The Oil Crunch

A wake-up call for the UK economy

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

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on Peak Oil & Energy Security

Taskforce member companies

Arup, Foster and Partners, Scottish and Southern Energy, Solarcentury, Stagecoach Group, Virgin Group.

The chairman of the Taskforce is Will Whitehorn of Virgin, and the editor of this report is Simon Roberts of Arup. Contributors from the companies include John Miles (Arup), Stefan Behling (Foster and Partners), Ian Marchant and Jeff Chandler (Scottish and Southern Energy), Jeremy Leggett (Solarcentury), Steven Stewart (Stagecoach Group), and Nick Fox and Alan Knight (Virgin Group).

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

Editor Simon Roberts (Arup)

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Foreword:

The credit crunch of 2008 foreshadowed major economic, political and social upheaval. It stress-tested the responses of governments, policy-makers and businesses to the extreme. If only there had been greater time to prepare for its impact and a greater level of understanding about the issues.

The next five years will see us face another crunch - the oil crunch. This time, we do have the chance to prepare. The challenge is to use that time well.

As we reach maximum oil extraction rates, the era of cheap oil is behind us. We must plan for a world in which oil prices are likely to be both higher and more volatile and where oil price shocks have the potential to destabilise economic, political and social activity.

Virtually every sector of our economy is still dependent on oil. This is why it is vital that whichever party forms the next government, they have a coherent set of policies to help the UK adapt. This is especially important for the UK, and other developed economies, which have been so reliant on low-cost oil for decades.

There are two challenges for government and policy-makers. Firstly, to recognise the situation we face, and secondly to take action to mitigate the worst implications of the crunch.

Unless we do so, we face a situation during the term of the next government where fuel price unrest could lead to shortages in consumer products and the UK's energy security will be significantly compromised. This has the potential to hit UK business and commerce as well as the most disadvantaged in society with yet another crisis.

While responsibility for addressing these changes must be taken up by government, we must also build a coalition of interests including businesses and the public if we are to implement the changes needed to help us adapt and prosper.

The energy sector is facing major challenges over the next decade with the need to green the energy mix,

"Our message to government and businesses is clear. Act now."

Richard Branson, Founder, Virgin Group

Ian Marchant, CEO, Scottish & Southern Energy

From recognition to action

maintain security of supply, while at the same time minimising the cost to customers. Scottish and Southern Energy, for instance, are investing in renewable generating capacity and decarbonising electricity production, partly so that the UK is less exposed to volatile fuel prices.

Our transport system, which is central to our economy and social fabric, is largely dependent on fossil fuels and older combustion technologies. Businesses such as Stagecoach and Virgin are at the forefront of the drive to shift to newer, cleaner technologies and more sustainable public transport.

Our urban infrastructure also needs to respond to these changes. We are placing ever greater emphasis on the need for energy efficient buildings and the design of energy efficient urban developments. We are also looking to deploy new technologies within the fabric of our buildings and cities that will enable us to generate cleaner and more efficient energy in future. Arup and Solarcentury are all contributing to the development of these activities.

The impacts of climate change make this an urgent task. However the addition of a peak in oil production and the need to find replacements will speed up that urgency and add even greater focus.

Our message to government and businesses is clear. Act now. If we don't, we run the risk of a return to the oil price shocks of the 1970s and 2008 with all the inherent uncertainty and trauma that brought.

Don't let the oil crunch catch us out in the way that the credit crunch did.

Richard Branson,
Founder, Virgin Group

Ian Marchant,
CEO, Scottish & Southern Energy

Brian Souter,
CEO, Stagecoach Group

Philip Dilley,
Chairman, Arup

Jeremy Leggett,
Chairman, Solarcentury

Brian Souter, CEO, Stagecoach Group

Philip Dilley, Chairman, Arup

Jeremy Leggett, Chairman, Solarcentury

Executive summary

This is the second report issued by ITPOES (the UK Industry Taskforce on Peak Oil and Energy Security). The interpretation of the current position, and the viewpoints expressed in the final recommendations, are those of the ITPOES membership - a group of private British companies whose interests span a wide range of business sectors. The work therefore represents an independent, business-minded, view of the national position.

