low-carbon transport fuels and advanced batteries on the transport side to innovative renewables and smart-grid delivery on the power side. Clean technology is now the third most popular investment for venture capital, behind the internet and biotechnology. In April 2008, as the oil price has soared, "VCs" in Silicon Valley added hundreds of millions of dollars of investment to their funds in just weeks. Leading practitioners profess to have identified 50 sectors in green tech. The demand side is just as exciting as supply, and indeed returns can come faster because you can build companies quicker. Opportunities include energy-saving building materials, energy management systems for buildings including smart grids, and energy storage.[59]

Investment in renewables totalled nearly $150bn (€95bn, £75bn) in 2007, according to UNEP in its Global Trends in Sustainable Energy Investment 2008 report. New energy investment of all kinds including in oil and gas was $1.3 trillion. In other words, over a tenth of global investment in energy went to renewables although renewables provide only 5% of world energy. This figure is up 60% on 2006's $93bn, and a five fold increase on 2004's $33bn. The trend is continuing through the 2008 downturn, with first half spending in 2008 up on 2007, despite a fall in the first part of the year. Renewables provided fully 23% of new electricity capacity globally in 2007.[60]

This clear megatrend, and the sense of optimism it engenders, has led many to refer to a "green industrial revolution" in the making. At one simple level, "all" that countries like Britain have to do is play their part in the acceleration of this megatrend, and make sure that it is embedded in their own domestic economies.

The boundaries in the realm of the possible have recently been extended by Al Gore. In a landmark speech in July he called for a national US mission to 100% power electricity without any fossil fuels, by expanding renewables, within 10 years. He appealed to both candidates in the presidential election to emulate John F. Kennedy's Apollo mission. "We are borrowing money from China to buy oil from the Persian Gulf to burn it in ways that destroy the planet," he said in his speech. "Every bit of that has got to change." Climate change is happening faster than we thought, he argued. Low-carbon technology is ready. "We can start right now using solar power, wind power and geothermal power to make electricity for our homes and businesses…. This goal is achievable, affordable and transformative." New infrastructure will be needed: "we do not have a unified national grid ….outages and defects in the current grid system cost US businesses more than $120 billion dollars a year. It has to be upgraded anyway."

9.2 Transport

Transport is arguably the most important sector, because it relies on petroleum products to supply 99% of its energy,[61] and because oil-dependent supply chains will need to be maintained even as they shorten and become more localised. Here we can see rapid systemic change driven by the high oil prices of 2007 and 2008, even without the considerable additional stimulus that peak oil will add. Car companies increasingly are betting on electricity as the transport fuel of the future, and there is no reason why this electricity cannot be provided by renewables and nuclear. Electric vehicles powered by lithium ion batteries are poised to go mainstream. This is in major part because breakthroughs in this particular member of the cleantech family now mean the batteries are light enough and small enough to fit into cars without weighing them down. Tighter vehicle-emissions regulations are also helping, plus higher manufacturing volumes - as so often happens with technology - are causing the price differential between the disruptive technology and the traditional technology (in this case between a hybrid car and a gasoline-fuelled one) to shrink.[62] Renault-Nissan says it aims to lead the industry in all-electric cars. By 2012, they intend to have a range of EVs in all main markets offered at prices lower than equivalent petrol models. Nissan and NEC are investing heavily in the lithium-ion batteries needed to make this happen.[63]

Japan plans to build hundreds of quick-recharge stations before plug-in hybrids enter the market next year. Japanese drivers will be the first in the world to be offered plug-in cars by the major carmakers: in 2009 by Mitsubishi Motors and Subaru and 2010 by Toyota and Renault-Nissan. Tokyo Electric Power (TEPCO) has developed a device that recharges enough of the battery in five minutes to allow a 40 km drive. 10 minutes gives 60km. The device costs $36,500 and will be installed in supermarkets and other public places. The government, aiming for half of all new car sales to be electric by 2020, is doing its bit: offering discounts to EV drivers on parking, loans, insurance and other tactics.[64] In London, EDF plans to build a network of charging stations for EVs.

Israel has announced a nationwide electric car project aiming to remove the need for oil imports within a decade. A private plan, with the backing of the President, involves installing 500,000 recharging points and battery-swap stations for electric cars in 2008 and 2009, halving oil dependence within a few years. Solar electric plants will be built to offset the rest of the oil imports. Project Better Place, a US start-up company, has raised $200m for the initial stages of this visionary scheme. The rest of the infrastructure and vehicles is expected to cost a further $800m. Shai Agassi, the founder, calculates that if Israel's fleet of 2m cars were all electric, they would require 2,000MW of electricity per year, entailing an investment of $5bn in solar plants. This is eminently doable, he believes. He likens the idea to the early infrastructure companies that made the widespread use of mobile phones possible.[65]

Car-based transport is a significant consumer of fossil fuels. Carbon emissions from the transport sector are around 25% of the UK total, with car travel accounting for more than half of the transport sector's carbon output. Around 63% of carbon dioxide emissions arise from journeys of less than 25 miles, which can readily be made by a public transport alternative. Public transport has a crucial role to play in helping to reduce the UK's dependence on oil by encouraging people to switch from the car to more sustainable bus, coach, tram and rail travel. Central and local government has a responsibility to help make public transport more attractive to motorists by taking steps to improve the reliability of bus travel, the most widely used mode of public transport. This can be achieved by investment in more park and ride facilities, expansion of bus priority measures, such as bus lanes and traffic light priorities, pro-public transport car parking regimes and planning decisions with public transport built in. Less congestion will increase the average speed of buses, which will in turn improve fuel efficiency and reduce carbon emissions. Capacity in the rail network should be funded and opportunities for high speed rail assessed. Central and local government and transport operators need to work together to promote the role of public transport in supporting more sustainable travel and achieving modal shift.

Government can assist the development of more fuel efficient, low carbon public transport solutions by providing financial incentives to bus and rail manufacturers to improve vehicle design. Steps should also be taken to support public transport operators investing in new technologies, such as hybrid and electric solutions, as well as by funding related infrastructure. More bold and imaginative pro-public transport policy measures by central and local government, such as zero tax on fuel for all public transport operators, would significantly lower the cost of public transport and incentivise consumers to switch modes.

This quick survey of the transport scene is not exhaustive. Other options are cited in our Annexes. The main point is this. The options for mobilisation to achieve a new low-carbon transport infrastructure are boundless, and they would be "working with the grain" in terms of existing trends in transport.

9.3 Electricity, heating, and other energy demand-reduction

Peak oil is about much more than transport. Oil is used for heating buildings, and for transporting coal to power plants, for example. Moreover, the price of gas tends to follow the price of oil closely. On top of this come the geopolitical risks we have identified earlier. There is no doubt that power supply would come under immediate and pressure in a peak oil "descent" scenario.

Annex 1 illustrates a variety of the demand side reductions which can be employed to lessen the impact of an oil crunch and improve energy security. They range from low cost, simple measures (the so called "low hanging fruit") to large scale, long term investment in infrastructure. It is important to note that there is no single measure in each sector which will solve this problem. Instead an array of measures with greater or lesser impacts will be employed which, when combined, will be able to achieve deep reductions.

In this respect, as with transport, the opportunities for rapid systemic energy change are legion. McKinsey Global Institute (MGI), the research arm of the well-known global consultancy, believes the world could more than halve projected energy demand growth, using existing technology, profitably. The investments needed to do this would earn an average return on investment of 17%, and a minimum of 10%. These calculations cover all sectors of the global economy, but the sector with the most reduction potential is the residential sector, which offers 24% of the potential for improving energy productivity. The fact is that hundreds of billions of dollars of savings in energy efficiency go begging in the modern world, even at today's high energy prices. Around $170bn would have to be spent by 2020 to hit the McKinsey target, but the returns would be quick, and anyway that figure is a mere 1.6% of today's global annual investment in fixed capital. No wonder energy efficiency pundits refer to energy-efficiency savings-potential as "negawatts."

So what is holding people back? One answer in buildings, bizarrely, is that for a long time electricity and fuel have been too cheap to warrant the up-front expenditure on energy-saving equipment. Another is that landlords have had no incentive to invest in energy-efficient technology so that tenants receive cheaper energy bills. A third is that many governments have ignored the potential for leadership in energy efficiency, either in their own building stock, or that of voters. There are more "excuses" in the list, but the main point is this: with the current high energy prices, and the many forecasts that prices can only go up when it comes to traditional energy supply, the situation is surely set to change.

Business is booming for energy services companies that help families and organisations reduce their energy bills: so-called ESCOs. In America, ESCO income has grown from 3% a year in the early years of the century to 22% in 2006. An ESCO usually does an audit of the client's buildings, designs an energy reduction scheme, borrows money to pay for the energy-saving equipment, and makes its return on the money saved, or a part thereof. The client pays nothing, only saves.[66]

In the face of statistics like those from McKinsey, simple services like those provided by ESCOs, and the growing incentive of avoiding high energy prices, it is easy to imagine how quickly demand might reduce in the years ahead, especially as more national governments are forced by energy-supply concerns to lead from the front.

In terms of supply, a sixth of the world's electricity and a third of new electricity now come from micropower[67] rather than from central thermal stations. In 12 industrial countries, micropower now provides from one-sixth to over half of all electricity. Micropower added 43 to 58 gigawatts last year, whereas nuclear's net capacity added in 2006 was 1.44 gigawatts, less than that of solar cells and a tenth that of wind power. Distributed renewables alone received $56 billion of private risk capital.[68] Applied Materials, a giant of the digital revolution and a new entrant to the solar revolution, recently took its first order for a bespoke factory capable of manufacturing a gigawatt of cells each year. Many highly innovative low-energy technologies have yet to hit the market. For example, smart grid technologies that optimise all electricity and heating in buildings have huge potential but have barely emerged into the marketplace. AC photovoltaic panels will allow consumers to plug small, increasingly valuable modules direct into household plugs.

Nuclear power holds the potential to cut emissions in the longer term, provided its own economics can be made to work in a world of rising construction costs. Much of the automobile industry has aligned behind electricity as the ground-transport fuel of the future of late. This will play to the advantage of nuclear power in the long term, though many renewables advocates profess that their family of technologies can do the job quicker, and ultimately more economically.