Like its predecessor, published in the autumn of 2008, this report addresses the question of future oil supply and its potential consequences for the UK. It does not address the questions of climate change and carbon reduction directly - there are many other texts which do that - but there are massive areas of overlap between the distinct issues of resource depletion and atmospheric pollution. In some parts of our report that overlap is recognised but the main thrust of the report focuses on the questions of oil price and availability over the coming decade. In particular, it seeks to highlight issues which are likely to confront the new government following the General Election in 2010. It follows the style of the first ITPOES report, titled "The Oil Crunch, Securing the UK's energy future" in that two expert opinions have been commissioned and used as the basis for an analysis by the ITPOES membership.

Opinion A has been prepared by Chris Skrebowski, a recognised independent oil-industry expert. He looks in some detail at the evidence which defines global oil reserves and extraction rates, and concludes that the global peak production rate for oil is likely to occur within the next decade (maybe within 5 years) at a value no higher than 92Mb/d (million barrels per day). This compares with the current record extraction rate of 87Mb/d set in July 2008, and the conclusions drawn are essentially the same as those reached in the previous ITPOES report. At first sight, this is surprising but on closer examination it is clear that the fundamental issues identified in the 2008 report remain unchanged. Namely:

- The net flow rate data shows that increases in extraction will be slowing down in 2011-13 and dropping thereafter. Given the long lead-times involved in developing the necessary infrastructure, this trend is unlikely to be reversed within the next 5 years.
- The industry is not discovering more giant fields at a sufficient rate.
- There are concerns about the levels of reserves quoted by the OPEC countries (which are critical to the confidence levels associated with future production capacity).
- There are indications that underinvestment in the oil industry over the past decade has led to infrastructure and underskilling problems that will make it particularly difficult to increase production capacity rapidly in the short-term.

The intervening economic crash has done little to blunt our expectations; the time to a peak in global production is, essentially, little changed as cancelled new capacity broadly offsets recession-deferred demand. When combined with current demand projections, a price crunch is still projected to occur following the peak.

Opinion B has been prepared by Dr Robert Falkner of the London School of Economics (LSE). He considers the likely effects of tighter supply conditions and rising oil prices on the British economy, particularly focusing on the coming 5 years. He concludes that the economy is not as prey to the price of oil as might be expected at first sight, but there are fundamental issues which could nevertheless spring a nasty surprise on the incoming government.

Following the presentation of these expert opinions, the key findings from several other reports and reviews of the oil-supply situation, all of which were published in 2009, are presented. In particular, these reports include the Wicks Review on Energy Security for the UK Prime Minister in August, and the latest major research report by the UK Energy Research Centre (UKERC), called "Global Oil Depletion", in October.

The second half of the report reviews the material put forward above and tries to assess the implications for business in the UK. Looking through the eyes of the Taskforce members, it expresses a view that the price of oil could rise to a new and sustained, level which is well above US$100/b and that this is very likely to be the

case within the next 5 years. In our view, this could have a significant impact on a number of important UK industry sectors. It could also have a significant impact on several key societal indicators such as fuel poverty and mobility. The penultimate section of the report looks at some of the particular negative effects which might afflict industry in the UK and suggests some actions designed to combat them.

The report concludes with a clear message to the incoming UK government that, although the immediate slow-down in the global economy has removed short-term pressures on oil consumption, the underlying issues highlighted in last year's report have not changed. Therefore, future government policies must explicitly recognise the potential for:

- Oil prices on the world markets that are significantly higher than historic averages as soon as global economic activity revives.
- The possibility of significant price volatility, with high peaks and (possible) supply disruptions.

Recommendations are put forward for policy consideration in the following areas:

General policies: National and local government policies (particularly those on the social, economic and financial fronts) should explicitly acknowledge the potential for high oil prices and promote appropriate contingency planning.

Transport: Passenger and freight transport are central to our economy. A mix of technological solutions and policies to incentivise behavioural change and modal shift from the car to public transport are identified as key priorities. We believe maintaining government investment in public transport is crucial and a long-term view should be taken of its wider economic, social and environmental benefits. We also highlight the need to lay foundations for alternative sources of motive power (e.g. vehicle electrification) and associated infrastructure.