As with transport, this snapshot of the electricity-and-heat supply-and-demand scene is not exhaustive. Other options are cited in Annexes 1 and 2. The main point, as with transport, is this. The options for mobilisation to achieve new electricity- and heat- infrastructures are boundless, and they would be "working with the grain" in terms of existing trends in investment.

10. Conclusions

10.1 Challenges

In terms of the discovery and production of conventional oil, both the risk opinions in this report demonstrate cause for concern. So too do the production figures of all the five major international oil companies: they have been falling for five consecutive quarters, with the steepest fall in the last quarter. What can befall the international oil companies can also befall the national oil companies: the largest oil companies in the world, which control 80% of the world's oil production. Old oilfields and provinces can descend very fast after peak-production, as we see in the numerous countries listed in Opinion A, even where the best enhanced-oil-recovery techniques are applied. So what is to stop global oil production descending fast too, once we pass the peak?

The industry is not discovering more giant fields, even after four years of rising oil prices. When they do make big discoveries, the lead times are long: often more than 10 years. Given these known lags in the system, it is difficult to understand why the net global flow-rate data presented in Opinion A, slowing as they do in 2011, are not sounding alarm bells in governments and industry.

On top of this, OPEC governments would seem to have been less than transparent about the size of their national reserves, after deciding to fix quotas based on the size of reserves in the 1980s. Some 300 billion barrels or more out of the 1.2 trillion barrels of supposed global proved reserves may be overstated, some experts claim: including within OPEC itself.

There are profound infrastructure problems, and major issues with underskilling and underinvestment in the global oil industry. Many drilling rigs, pipelines, tankers, and refineries were built more than 30 years ago, and according to some insider experts the physical state of the global oil infrastructure is a major problem even at current rates of oil production, much less the significantly higher levels anticipated in future. The fact that the average age of personnel in the oil industry is fully 49, with an average retirement age of 55, is little less than a human-resources time bomb. To add to the challenges, the industry's overall exploration budget has actually fallen in real terms in recent years. We fear these issues will synergise to compound the peak oil crisis, gravely impairing society's collective ability to respond.

Neither the government, nor the public, nor many companies, seem to be aware of the dangers the UK economy faces from imminent peak oil. Big as emerging economic problems are as a result of the credit crunch, peak oil means a very high probability of worse problems to come. The risks to UK society from peak oil are greater than those routinely on the government's risk-radar at present, including terrorism.

The core energy-related problems we think the country faces are as follows, in the sequence they are likely to hit. The most probable first arrival will be peak oil, with 2011 being a good candidate, as Opinion A argues. We need to buy immediate insurance against it. Wider energy security issues will probably arise next. Our gas supplies are much at risk from geopolitics, and unlucky developments could even leave us facing problems this winter. But on balance we suspect the system can limp on beyond 2011. Climate change in this approach comes third because its major impacts will be slower to manifest. In a very real sense, however, the timing doesn't matter, because the core policies needed to meet the challenges of peak oil and wider energy security are the very same as those needed if we are to achieve deep-enough cuts in greenhouse-gas emissions to abate climate risk.

When the full gravity of the oil crunch dawns on governments, we fear that there is scope for the peak oil threat to relegate the climate threat in importance, in policymakers' eyes. There will surely be further calls for expansion of production in the tar sands, and for major coal-to-liquids programmes, whether or not carbon capture and storage (CCS) can be brought to bear as a means to deal with greenhouse-gas emissions. We are concerned that CCS technology is well over a decade away from the prospect of commercial deployment, and that there is no demonstration project today that shows industrial-scale deployment is even feasible, or economic. We believe, accordingly, that alternative energy solutions hold much greater scope for effective long-term solutions to the peak oil problem than bolt-on adjustments to the fossil-fuel resource.

The mitigation of the effects of climate change alone would require infrastructure investment on a scale not seen in most of the last century, so a move towards new technologies in energy efficiency, production and distribution at the same time as making major investment in ground transport infrastructure will severely test Britain's engineering cadre, all at a time when buying in the expertise will not be easy either due to the global nature of the demand. Old oil, gas and nuclear engineers have not been replaced with young blood during the era of cheap oil and nuclear uncertainty from the mid 80s-2003. After two decades of decline, the UK rail transport industry faced this issue until privatisation brought in fresh blood. Even so it had to raid the airline, catering and retail industries and then still go through some steep learning curves. Such an option won't be available to oil, gas and nuclear, nor indeed to the grid, as they will all need skilled human resource at the same time. Co-ordinated planning is clearly required for post-peak-oil Britain.

10.2 Opportunities

A broad family of "clean-tech" energy technologies is in the process of being commercialised around the world, rapidly. These include both demand-side- and supply-side technologies, and the means of optimising integration of the two. Many of these technologies are classically disruptive, meaning that they can displace traditional energy markets very fast: far faster than many people probably realise. From patterns of investment in 2007 and 2008, energy financiers are clearly appreciating the scale of the opportunities emerging: new markets that will soon be measured in hundreds of billions of dollars. The first stage of a green industrial revolution is underway in energy, and among the factors driving it, peak oil has largely yet to feature. Once it does, growth can be accelerated still further.

Given the developments in cleantech of late, out-of-the-box thinking on ambitious targets for replacing oil and other fossil fuels are eminently feasible. There is a silver lining to the challenges: mobilising to deal with peak-oil risk can greatly accelerate the global policy response to climate-change risk.

11. Recommendations

11.1 National

- 1. We call on the UK government, and other companies operating in the UK market, to join us in an effort to appraise the risk from premature peak oil, and plan proactive and reactive strategies - local and national - for facing up to the problem.
- 2. A UK national energy plan to deal with the peak-oil threat needs to have four core themes. First, exploration for and production of conventional oil and gas needs to be expanded. Second, energy conservation and energy efficiency need to be maximised. Third, investment in renewable energy and sustainable renewable fuels must be accelerated. Fourth, a national skills programme is needed to address the dangerous shortfalls in skills and manpower evident in all areas of the energy industry.
- 3. Given the gravity of the risks we have described, there is no time to wait in drawing up and implementing a new national energy mobilisation plan. The policy measures in a national energy plan should include, but not be limited to, the following:

  - Development and implementation of a long term sustainable transport policy, with renewable transport at its heart. This should include measures to increase transport fuelled by sustainable bio-liquids and electricity, and measures to reduce the amount of fossil-fuel-based road transport. If we are to significantly reduce oil consumption, the current measures being proposed in the renewable transport arena must be just the start, and measures well in excess of those proposed will be required.

  - Policies in the current Renewable Energy Strategy process must go beyond the EU targets for renewable energy (20% of the EU-wide energy mix by 2020). The renewables industry is confident that 100% renewables energy supply is possible in 20-40 years, according to the overwhelming consensus of participants at the Tenth Forum on Sustainable Energy, held in Barcelona in April. They should be given the opportunity to prove it.[69]

- Nuclear decisions should be taken rapidly, and government should ensure that uncertainties over the nuclear renaissance should not act as barriers to the mobilisation of energy efficiency and renewables. Mass markets will be needed in these technologies whether we have a nuclear segment in the energy mix or not.

11.2 International

- 1. We call on oil companies and governments generally to be more transparent about oil reserves. OPEC governments could address concerns about the state of their reserves, as summarised in this report, with a minimal programme of verification by a small United Nations team of suitably qualified experts. Such a confidence-building measure has been proposed by the G-8 governments. It could ultimately be beneficial for the global economy whatever the findings. If its results show the fears expressed in this report to be groundless, oil prices would surely fall. If the programme confirmed reasons for concern, governments could work together with urgency to accelerate sustainable energy alternatives. In the meantime any resultant rise in the oil price would itself stimulate greater efficiency and renewables investment.
- 2. We urge all governments to combine efforts to deal with oil depletion and climate change in the multi-lateral post-Kyoto climate negotiations, and significantly to improve their level of co-operation in that forum. There is ample scope for the UK government to lead by example domestically in this respect. Such leadership could include ensuring rapid trialing of CCS, and rapid national nuclear decision-making so as to give investors clarity on their energy options. Unconventional oil should not be exploited if its net carbon footprint is higher than that of conventional oil.
- 3. All governments should draw up their own national responses to peak oil. National energy mobilisation plans should aim to accelerate the green industrial revolution already underway.

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Annex 1:

Demand-side options

A view from the Energy Saving Trust[70]

1. Transport

1.1 Switch to low emission internal combustion engine cars

It is a little recognised fact that the technology to reduce passenger car fuel consumption by a quarter exists today. Simply by taking advantage of the low emission (and hence low consumption) cars available on the market, a reduction in new car fuel consumption of greater than 25% could be achieved without any further action. However, even if everyone who was in the market for a new car purchased the cleanest vehicle in its class, it would take some time for these savings to accumulate as there are around 28 million passenger cars licensed in the UK and in 2007 2.4 million new cars were sold.[71] Looking purely at churn, it would take at least a decade for this fuel reduction to be fully realised. The average age of a vehicle in the UK parc is close to seven years[72] hence it will take about this duration for the average fuel consumption of the parc to reach the level of the new cars being sold. The European Union originally intended to introduce legislation which would require new cars in Europe to have average CO_2 emissions of 130g/km by 2012.

UK new car emissions lag behind the European average, so it is very unlikely that we would be able to achieve this target by this date, however reaching it by 2013 or 2014 would still enable the parc to attain an average of around 130g/km by 2020. The UK government is pushing for new car CO_2 emissions to be reduced further to 100g/km by 2020. Average CO_2 emissions of the UK parc would be expected to reach 100g/km from around 2027 if this policy were implemented.

Already a handful of passenger cars available on the market can achieve CO_2 emissions of around 100g/km and high fuel prices, along with the introduction of the European regulations, will rapidly increase the availability of these efficient vehicles. There are intense discussions going on within the EU over this legislation and strong lobbying from the manufacturers. It remains possible that the 130g/km regulation will be delayed until 2015.

During 2008, dramatic changes in the new car market are being witnessed as a direct result of high fuel prices coupled with the credit crunch. Recent reports highlight a 44% reduction in large sports utility vehicle sales in Europe.[73] In the UK, 2008 year-to-date registrations of all passenger cars were down nearly 4% at the end of August while the market share of smaller, more efficient vehicles is growing quickly.[74] CO_2 emissions over the first six months of 2008 were 3.2% lower than the same period in 2007, reducing by 5g/km to 160.5g/km.[75] This rate of emissions reductions would need to be sustained in order to meet the reduction targets outlined above.