Retail and agricultural: These sectors are both hit by a secondary dependence on oil. Retail, because of its dependence on sophisticated just-in-time deliveries (transport), and agriculture because of its dependence on oil-based crop and soil treatment products as well as fuels for cultivation and produce transport. In both cases, oil price rises will feed through to consumer prices on the shelves, and government policies need to be shaped to protect the disadvantaged.

Power generation and distribution: This sector is likely to see a significant change in its demand patterns if there is a significant move in the direction of road vehicle electrification. The introduction of Smart Grid technology may alleviate some of this, but the ground needs to be prepared for the introduction of such technology and all the economic and social implications of flexible pricing that are enabled in this scenario. The government has often talked of a green industrial revolution of late, and we believe that such a development is both feasible and imperative, in motive power and generation alike. However, even if such a revolution takes place, it will not produce results quickly enough to make a material difference to the oil production problems we describe.

Heating: Despite the fact that only a small fraction of UK heating is directly supplied by oil (or oil-based products, such as LPG), there is nevertheless a significant minority of households that use this form of heating. Once again, government policies need to be framed in the interest of protecting the disadvantaged members of our society.

The report concludes with a clear message to the incoming UK government that future policies must explicitly recognise the potential for world oil prices to rise and for the possibility of oil supply interruptions. Recommendations are put forward for policy consideration in the areas of transport; retail and agriculture; electricity generation and distribution; and commercial/domestic heating.

1. Introduction

The first report of the Industry Taskforce on Peak Oil and Energy Security (ITPOES) was published during the final quarter of 2008. It highlighted the probability that future oil production volumes are unlikely to rise much above the record global extraction rate of 87Mb/d achieved in July 2008, and that this will not match rising global demand. The consequences of this shortfall were summed up in the phrase 'an end to the era of cheap oil' and the term 'oil crunch' was coined to describe it.

One year on, this second report from ITPOES examines the changes which have taken place since Q4, 2008, and re-evaluates the conclusions which were drawn at that time. It concludes that, although many significant economic events have occurred in the past 12 months, the very simple fundamental factors which pointed to the oil crunch have not gone away, and an end to the age of cheap oil is indeed with us. Like its predecessor, this report is focussed on the issue of oil availability. It is not focussed on climate change or carbon reduction, although there are some important areas of overlap between these two distinct subjects.

This year's report starts with a scene setting description of 'peak oil' to clarify terms. As in Report 1, we then present two expert 'opinions'. **Opinion A** is (again) offered by Chris Skrebowski, an independent, and highly reputable, oil industry analyst. He concludes that, although the details of production volumes and timings may have altered, the basic issues remain the same.

Opinion B is offered by Dr Robert Falkner of the London School of Economics (Department of International Relations). Dr Falkner looks at the potential economic consequences of the coming oil crunch with particular reference to the UK. He concludes that times ahead will be tough.

Since our first report, there have been a number of important reports and reviews on energy and oil from a range of organisations. We list these publications and compare their conclusions to those from our two experts.

The report is completed by an appraisal of the opinions which have been offered. The Taskforce concludes that action needs to be taken by government to protect against the worse scenarios which are identified, and that this action must form a priority for the new UK government which will arrive during 2010.

2. Scene setting

2.1 Low prices and abundant resources - end of an era?

The idea that cheap oil is available and abundant is one of the great economic presumptions of our times. The price of oil, adjusted for inflation over the period shown in **Fig 2.1**, shows that market prices have generally been well below the equivalent of $30/b (US dollars inflation corrected to today's prices), except for the oil shocks of the 70's and now. And, over a similar period as shown in **Fig 2.2**, the global rate of production has been unremittingly upwards, suggesting an abundance of reserves. **Figs 2.1** and **2.2** encapsulate conventional wisdom on oil production: low prices and abundant resources.