France has recently achieved considerable success in reducing new car CO_2 emissions by introducing a “bonus/malus” or “feebate” system. This system rewards drivers for purchasing vehicles with emissions of 130g/km or less and penalises drivers purchasing vehicles with emissions of 160g/km or more with the latter part subsidising the former. Over the eight months since the scheme was introduced, sales of vehicles with emissions of 130g/km or less have increased by 45% and average new car CO_2 emissions have reduced by 9%.[76]

It should be noted that the “rebound effect” is a recognised phenomenon whereby improvements in efficiency prove not to be as great as the theoretical maximum. For example, more efficient passenger cars may lead to more disposable income, leading to increased driving. There is considerable controversy over the magnitude of the rebound effect, however figures of 10% are frequently ascribed to transportation.[77] In this analysis, the rebound effect has not been included. There are two reasons for this: firstly oil prices will continue increasing as oil supplies decline, offsetting the cost savings achieved by a switch to more efficient vehicles. Secondly, measures should be put in place to encourage higher car occupancy and modal shift to more efficient forms of transport as part of a demand reduction programme, thus reducing vehicle km driven.

1.2 Alternatives to petrol and diesel

While a shift in the next decade towards low emission combustion engine cars is important both from an energy and climate change perspective, a more general move away from petrol and diesel fuelled vehicles will need to be simultaneously encouraged and supported.

1.2.1 LPG

One alternative fuel currently used in the UK is liquefied petroleum gas (LPG or autogas). Another gaseous fuel used to a far lesser extent by passenger cars is natural gas. Some vehicles fuelled by natural gas exist, but refuelling facilities are not as well developed as for LPG. Some of the demand for petroleum could be reduced by increasing the number of cars converted to run on LPG or natural gas. However these vehicles would still remain exposed to potential declines in the supply of these fuels.

1.2.2 Biofuels

Biofuels have become more commonplace in the UK in recent years with European targets mandating their use for road transport use. The Renewable Transport Fuels Obligation (RTFO) requires transport fuel suppliers to source 2.5% of transport fuels from biofuel sources. Most common in the UK is biodiesel which is frequently blended with conventional diesel in concentrations of 5%. Bioethanol is less popular in the UK than in other countries such as the US and is available in a limited number of petrol stations.

Recently, questions about the sustainability of biofuels have been raised, especially concerning their effects on food production and their wider environmental impacts. The Renewable Fuels Agency recently announced that an estimated 80% of all biofuels sold in the UK failed to meet their sustainability criteria.[78] The European Parliament Industry Committee recently concluded that “imposing a binding target on fuels for the transport sector coming from biomass of 10% cannot be achieved in a sustainable way” stating that “sustainable biomass will be more efficiently used for other energy purposes”. Instead the Committee has approved a report which maintains a target of 10% of transport fuels coming from renewable sources with at least 40% coming from non-food, second generation biofuels, electricity or hydrogen.[79]

Second generation biofuels such as cellulosic bioethanol, which could potentially be generated from a wide variety of feedstocks and grown on marginal land, or algae-derived biofuels offer the prospect of a more sustainable biofuel, and research is underway to commercialise the processes required to produce it. However it is too early to quantify the impact which this form of biofuel may have on fuel supplies.

1.2.3 EVs

It is likely that a significant market penetration by electric vehicles would be necessary in order to achieve fleet average new car CO2 emissions of 100g/km in 2020. These will come in the form either of battery electric vehicles (BEVs) or plug-in hybrid electric vehicles (PHEVs). One of the principal benefits of electric vehicles is that electric motors are considerably more efficient than internal combustion engines.

The electric vehicle's limited range is frequently cited as being a barrier to widespread uptake and to a certain extent it is. The electric cars appearing on the market today have ranges of between 70 and 110 miles. Cars capable of greater ranges before recharging are not far from being a reality as more and more manufacturers enter the market. Many of the major vehicle manufacturers will be releasing electric models into their product range by 2010, hence mainstream electric vehicles are edging closer to mainstream acceptability. However it is worth bearing in mind that 99% of all passenger car journeys are of 100 miles or less, accounting for 91% of the 400 billion vehicle km driven each year by cars in the UK. Electric car technology is therefore close to being sufficiently mature to account for the vast majority of journeys driven in the UK.

Electric vehicle batteries comprise a significant proportion of the vehicle's cost and currently have relatively short lifetimes in the majority of cases, necessitating replacement after a few years. Increasing cycle life (the number of recharge cycles the battery can tolerate without appreciable loss of performance) and reducing costs are priorities for battery manufacturers around the world and great strides are already being made in this direction.

New energy storage technologies, such as supercapacitors, are also being investigated with these technologies offering the potential of low cost, low weight, high cycle-life energy storage devices, although production-ready examples are yet to appear.

Other than by improving battery technology, the range limitation barrier can be overcome through the use of plug in hybrid or range extended electric vehicles (incorporating a small, efficient, constant speed generator which charges the battery as required). Both of these technologies enable a vehicle to drive in electric mode much further than current hybrid vehicle technology permits, with an internal combustion engine (running on fossil or biofuel) allowing the vehicle to be driven beyond the battery-only range.

Another solution is the installation of a network of fast recharge points which can quickly deliver electricity to a suitable battery, or battery swap infrastructure such as is being proposed in countries including Israel, Denmark and Portugal.

It is difficult to estimate the rate of market penetration which alternative fuel vehicles and EVs might be expected to achieve in 2020. The Energy Saving Trust's Market Transformation Model projects that with current policies, penetration of electric vehicles will be low in 2020.[80] However with political will starting to lean in the direction of EVs and PHEVs, this situation could rapidly change.

Electric vehicles also offer another significant advantage: vehicle-to-grid, also known as V2G. Managers of electricity grids must vary the supply of electricity to closely match the continually varying demand. A V2G system links electric vehicles into a smart electricity grid. Depending on the supply and demand at any point, energy can be stored in or drawn down from vehicle batteries as required. V2G therefore offers the dual benefits of grid balancing services (which currently impose a large cost on the electricity industry) and storage capacity for renewably generated electricity, potentially allowing a higher proportion of renewable energy sources on a grid.

1.3 Car usage

Using our passenger cars more effectively and efficiently is also key to reducing energy demand from this sector. With recent high fuel prices, reports have been emerging of changes in car usage in the UK. The Department for Business, Enterprise and Regulatory Reform (BERR) tracks deliveries of fuel in the UK. This data shows a pronounced reduction in deliveries of motor spirit of 6% between the second quarter of 2007 and the same period in 2008[81] while deliveries of diesel decreased by 1%. Furthermore, figures have emerged which show a reduction of 12% in congestion on Britain's motorways and trunk roads in the first half of this year.[82] Meanwhile in the United States, the effects of high oil prices are also becoming evident. The Federal Highway Administration monitors travel on roads on a monthly basis and has noted seven months of decline in the distance travelled by US drivers. Americans travelled 9.6 billion fewer vehicle miles (15.4 billion vehicle km) in May 2008 than in May 2007, a reduction of 3.7%.[83]

It will be essential to arrest the growth in distance driven in cars, currently standing at 400 billion vehicle km, and then attempt to reduce this through a combination of modal shift (swapping car journeys for other, more efficient forms of transport), avoiding journeys and increasing car occupancy. To date, little has been done to encourage increases in car occupancy in the UK and as car ownership has increased, the effects are clear. Average occupancy in cars has been declining very slowly and currently stands at 1.6 people per car.[84] Increasing this to an average of 1.7 people per car would cut the number of vehicle journeys by 7%. Commuting to work accounts for 110 billion vehicle km, a quarter of the distance driven by cars in the UK and yet it has the lowest occupancy rates of all car trips, averaging 1.2 people per car and with 85% of all commuting cars only have one occupant. This would be the main area to target to increase occupancy as the journeys are regular and predictable.

High occupancy vehicle (HOV) lanes, which permit only cars with two or more passengers have been introduced in various countries with mixed success. To date, the UK has only seen limited uptake of HOV lanes. A strong driver towards higher occupancy rates is likely to be high fuel prices which will push drivers towards sharing their commute and other journeys in order to reduce fuel costs.

A policy of encouraging people to work from home or work a condensed working week will also help reduce the distance driven. Working from home one day per week would cut a motorist's mileage by more than 500 miles (800km) a year or 6% of a car's annual mileage. With broadband internet access now common across the UK, there is no practical reason why increased home working should not be encouraged, however energy savings are reduced somewhat during winter, when home workers need to have their heating and lighting on.

The fuel consumption of passenger cars depends heavily on speed. The most efficient speed is normally around 40mph – 45mph and travelling at speeds above or below this point leads to increases in fuel consumption. Passenger cars driving on motorways and dual carriageways have average speeds of 70mph and 68mph respectively. 54% of car drivers exceed the speed limit on motorways and 45% exceed the speed limit on dual carriageways, both of which are set at 70mph.[85]

By reducing the average speeds on these roads to 60mph, a reduction in fuel consumption of around 6% is achievable. A reduction to 55mph would reduce fuel consumption by around 8%. The Spanish government has recently announced that, along with a raft of other energy efficiency measures, the speed limit on motorways and dual carriageways will be cut from 100km/h (60mph) to 80km/h (50mph).

Driving style has a large impact on fuel consumption by passenger cars and employing what are known as "smarter driving" techniques can offer greater savings than simply reducing your speed. Average reductions in fuel consumption of 15%[86] are achievable by most drivers after a short lesson and would be an easy win, requiring no infrastructure or new technologies.

1.4 Modal shift

Modal shift from cars to coaches and trains for long distance journeys and to buses, bikes and foot for shorter journeys would make a significant impact on the total distance driven. Journeys of five miles or less account for more than 50% of passenger car journeys and around one fifth of the total distance driven in passenger cars. With oil prices as they are, increases in the number of people walking more, cycling and taking public transport are already being seen.

1.4.1 Walking and cycling

Walking is accessible to all but particularly applicable in urban locations where journey stage lengths are shorter. On average, people in the UK walk around 200 miles (320km) per year but with improvements in conditions for pedestrians this could be increased, with additional benefits to health through increased exercise. Innovative websites such as walkit.com allow people to map out their walking journey enabling them to pick quieter, less polluted routes.

In the Netherlands, one of Europe's great cycling success stories, bicycles are the most popular mode of transport for journeys of up to 7.5km (4.6 miles), accounting for 35% of trips.[87] In the UK, only 2% of journeys up to five miles are made by bicycle. In the Netherlands, cycling is also popular over longer distances with bicycles[88] accounting for 15% of journeys of 7.5km – 15km (9.3 miles) and 3% of journeys of 15km or more. In order to attempt to approach these levels of bicycle travel, large investment in cycling facilities will be needed across the country however these costs can be offset by a reduction in healthcare and congestion costs.[89]

1.4.2 Encouraging less car use

Reducing the number of journeys of under five miles driven by car by a quarter would result in a reduction in distance driven of 30 billion vehicle km (a drop of around 8%) however a dramatic improvement in walking, cycling and public transport facilities would be necessary to support this change in journey mode. Encouraging more passengers onto public transport will be paramount if reductions in the distance cars are driven is to be achieved, however there are a number of barriers. Cost is a significant barrier for many. Less affluent families are less likely to have a car but are therefore also affected by rising public transport costs. Between 1980 and 2006, that the real cost of both rail fares and bus and coach fares increased by around 40% while the cost of motoring reduced by 14%.[90]

This gives some context to the rapid growth in passenger car usage in the last decade. Over the last six months, with the large increases in the cost of oil, motoring will have become significantly more expensive.

In order to facilitate a switch from cars to other modes, public transport must be convenient and easy to use. Effective integration of different transport modes - so that transferring from one to another is fast and simple - will help, while improvements in telematics, and with mobile telephones now incorporating internet applications, mean that live transport updates detailing exact arrival times and up to date routings of public transport is now being rolled out.

Public transport operators have directed considerable effort towards addressing concerns such as the safety, cleanliness and reliability of public transport and more work is needed in these areas so that public transport is perceived to be an attractive, convenient and affordable alternative to car driving. Without this, many will be reluctant to exchange their car for other forms of transport.

1.4.3 Buses and coaches

Looking forwards, improvements in the efficiency of buses are on the horizon. Series hybrid buses are similar to range-extended electric cars in that they are driven primarily by electric motors linked to batteries, and are fitted with regenerative braking systems which recover energy usually lost in braking. The battery can be charged from mains electricity when the vehicle is parked and an efficient generator keeps the battery topped up while driving. Fuel consumption reductions of 20% - 40% are achievable compared with conventional bus technologies. The capital costs of hybrid buses will need to reduce before they are cost effective, however it is estimated that given today's high oil prices, a reduction in capital costs in the order of only 15% will be required in order for this technology to become a viable option.[91]

For journeys of 50 to 150 miles, 85% are taken by car. For these longer journeys, coaches are the most efficient way of moving people about, reducing fuel consumption by around 80% compared with passenger cars. They also have the benefit of reducing congestion – a coach full of people takes up much less space than the equivalent number of cars.

Coaches can be vulnerable to traffic congestion, especially when passing through large cities at the start and end of their journeys. This can add an unpredictable element to the duration of a coach journey although the effects can be mitigated to a certain extent by giving priority access to high occupancy vehicles such as coaches through dedicated lanes.

1.4.4 Rail

Rail transport offers the best combination of high speed and efficiency. While trains are less efficient than coaches, they can achieve higher speeds and carry more passengers. Rail travel has grown quickly over the last decade with a 33% increase in passenger-km travelled. In a white paper published in 2007, a further 30% growth is projected over the next 10 years.[92]

UK rail transport energy consumption is split roughly 50/50 between electricity and diesel. The UK lags behind most European countries, with only a third of its network electrified (5,200km out of 15,800km). Spain and Italy, countries with similar sized networks, have electrified 56% and 69% respectively and the European average is 50%. Further electrification of the UK rail network will be required in order to operate in a post-peak world.[93]

Electric rail offers significant benefits over diesel rail: electric motors are more efficient than diesel engines and just as electric cars can recover energy normally lost in braking, so can electric rail. According to the Association of Train Operating Companies, savings as high as 20% are being seen through the use of regenerative braking.

Modal shift from aircraft to high speed rail could be achieved on domestic routes and many short range European routes and Network Rail is investigating the potential for a new network of up to five high speed routes. Journey times to Scotland could potentially be reduced to less than 2.5 hours making this option significantly quicker than aircraft.

Sustained investment in bus, coach and rail facilities around the UK will be needed in order to cope with a significant shift from passenger car use to public transport. Buses and coaches have the potential to scale their operations quicker than rail due to their lower infrastructure requirements.

1.5 Freight Transport

Road transport has accounted for around 60% of total freight since 1970. Road freight's market share dropped to a little over 50% in the late 1970s and early 1980s as water freight expanded. Rail freight's market share has declined slowly from around 18% of freight carried in 1970 to 6% in the mid-1990s but its share has slowly grown to a level of around 9% now.

In previous decades, freight transport in the UK was very closely coupled to GDP. Since the mid 1990s GDP has continued to grow while freight transport has remained largely static. By contrast in Europe, freight transport remains largely coupled with and in certain countries is outstripping, GDP growth. Reasons for this decoupling include a shift towards a more service based economy and the offshoring of manufacturing.

Road freight accounts for 27% of UK transport energy demand.[94] 44% of this energy is consumed by light goods vehicles (LGVs) with the balance being consumed by heavy goods vehicles (HGVs). In the last 10 years, the number of LGVs on the UK's roads increased by 40% while the number of HGVs increased by 20%.

There have been significant improvements in the fuel efficiency of HGVs since 1990. Most of these gains have been seen in articulated vehicles which operate at higher speeds for longer so technological improvements have a more pronounced effect. Driving style has a large impact on goods vehicle fuel consumption and some successes have been made in changing driving technique, however there is still some way to go in this area. Other efficiency improvements in aerodynamics, tyre technology and more efficient vehicles are still to be made.

Apart from improvements in the efficiency of goods vehicles, a number of measures can be employed to reduce energy consumption from road freight by improving vehicle utilisation.

Empty running, when freight vehicles have dropped off their load and are repositioning in order to collect another load, is an area which deserves attention. Typically around 27% of HGVs are operating empty. Improved logistics can help reduce this proportion by efficiently matching loads with vehicles.

Backloading is the practice of picking up loads for the return leg of a delivery journey. This might be internal (carrying your own goods such as returned stock or packaging or picking up products from suppliers) or external (carrying goods for a third party). Load matching services exist to connect vehicles with loads, thereby reducing rates of empty running and collaboration between companies to maximise the utilisation of vehicles could also help.

Another measure of vehicle utilisation is the lading factor, which measures what proportion of a vehicle's total capacity is taken up with goods when loaded. In 1996, the lading factor for HGVs was 63% however this has declined in recent years to 56%.[95] Increasing the average lading factor will be an effective way of reducing energy consumption.

Sophisticated route planning software exists which can reduce the distance travelled by goods vehicles by 5% to 10%[96] with associated fuel savings, while recent advances in vehicle telematics and communications mean that vehicles can be easily and efficiently rerouted in response to traffic conditions or changes in customer requirements.

Shipping by water and rail are very efficient ways of moving freight around, however both of these modes of transport can usually only carry a load freight for one portion of its total journey distance before it must be switched to another mode.

One of the reasons why rail freight growth has been limited to date is the lack of suitable infrastructure to transfer freight between other modes (such as roads) and the railway system efficiently. Rail freight interchanges are strategically located facilities which enable this transfer to occur as rapidly as possible, while maximising the distance freight is carried by rail.

Rail freight has grown by around 5% per year since 2000 and projections suggest demand growing to around 30% by 2015 and doubling by 2030[97] however to achieve this growth, long term investment in rail freight infrastructure will be necessary. Freight interchanges would enable the rail freight industry to diversify the goods carried away from fossil fuels towards retail goods and therefore take freight away from the roads.

The most efficient form of freight transport is waterborne freight. The vast majority of waterborne freight carried in the UK is coastal while inland waterways account for around 2.5% of total waterborne freight transport in the UK. The remainder is taken up by coastal shipping, much of it of servicing the extraction of fossil fuels in the North Sea. Improvements to water freight infrastructure will be needed to enable the transport or goods normally carried on roads.

1.6 Transport energy savings

Based on the measures proposed above, passenger transport energy consumption could be reduced by around 104TWh or 30% between now and 2020.[98] Key to this reduction will be the improvement of the energy efficiency of the vehicle parc and a reduction in vehicle km driven. Rapid growth in more efficient forms of transport will enable the total passenger-km travelled to grow, but with a lower energy demand.

In the freight sector, maximum potential reductions in UK domestic freight transport CO_2 emissions of 28% from 2004 levels have been identified by 2015. This scenario includes reductions in CO_2 due to an increase in biodiesel use in road freight transport therefore reductions in energy consumption of between 20% and 25% by 2020 would be representative.

2. Households

Household energy demand comprises the largest single sector in the UK (27% of total energy demand). Keeping UK homes warm and lit will be of paramount importance and there are two main steps that will be needed in order to deal with a reduction in gas and oil supplies. The first is to upgrade all homes to a high standard of both thermal and electrical efficiency while the second is to commence a programme of fuel switching.

A wide variety of energy efficiency measures are available to us:

- Cavity wall insulation (7.3 million homes potential)
- External and internal solid wall insulation (6.2 million)
- Loft insulation (11.8 million)
- Double glazing (most homes)
- Draught proofing and air tightness (most homes)
- Heating controls (6 million – 12 million depending on the control)
- Compact fluorescent and LED lighting (most homes)
- Upgrading appliances (50 million appliances)

The main programme covering domestic energy efficiency in the United Kingdom is the Carbon Emissions Reduction Target (CERT). This programme is the successor to the Energy Efficiency Commitments which ran between 2002 and 2008. CERT is an obligation on energy suppliers to achieve targets for promoting reductions in CO_2 emissions in the domestic sector through the installation of energy efficiency measures.

The figures in parentheses after each measure are Energy Saving Trust estimates of the remaining number of households which can have this measure installed. It is evident that there is still a lot of work left to be done to reduce energy demand in the existing housing stock and considerable investment will be required both in installing the measures themselves and also in training a workforce sufficiently large enough to achieve this before the end of the next decade.

82% of the UK's 25 million households are heated with natural gas, 9% with electricity and 6% with oil. 22% of domestic energy consumption is electricity while 69% is natural gas. However around 37% of the UK's electricity supply is also generated in gas fired power stations. The UK's homes are therefore very reliant on natural gas and so any decline in supply could have a significant impact on our quality of life if we don't take action to find solutions to our energy supplies.