But the significant rise in prices over the past decade presents a cause for concern. Is this a temporary market aberration, or is it an indication that demand is beginning to run ahead of supply? Might it even represent a turning point in the history of oil production: the point where the highest practicable rate of global production has now been achieved and from which future levels of production will either plateau, or begin to diminish (so-called 'peak oil')? And, if it marks the recognition of peak oil, how big might be the shock to our economic landscape?

'Peak oil' is an expression that is widely mis-understood. It does not relate to a prediction that there's no more oil left to extract from the earth's oil fields (although oil is a finite resource and it must run-out sometime). Rather, it relates to the maximum rate at which we can extract oil - which, in turn, relates to ease of access and rates of extraction at the wells. These limits to access, and rates of extraction, may come about for several, quite different, reasons

The first possibility is that we are already producing at, or near, the maximum capacity of our existing fields and no more significant oil fields can be found, despite increasingly intense exploration activity. This is the conventional understanding of the case for 'peak oil'. Despite the facts that there is a large amount of known oil in the ground (more than we have extracted to date), and that new finds are constantly being reported, none of this adds up to enough to replenish the current levels of draw-down. The new, easily accessible, super-giant fields which are necessary to replenish the mainstay of current production are nowhere to be seen.

The need to find new super-giant fields is illustrated by the fact that, although there are some 70,000 known fields in current production world-wide, the vast majority of these produce oil in insignificant volumes. A mere 120 fields are the source of 50 percent of global production, and one field alone, the super-giant Ghawar field in Saudi Arabia, yields over 5 percent of the world's current production. Ghawar and the world's other giant fields are, for the most part, quite old, and no new finds of this size have been reported for a very long time. This suggests that they are not going to be found very easily in future and, as a result, 'peak oil' is at hand. It is our view that this description of the present state of global oil production is quite credible.

The second possibility is that we are producing oil at, or near, the maximum capacity of the existing fields, but large new (and easily accessible) finds will be brought

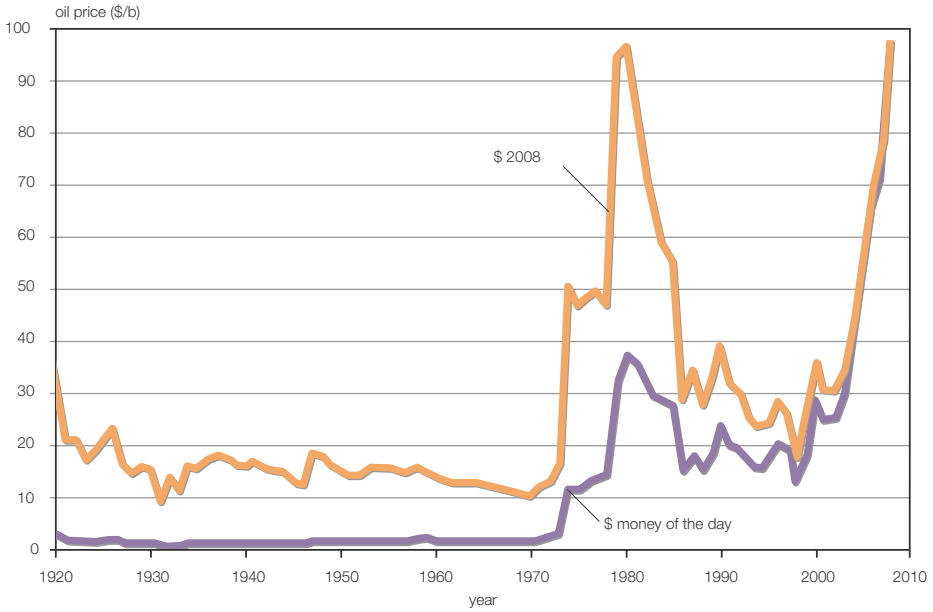

Fig 2.1 Price of oil over the period 1920 to 2008, both at prices of the day and inflation adjusted to 2008 US dollars. (Source: BP Statistical Review of World Energy 2009)

on stream in future despite the fact that these sources are currently unidentified. The relative absence of obvious candidates for immediate exploitation merely reflects the comparatively low levels of oil-industry investment in exploration and production over the past decade (due, mainly, to the relatively low market prices for oil). Unfortunately, even if large new finds are in the offing, only limited new capacity will arrive on stream within the next decade or so, because large fields take many years to develop. In a world with rapidly rising global demand, this will inevitably lead to a sharp and sustained rise in oil prices over the coming decade, even though prices may retreat again in the longer term. In our view, this description of the present state of global oil production is credible, but unlikely.