The most efficient way to generate heat (which accounts for around 50% of domestic energy demand) would be to fit ground and air source heat pumps. Ground source heat pumps extract heat from the ground via a fluid-filled loop buried in the earth surrounding a home. Air source heat pumps do the same but extract heat from the air. This form of heating system requires an electricity source to operate the pump but for every unit of electricity consumed, the system typically outputs between two and three units of heat, depending on the source, time of year and quality of the system.

Other sources of heat include biomass and combined heat and power (CHP). Biomass boilers are similar to conventional gas and oil fired boilers except they use either wood pellets or chips as fuel. Domestic (or micro) CHP systems are also under development. These systems are similar in size to conventional gas or oil fired boilers but contain stirling engines or fuel cells which generate electricity to power the house or feed into the grid. The waste heat produced as a by-product of this process is then used to heat the home and hot water, leading to increases in overall efficiency.

The Carbon Trust has been running a field trial under their Micro-CHP Accelerator Programme[99] however it is not yet possible to estimate the potential for energy savings as the technology is in its early stages and more development will be required. Initial results suggest that the technology will be more suitable for larger homes with greater heat demand.

Large scale investment would be required to switch all oil and electrically heated homes to biomass and heat pump technologies. This would be coupled with continued replacement of conventional gas boilers (averaging 72% efficient) with high efficiency condensing boilers (90% efficient) with some switching from gas to other sources of energy a possibility, depending on the rate of reduction of gas supplies.

Although a switch towards electrically operated heat pumps has been proposed, the increase in electricity consumption from these would be offset by reductions in lighting and appliance electricity demand across all households through the use of high efficiency lighting and improvements in appliance and information and communication technology efficiency.[100]

Total electricity demand is projected to be around 105TWh in 2020. Gas consumption is projected to decrease from current levels of 350TWh to 230TWh per year while biomass consumption would increase to around 22TWh per year.[101]

To the energy demand from existing homes must be added the demand from new build homes constructed between now and 2016. After 2016, all new build homes are expected to be zero carbon and in many cases will be close to self sufficient for their energy needs. Between now and then there will be development of new homes which are not zero carbon but are significantly more efficient than the existing housing stock. The extent of the additional energy demand from new build homes is not yet known as rates of house building have slowed in recent months.

It should be noted that in order to embark on a fuel switching and insulation programme such as this, a large, skilled workforce will be needed and production rates of these technologies will have to be greatly increased.

3. Business, industry and commerce

Energy consumption by this sector is mostly accounted for by gas (39%) and electricity (38%), while petroleum products comprise 16%. Total energy consumption has declined by around 8% over the last decade. In the UK Energy Efficiency Action Plan, Defra identifies savings from the policies and measures which are currently in place. These include the Climate Change Levy, updates to the Building Regulations, the Carbon Reduction Commitment and the Energy Performance of Buildings Directive amongst others. The main aim of these measures is to reduce carbon dioxide emissions and in many cases this is achieved through improvements in energy efficiency. The identified measures are projected to save 93TWh by 2020.[102] A reduction of 93TWh per year would mean that energy consumption from this sector would be 17% lower than it was in 2007.

In common with other sectors, studies looking at projected energy consumption from industry view savings from a climate change perspective and assume unrestricted energy supplies. Proposals for improvements in energy efficiency are therefore being driven by climate change rather than security of supply concerns. It is possible that high energy prices will drive further efficiencies beyond those outlined in climate change strategies and more work will be needed to identify to what extent further measures could be incorporated.

4. Conclusions

This annex has analysed a selection of the wide variety of energy demand reduction measures which are available within the UK. These range from the low-cost and simple to implement, through to those necessitating long-term and large-scale investment in infrastructure and capacity. Their impacts on energy consumption reduction vary widely and it is important to emphasise that there is no single solution. To achieve a significant energy demand reduction we must employ a whole raft of measures across all sectors of the economy in order to be better prepared and insulated against a future reduction in oil and gas supplies.

Transportation is particularly vulnerable to dwindling oil supplies, relying on petroleum products to supply 99% of its energy demand. Reductions in petroleum usage in the passenger transport sector of 30% by 2020 are possible, but effective policies and incentives to reduce new car fuel consumption and encourage a shift towards public transport are urgently needed. The freight transport sector is equally dependent on petroleum products, and improvements in the efficiency of both vehicles and logistics could achieve savings of over 20% within the 2020 timeframe. In the face of a continued decline in oil supplies and in order to fulfil our long-term emissions reduction targets, the total decarbonisation of our transportation system will ultimately be required.

In the domestic sector our vulnerability lies in our reliance on gas supplies for the bulk of our energy. The majority of UK homes are heated with natural gas, while electricity supplies are also heavily dependent on this energy source. A comprehensive insulation programme combined with fuel switching for oil and electrically heated homes would make a large impact on domestic energy demand. With over 25 million households in the United Kingdom, the magnitude of work needed to complete this task is large, and the existing insulation and heating system supply chains will have to be greatly augmented in order to achieve this ambitious goal.

Finally the UK's business, industrial and commercial sectors can also make reductions in their energy demand. The extent of the total energy reduction potential in these sectors is not yet completely clear as the work undertaken to date has assumed that energy supplies will continue to grow. More work is needed in order to identify further savings.

While some demand reduction measures entail little or no cost, the common theme across all sectors is that a sustained financial commitment will be required, involving large scale investment in both energy efficiency and infrastructure. Equally important will be the recruitment and training of a large, skilled workforce required to implement these measures within a short timescale.

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Annex 2:

Supply-side options

A view from the Open University Energy and Environment Research Unit and the Centre for Alternative Technology[103]

1. Introduction: A scenario for rapid deployment of UK renewables and energy efficiency

Our scenario uses as the main basis of its renewable energy supply projections figures from the recent UK Government (BERR) consultation document on renewables[104] together with other official projections such as those of the Government's Renewables Advisory Board (RAB).[105] These projections are considered optimistic by some, pessimistic by others. For some renewable sources, where we consider the official projections excessively pessimistic, we have made our own estimates, based for example on experience in other EU countries. The data used in the scenario described here use as their starting point the Digest of UK Energy Statistics (DUKES), 2008, which gives energy data for 2007.[106]

The scenario, created using our 'Matrix' energy model (see Section 6), envisages a fairly rapid decline in UK oil and gas supplies from 2011, oil at a rate of approximately 5% per annum and gas at a rate of c 2% per annum. This necessitates (a) a rapid increase in renewable supplies of electricity, heat and transport fuel; (b) a rapid increase in combined heat and power generation (particularly for industrial purposes); and (c) substantial demand-side energy efficiency improvements in the domestic, commercial, industrial and transport sectors.

2. Renewable electricity supply

2.1 On-shore wind

The BERR Consultation document envisages the installation of c 14 GW of onshore wind (equivalent to c 4,000 x 3 MW turbines) by 2020, up from c 2 GW onshore today. The Renewables Advisory Board target is slightly lower, c 13 GW. These figures imply a build rate of c 1 GW p.a. between now and 2020. Assuming BERR's figure of 14 GW installed and an annual average capacity factor of 0.3, this should deliver c 37 TWh p.a.

2.2 Offshore wind

The BERR Consultation envisages an additional c 14 GW of offshore wind capacity (equivalent to c 3000 x 5 MW turbines) by 2020, compared to less than 1GW today. Again, this implies a build rate of c 1 GW p.a. between now and 2020. The RAB Report is more optimistic, envisaging c 18 GW of offshore wind installed by 2020, equivalent to c 1.5 GW p.a. Assuming a somewhat higher annual average capacity factor for offshore turbines of 0.35, 14 GW of offshore wind should deliver c 43 TWh p.a, and 18 GW should deliver 55 TWh p.a.

The RAB, however, also envisages a more challenging "further stretch" option, involving an additional 6 GW of wind (mostly off-shore) by 2020. This 6 GW could provide an additional c 18 TWh by 2020, making a total from offshore wind of 73 TWh p.a. by 2020.

The USA installed c 5 GW of (on-shore) wind last year, and Germany and Spain have regularly achieved 2 GW p.a., mostly with turbine capacities considerably lower than the machines that are envisaged for the coming decade, so such installation rates should be achievable in the UK, provided the present supply chain constraints can be eased, a point emphasised in the BERR consultation.

2.3 Biofuelled electricity generation

The BERR consultation estimates the long-term technical potential of bioenergy sources of both electricity and heat as c 100 TWh of primary energy p.a (BERR Table 7.1). It suggests that the total land area available for biofuel and energy crops could increase by 350,000 hectares to c 1 million hectares by 2020, some 17% of the UK's arable land. Total UK land area is c 24.5 million hectares, so 1 million ha is about 4% of this overall total. The BERR consultation does not explicitly quote a capacity figure for biomass-fuelled electricity generation, but from their Figure 3 one can deduce that it estimates a capacity of c 3 GW from "sewage gas and biomass/waste" by 2020.

The RAB report is more explicit, suggesting c 4 GW of generating capacity from biomass and SRF (short-rotation forestry), not including sewage gas, by 2020. If we assume 4 GW installed capacity and a capacity factor of 0.8, this should deliver 28 TWh p.a. by 2020. Additionally we assume that BERR's 100 TWh includes 22 TWh from waste (equivalent to c 60% of the UK potential as calculated by the Chartered Institute for Waste Management). Subtracting this total of 50 TWh from the BERR estimated long-term potential of 100 TWh leaves a further 50 TWh as the potential for biofuelled heat (see Section 3).

2.4 Wave and tidal stream

BERR suggests that only c 2 GW of generating capacity is likely to come from wave and tidal stream generation by 2020. At an annual average capacity factor of c 0.3, this would deliver c 5 TWh. This may be too pessimistic an estimate. As the BERR Consultation itself states (p 213): "The Carbon Trust Future Marine Energy report has estimated that, in the UK, the practical offshore wave energy resource is in the region of 50 TWh/year, that the UK tidal stream resource is 18 TWh/year, while the practical near-shore and shoreline wave energy resources have been estimated at 7.8 TWh/year and 0.2 TWh/year respectively." In this scenario however, we have conservatively assumed that wave and tidal stream capacity increases to c 2GW by 2020, contributing c 5 TWh per annum by that date, as in the BERR document.

2.5 Tidal Barrages and Lagoons

BERR estimates that the Severn Barrage, if built, could supply c 17 TWh p.a from c 8.6 GW of capacity; or, if the smaller Shoots barrage on the Severn were built instead, it would have c 1 GW of capacity producing c 2.75 TWh p.a. We have assumed a 17 TWh p.a. contribution from the Severn Barrage by c 2020. As the BERR consultation document points out, although it is unlikely that a Severn tidal barrage could be operational before 2022, the draft EU Renewable Energy Directive "includes a clause which would allow exceptionally large renewable energy projects that are not operational by 2020 (but are under construction) to count towards national targets, provided they meet certain qualifying criteria." (Tidal lagoon schemes have the potential to make a significant additional contribution to UK generation, but as the technology is not yet fully mature it has not been included in our scenario to 2020.)

2.6 Photovoltaics (PV)

The BERR consultation considers PV under the heading of Distributed Energy. From BERR's figure 5.1, one can deduce that their estimate of the maximum contribution of PV by 2020 is c 2 TWh. Assuming an annual PV capacity factor (for a UK installation) of c 0.1, this equates to an installed capacity of c 2GW.

This figure seem excessively pessimistic to us, given that Germany now has c 4 GW of PV capacity installed after only c 10 years, and aims to have 15 GW of PV capacity installed by 2020 (see Table 1). We assume in our scenario that a somewhat lower PV capacity of 11 GW, generating c 10 TWh, could be installed in the UK in the 11 years to 2020. Worldwide, PV costs are falling and PV production is expanding very rapidly, with PV production plants of 1 GW p.a. capacity currently under construction.

It is worth noting here that turnover of the renewables industry in Germany in 2007 was €25 bn, of which €17bn was in the electricity sector. The forecast turnover in the electricity sector by 2020 is over €100 bn. Employment in renewables in 2007 was 250,000 jobs. The forecast for 2020 is at least 400,000 jobs. Avoided energy import costs through use of renewables in 2007 were €1.3bn. In 2020, they are projected to be around €3.3 bn.[107]

Table 1: German Environment Ministry (BMU) Forecasts for Renewable Electricity to 2020. Increase projected in renewable electricity generated and installed capacity to the following levels:

	Electricity generated (TWh)	Installed capacity (GW)
Total renewables	180	65
Onshore wind	53	28
Offshore wind	39	10
Biomass	42	6.1
Hydroelectricity	24	5.1
Photovoltaic	13	15
Geothermal	2	0.28

2.7 Hydro

BERR does not envisage a significant increase on the current UK hydro contribution of c 4 TWh p.a. However a recent report by the Forum for Renewable Energy Development in Scotland suggests that an additional 657 MW of financially viable capacity remains to be exploited – roughly a 50% increase on the present 1379 MW of hydro capacity.[108] The contribution of this additional capacity has not been included in our scenario.

2.8 Total projected renewable electricity generation by 2020

The total annual electricity contribution of the sources listed above is 196 TWh. If we round this down to c 190 TWh, it amounts to just over half of current UK electricity consumption (c 360 TWh). This 190 TWh from renewables would displace equally the generation of electricity by coal and by gas, enabling major reductions in coal and gas imports.

The conclusions from our modelling and scenario work in the UK electricity sector are broadly consistent with those of a recent report by Poyry Consulting for Greenpeace and WWF.[109] Their report finds that if the UK Government achieves its commitments to meet EU renewable energy targets and its own ambitious action plan to reduce demand through energy efficiency, major new conventional power stations would not be needed to ensure that Britain can meet its electricity requirements up to at least 2020. It also concludes that a strong drive for renewable energy and energy efficiency can reduce emissions and improve energy security.

3. Renewable heat supply

3.1 Biofuels & biogas for heat

(a) Direct heating

BERR's Figure 4.3[110] suggests a contribution of c 38 TWh from biofuels, plus another c 12 TWh from biogas by 2020, a total of c 50 TWh.

(b) Biofuelled combined heat and power (CHP).

BERR does not give an estimate for this. However, in our modelling (see section 7 below) we have allowed for a small proportion of the gas for gas-fired industrial combined cycle gas turbine (CCGT) CHP to come by 2020 from biogas, rather than natural gas.

3.2 Solar water heating

BERR's Fig 4.3 suggests up to c 24 TWh p.a. could be supplied by solar water heating by 2020. This is the contribution we have assumed.

3.3 Heat pumps: ground and air source

BERR's Fig 4.3 suggests c 10 TWh could be supplied from ground and air source heat pumps by 2020. Heat from such heat pumps would displace oil-fired space and water heating in buildings in rural areas away from the gas grid. Otherwise it would mainly displace gas-fired space and water heating.

Modelling for this project by our EST colleagues (see Annex 1) suggests a much larger potential heat pump contribution by 2020, namely c 97 TWh of heat p.a. This would require an electricity input of c 35 TWh p.a., nearly half of which would be from renewables.

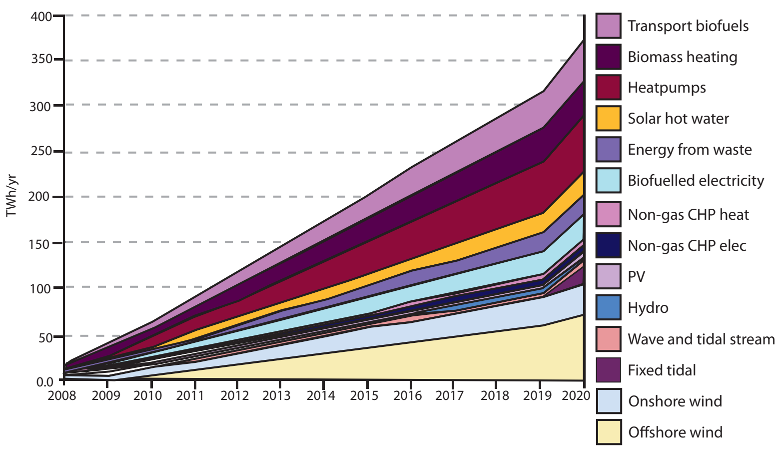
3.4 Geothermal

The BERR report does not give any figures for geothermal heat (apart from Ground Source Heat Pumps (GSHPs), which are in most cases not true geothermal devices). The UK has one small geothermal aquifer scheme in Southampton and there may be potential for more. In addition there is the more advanced geothermal "hot dry rocks" technology, which the UK tried unsuccessfully in Cornwall, but is still being developed at Soulz in France. New moves to exploit this technology have also recently been reported in the USA and Australia.[111] We have not assumed any contribution from geothermal in our scenario.

3.5 Total renewable heat supply

Adding sources 3.1 to 3.4 above, we get c 170 TWh of renewable heat by 2020. Since this is mostly for space and water heating in buildings, which in the UK mainly uses gas, this heat should displace about the same quantity of natural gas (increasingly imported), although some of it would displace oil used for space and water heating in homes and other buildings away from the gas network.

Figure 1: Energy from Renewables 2008 – 2020



4. Supply of renewable transport fuels

4.1 Biofuels

BERR suggests that by 2020 some 10% of road transport fuel should come from biofuels, provided that these are from sustainable sources. After the efficiency reductions described in Annex 1, including electric cars, 10% of road transport fuel (including electricity) from biofuels would directly displace c 4 million tonnes of oil p.a (c 45 TWh).

4.2 Electric vehicles and 'Vehicle-to-Grid' (V2G) technology

BERR suggests (p 174, section 6.3.9) that if all 26 million UK cars were electric, UK electricity demand would increase by c 64 TWh. However, generating capacity would not need to increase substantially because most charging would be at night, when demand is low.

The batteries of electric vehicles using V2G, BERR also suggests, would provide useful storage capacity to help smooth the variability of renewable electricity sources. This would become increasingly important if, as we envisage, there is a high percentage of renewable electricity generation on the UK grid.[112]

We conservatively estimate that there will be c 1,000,000 electric vehicles on the roads in 2020, increasing electricity demand by 2.4 TWh. We envisage by 2020 a mix in which a proportion of UK vehicles are all-electric or plug-in hybrid; and most of the rest run on a mandatory blend including 10% biofuels, with some flex-fuel vehicles running on c E85% ethanol. The model assumes that 10% of road transport fuel (including electric cars) is from biofuels. The specific mix of biofuels is not specified.

4.3 Industrial combined heat and power supply

The recent Poyry report for Greenpeace[113] suggests that the UK has a neglected potential for up to 16 GW of gas-fired combined heat and power (CHP) plant, using high-efficiency combined cycle gas turbine (CCGT) systems. Most of this potential is located at nine large industrial sites. This gas-fired CCGT CHP could significantly UK reduce gas imports, by enabling the waste heat from gas-fired electricity generation to be used in place of direct gas-fired heating in industry; but it would not substantially reduce oil imports.

Some of this CCGT capacity, we suggest, could be fuelled by biogas rather than natural gas, perhaps by blending approximately 1.5% biogas into the natural gas supply chain, equivalent to around 12 TWh of biogas going into the gas network.

VERY HIGH RENEWABLES SCENARIOS

Various recent studies have projected renewables-intensive energy futures for specific European countries. For Germany, studies by Lehmann et al (http://www.isusi.de/downloads/simren.pdf) show the feasibility of a very high renewable electricity contribution to national supplies by 2060. For Denmark, the Danish Society of Engineers has developed a detailed plan to provide some 100% of the country's primary energy from renewables by 2050 (www.energyPLAN.eu).

For the UK, some recent studies have considered very high renewable contributions to supply. A 95% renewable electricity system for the UK has been simulated by Barrett[137] at UCL; and the Centre for Alternative Technology's Zero Carbon Britain study has projected a 100% renewables contribution to UK primary energy (http://www.zerocarbonbritain.com/).

A recent experiment illustrated the feasibility of a 100% renewable electricity system for Germany:

"Three companies [Enercon, Schmack and Solarworld] and a university (Kassel) conceived and ran a "Combined Renewable Energy Power Plant" experiment aiming to show in miniature via what could be done, if the will can be summoned on the national scale to replace both fossil fuels and nuclear power.

"They linked 36 decentralised wind, solar, biogas combined heat-and-power and hydropower plants in a nationwide network controlled by a central computer. Using detailed weather data, they turned up the biogas and the hydropower, the latter in the form of pumped storage, whenever necessary to compensate for wind and solar intermittency. The system was scaled to meet 1/10,000th of the electricity demand in Germany, and was equivalent to a small town with around 12,000 households. It worked perfectly, meeting both continuous baseload and peakloads round the clock and regardless of weather conditions. The network was capable of generating 41 gigawatt hours of electricity a year. Over the period of the experiment, 61% of the electricity came from eleven wind turbines (total 12.6 megawatts capacity), 25% from four biogas CHP plants (total 4 MW capacity), and 14% from twenty PV installations (5.5 MW capacity). (…) Extrapolating the results of the experiment suggests that by 2020, 40% of German power demand could be met with wind, solar and bioenergy, and by 2050 100% could be."

Source: "A reliable ten thousandth," Christoph Podewils, Photon, December 2007.

See also video at http://biopact.com/2007/12/germany-is-doing-it-reliable.html

5.1 Nuclear

In line with government projections, we assume the gradual phasing-out of older nuclear power stations, leaving a total contribution of c 23 TWh from the remaining nuclear plants by 2020. We have not included new nuclear in this scenario because we are concerned about its uniquely "brittle" political, economic and technological characteristics in the face of the potential instabilities of the 21st century.

International co-operation will be vital in dealing with the impending peaks in fossil fuel supplies. If the UK and other developed nations make new nuclear power a core component of their response to energy security, as its advocates suggest, many other rapidly developing economies will want to follow suit, resulting in many more nuclear materials and skills in global circulation, often under conditions much harder to control. This would increase the risks of their diversion for a variety of malign purposes. Even greater risks of this kind would be incurred if plutonium-generating breeder reactors were built in response to the shortage of high-grade uranium ore inevitable with a global expansion of nuclear technology. It will then be very hard for resurgent nuclear nations to make a foreign policy case that other nations should not be granted access to the same technology. This creates very considerable political tensions that could undermine the delicately-structured international order required to steer humanity through the coming, challenging decades.

Another aspect of its brittle quality manifests in security of supply. Following a serious incident, or perhaps several related incidents, it could be considered necessary to shut down a large proportion of the nuclear stations in a network indefinitely, leaving a major shortfall in the electricity supply system. The role of nuclear as base-load supplier, usually thought of as a strength, could become its weakness.

The economics of new nuclear are also brittle. In addition to the proven history of escalating nuclear build costs, the cost of current UK nuclear decommissioning liabilities has been rising sharply over recent years. Nuclear economics are heavily back-end loaded, i.e. many costs occur after the plant has performed its useful life and the energy has been sold. These include the costs of long-term waste management, the safe transport, reprocessing and storage of fuel and wastes, and the decommissioning of power stations - plus the long-term cost of protecting each gram of fissile material. In a future world with increasing energy costs and ever more stringent security requirements, any estimates of the full life cycle costs of new nuclear must be fragile, to say the least.

New nuclear implies serious risks that should only be taken if there is absolutely no alternative. We believe there are viable investments in renewable energies that offer more attractive and more predictable returns. The choice is clear: if a minority of powerful nations continue to favour an economic system under-pinned by centralised nuclear technologies with inherently vulnerable supply lines, we will need to protect it with a huge world-wide police force at enormous expense and risk to our civil liberties. On the other hand, if we all begin a shift to a world economy based on a decentralised equitable and efficient use of clean, renewable energy sources, we can create robust economic systems that no organisation can easily threaten and, perhaps more importantly, that are not perceived to threaten anyone else.

5.2 Fossil-fuelled electricity generation

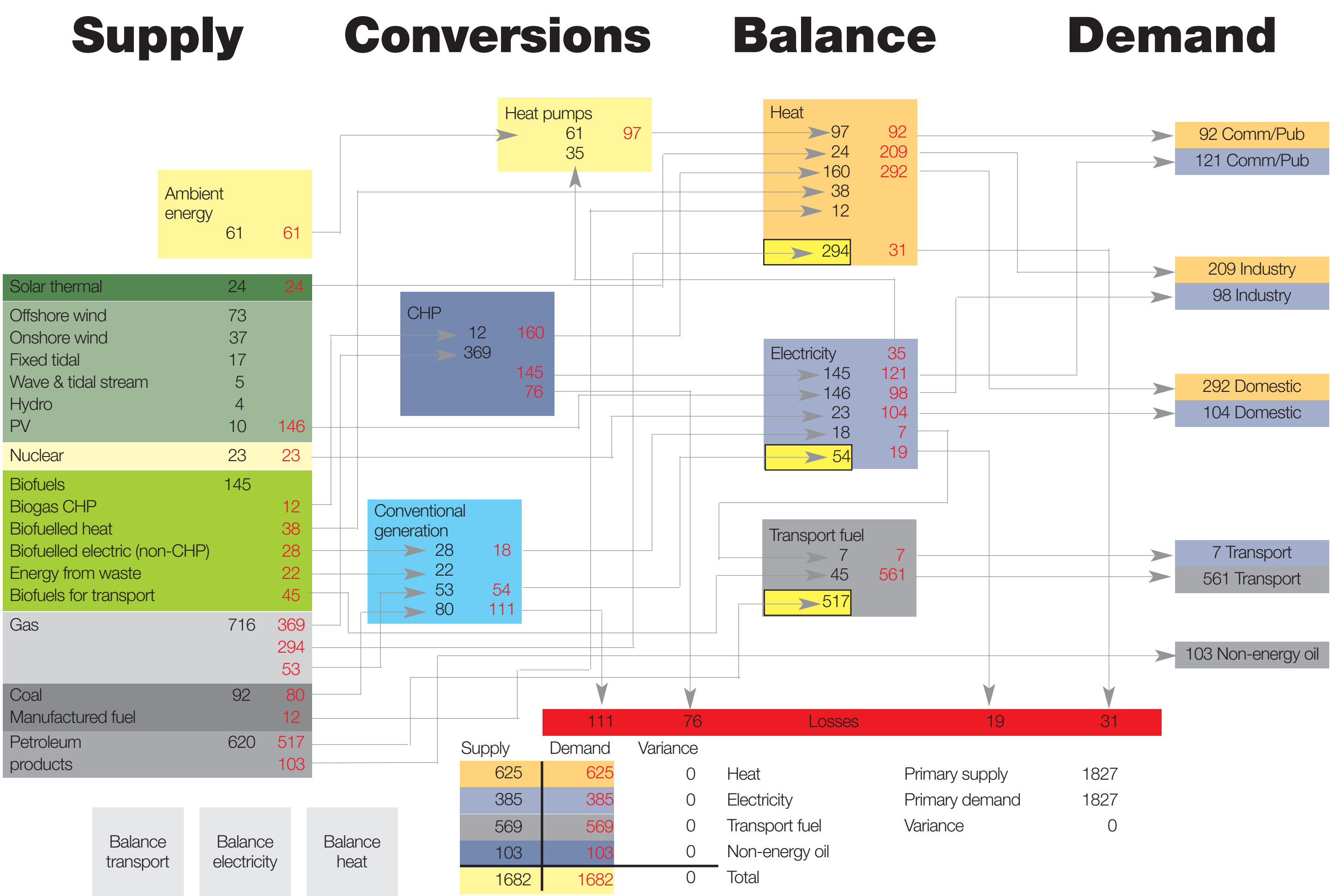
Our "Matrix" model (see below) assumes that, after our projected supplies of renewable and nuclear electricity generation, plus electricity from CHP, are taken into account, fossil fuelled electricity generation - equally split between natural gas and coal - makes up the difference.

6. The "Matrix": A Model of UK Future UK Energy Supply and Demand for ITES

The "Matrix" energy model was originally developed for CAT's ZeroCarbonBritain project. It has now undergone further development for the ITPOES project to allow us to model a future with some contributions from fossil fuels, in order to address the issue of fossil fuel depletion.

The Matrix is based on a "Sankey Diagram" of energy flows, similar to that produced periodically by BERR from DUKES data, and to that used in ZeroCarbonBritain. It is a simple energy accounting model made up of several balanced modules with energy inputs on the left (black) and outputs on the right (red). See Figure 2 below. The numbers for demand start with current demand.[114] The end demand figures have been drawn from EST and allow for increases in efficiency, e.g. of electric motors compared with internal combustion engines, or improved home insulation. The bases for some of these estimates can be found in Annex 1 from EST.

Figure 2: The ITES Matrix Model Sankey schematic, showing energy flows from supply to demand in 2020. Units are TWh.



Supply	Demand	Variance	
625	625	0	Heat
385	385	0	Electricity
569	569	0	Transport fuel
103	103	0	Non-energy oil
1682	1682	0	Total

Primary supply	1827	
Primary demand	1827	
Variance	0	

6.1 Supply module

On the left hand side of the Sankey schematic page is a summary of supply, mostly drawn from assessments by BERR and RAB (as described in sections 2 to 4 above) and laid out in a separate "Supply" spreadsheet in the model. In addition, the energy supplied from fossil fuels is shown here, i.e., gas and coal for electricity, gas for heating and petroleum for transport. These figures are variable and are used to balance supply and demand (see 6.4).

6.2 Demand module

A summary of the demand sheet appears on the right hand side of the schematic page. This draws together all the demands under the headings of Commercial/Public, Industry, Domestic, Transport and Non-energy Oil. Electricity demand is highlighted in blue, heat in orange and petroleum products in grey.

6.3 Conversion modules

The main work of the model is carried out in the conversion modules. Each module is a balanced unit. For example the "Heat pumps" module has inputs of electricity and ambient energy (collected from the ground, air or water) and it outputs to the "Heat" module. The simpler modules (those which only balance) are dealt with on the Sankey summary spreadsheet, but others such as CHP have their own spreadsheets for clarity.

The CHP module assumes large-scale high-efficiency CCGT plant, as described in the Poyry/Greenpeace report, which estimates that there is scope for 16 GW of such plant.

There is also a "Conventional generation" module which calculates the primary fuel required to generate the required amount of electricity to balance supply and demand. The energy generated is assumed to be 50% from natural gas and 50% from coal.

This sheet also contains a calculation for energy from biomass and waste fuelled generation.

6.4 Balance module

The model balances supply and demand in three modules, "Heat", "Electricity" and "Transport fuel", through the use of the "Balance" buttons. The fuels used to balance are, respectively, natural gas (for heat), natural gas and coal in a 1:1 split (for electricity), and petroleum products (for transport fuel).

The cells highlighted in yellow are varied using Excel's 'Solver' add-in. In effect, this adjusts the amount of energy required from fossil fuels in order to balance input and output.

6.5 Outputs of the Matrix model

The main outputs from this model are the Matrix graphs, examples of which are given opposite, showing reduction in energy use and reduction in oil consumption.

Figure 3 shows a reduction in natural gas use of 26% by 2020, coal by 79% and petroleum by 46%. The rate of decline in petroleum use (Figure 4) is slightly more than a 5% decrease per annum, from a peak in 2011.

Figure 3: Annual primary energy

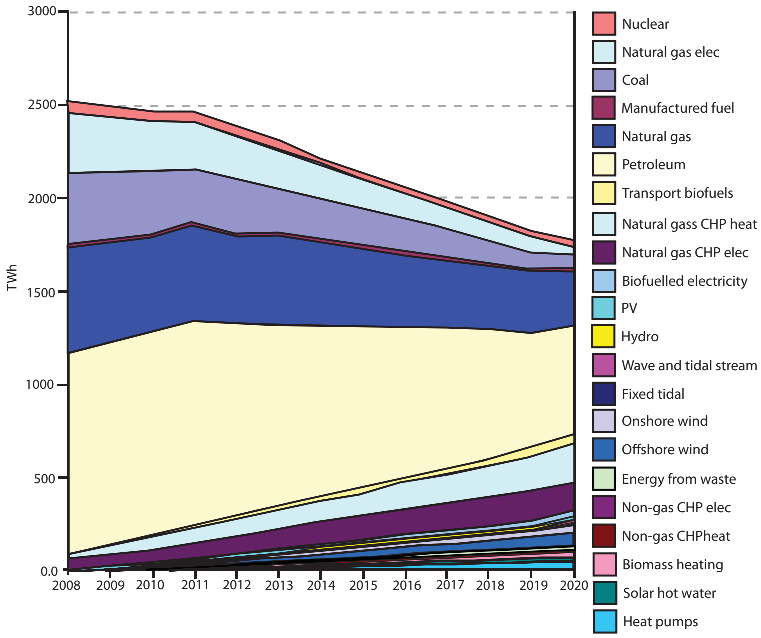
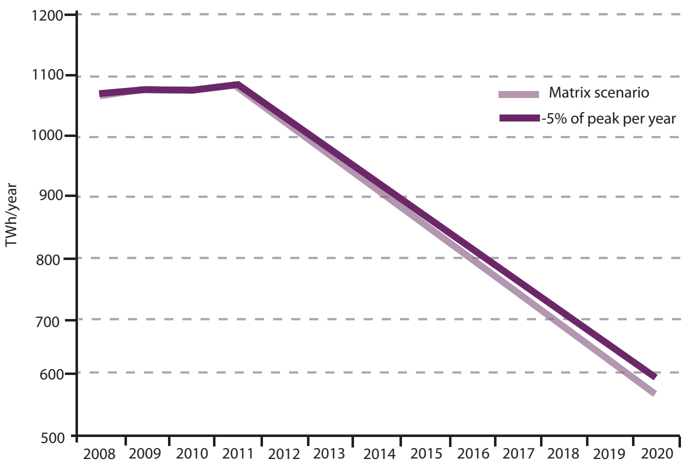


Figure 4: Petroleum consumption



7. Notes on assumptions

7.1 Assumptions on domestic sector demand

These are based on figures given by EST in Annex 1. It is a very challenging scenario involving a large amount of home renovation each year to increase levels of insulation and install more efficient heating systems. The reductions identified in this sector are more useful in avoiding reliance on natural gas than in mitigating peak oil.

Heating

Overall energy demand for heating is projected to fall by 38%. The demand is partially met by a large increase in heating from heat pumps. Also included are 38 TWh from biomass (both biomass boilers and wood-burning stoves). Overall the energy saved on heating is 104 TWh per annum.

Non-heat electricity

Electricity consumption in the home (excluding heat pumps) is assumed to fall by 38%. See Annex 1 for details on this. The total reduction is 44 TWh.

7.2 Assumptions on Transport Demand

Annex 1 projections on the potential for energy savings in the domestic and freight transport sector form the bulk of the reduction in consumption of petroleum products.

Passenger transport

For details on modal shift to public transport, and increase in passenger km travelled, see Annex 1 from EST.

The total reduction in passenger transport energy is 217 TWh per annum. An important assumption is that 2.5% of car passenger km are projected to come from electric vehicles in 2020. This represents an increased electricity demand of 2.5 TWh per annum and a reduction in petroleum demand of 7 TWh per annum. The promotion of electric cars is seen as a key strategy whereby much larger savings on petroleum use can be made if necessary.

Freight transport

Freight is assumed to make a 25% improvement in energy efficiency by 2020, based on work by the Commission for Integrated Transport (2007). These improvements are based on estimates of carbon reductions which are converted to energy savings of 34 TWh per annum in 2020.

Aviation

Domestic air transport is assumed to switch to rail. The time horizon for this is very tight and decisions would need to be made on investment in high speed links if this is to be achieved. This represents a saving of 160 TWh per annum in 2020. We also assume no further growth in demand from international aviation. This is key to mitigating the impact of peak oil as continuing growth of international air travel could swamp any efficiency gains made in other sectors.

7.3 Assumptions on commercial and industrial demand

Energy savings from these sectors have not been assessed in depth. The approach used takes the projection given in the National Energy Efficiency Action Plan (Defra, 2007). This is converted to an annual decrease in energy demand of 1.5% per annum, spread equally across all fuel types. This leads to a saving of 93.1 TWh per year in 2020. Opportunities for demand reduction in these sectors would benefit from more specific assessment.

8. Conclusions

The measures outlined in Annex 1 demonstrate that Britain can substantially reduce the amounts of energy needed to deliver the energy services that we need without reducing comfort or amenity. When combined with the measures described in Annex 2, the result by 2020 is a reduction of UK oil consumption by 46% (compared with 2007 levels), coal consumption by 79%, natural gas by 26% and CO_2 emissions by 44%.

The supply scenario described in Annex 2 assumes a fairly rapid decline in UK oil and gas supplies from 2011 onwards (oil at a rate of c 5% per annum and gas at a rate of c 2% per annum), and outlines a path for harnessing Britain's indigenous renewable energy resources over a period to 2020 to meet the reduced energy demands outlined in Annex 1.

In the scenario, an increasing proportion of electricity, heat and transport fuel demands are met by a mix of renewable energy sources. The renewables' contributions are mainly based on projections from the recent UK Government (BERR) consultation document on renewable energy, together with other official projections such as those of the Government's Renewables Advisory Board, whilst the general approach and technology path is based on the Centre for Alternative Technology's report Zero Carbon Britain.

By initiating a transition to a sustainable energy future, instead of remaining at the end of a peaking fossil fuel import pipeline, Britain can take advantage of its extensive indigenous renewable energy reserves, employing renewable technologies appropriate to each scale or location. These renewable reserves, by their very nature, will not peak: indeed, as the technology matures and becomes economic in a wider range of applications, the available reserve actually increases.

In line with government projections, in Annex 2 we assume the gradual phasing-out of older nuclear power stations, leaving a total contribution of c 23 TWh from the remaining nuclear plants by 2020. In our view, the uncertainties of the coming decades are challenging enough: a revival of nuclear power would present further serious and un-answered economic, environmental and political risks that should only be taken if there is absolutely no alternative. We believe that investments in renewable energy and energy efficiency offer a much better and more sustainable return.

This approach not only tackles energy and climate security: it also helps deliver a solution to our pressing economic challenges by getting British manufacturing and construction back to work, forestalling recession. To gain maximum economic benefit and to ensure a secure supply of renewable generation technologies we should manufacture a substantial proportion of the technology within the UK. This will necessitate a significant re-skilling - training many tens of thousands of professionals in new energy skills and approaches. It will result in jobs for construction workers, engineers, economists, agriculturalists and many others.

Additionally, a switch to our indigenous renewable reserves will make the British economy more immune to politically motivated blockades or price hikes from overseas suppliers, whilst also helping to avert a potential balance of payments crisis as North Sea exports tail off and the price of energy imports goes through the roof, as many predict.

The urgent challenges of the 21st Century require a smart, systematic approach, integrating our detailed knowledge and experience from the agriculture, construction, transport, energy and other sectors into a national framework offering a common, coherent vision linking government, industry and citizens - endorsing, supporting and connecting actions across all sectors of society.

If we learn the hard economic lessons of the past few decades we can re-focus the ingenuity of the finance sector on these new challenges. This will require a national investment programme on a scale that has not been seen since Britain's re-construction following the Second World War, but the returns are tangible and quantifiable. There are massive income streams lying dormant in renewable energy assets that can be awakened, offering a new way to stimulate economic growth and to make a direct contribution to taxation.

The right investments now can deliver real long-term security through creating a new kind of economy - sustainable, locally resilient but still active in a global context, rich in jobs and reliant on our own indigenous, inexhaustible energy supplies. But in order to get the maximum benefit from such a massive energy transition we need to use the remaining supplies of time, oil and gas to their very best effect. If we wait until an energy supply crisis is upon us before becoming serious about implementing sustainable solutions, in the ensuing dislocation we could no longer be able to muster the resources required.

[103] Godfrey Boyle, Open University, Jamie Bull, oCo Carbon, and Paul Allen, Centre for Alternative Technology.
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[105] " 2020 VISION – How the UK Can Meet its Target of 15% Renewable Energy," Renewables Advisory Board (RAB), 2008, 10pp.
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[107] "Eneuerbare Energien in Zahlen (Renewable Energy in Figures), 2008 (in German). Summarised in BMU press release no 166/08, Berlin 31 July 2008; www.bmu.de
[108] September 3rd 2008. http://www.egovmonitor.com/node/20750.
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[110] BERR, 2008 p. 113.
[111] "Google.org says enhanced geothermal technology could be the 'killer app of energy' as it announces $10m investment". guardian.co.uk, 20 August 2008.
[112] Barrett, 2007, in Boyle, G. (ed), 2007 "Renewable Electricity and the Grid: the Challenge of Variability," Earthscan, pp 157-180.
[113] "Securing Power: Potential for CCGT CHP Generation at Industrial Sites in the UK," Report for Greenpeace, Poyry Energy Consulting, Oxford, 40pp.
[114] From DUKES 2008 based on 2007 data but taken as representative of 2008.

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