The third possibility is that there will be new discoveries of large new oil sources, but they will not be easily accessed, or they will be difficult to extract from. The recent deep offshore, sub-salt, finds in South/Central America, and the tar sands of Canada, are good examples. Under these circumstances, even though abundant oil reserves may be uncovered with the passing of time, the ability to extract that oil will be limited both physically and by the sheer cost of exploration and production. Consequently, there will be a sharp, and permanent, rise in oil prices from which there will be no retreat. In our view, this description of the present state of global oil production is probably the best that is available.

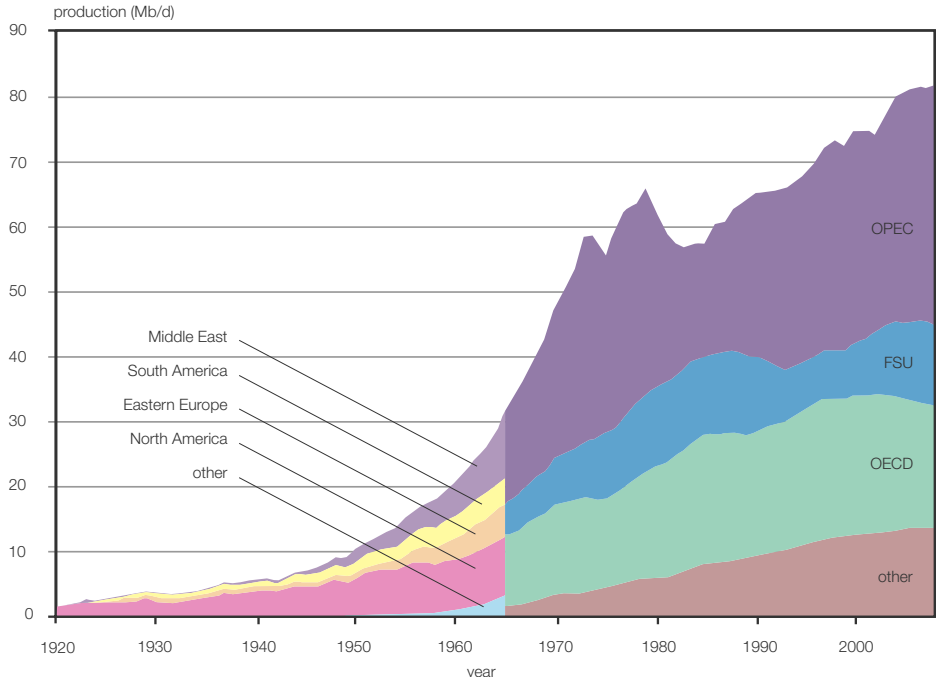

Fig 2.2 Global oil production 1920-2008. (FSU: former Soviet Union, since December 1991.)
(Sources: US Department of Energy for 1920-1964, and BP Statistical Review of World Energy for 1965-2008)

2.2 The rate of production - are we really at the peak?

The historic global rate of oil production is shown in **Fig 2.2**. For details of "oil" included, see "Definition of liquids production" in box. It is tempting to conclude from this that the rate can continue to rise indefinitely, even though production seems to have plateaued in the past five years.

If we look behind the scenes, the current global rate of production is simply the aggregate of a large number of known individual fields. We know how many fields are producing world-wide, their ages, and (within some important limits) the production characteristics of those fields - so we can predict, with some confidence, the ability of those wells to produce oil in future.

DEFINITION OF LIQUIDS PRODUCTION

Oil production figures generally used in this report are actually composed of three elements:

1. crude and lease condensate production (everything that comes out of an oil well as a liquid)
2. natural gas plant liquids (the propane, butane and other liquids extracted in gas processing plants)
3. biofuels and other fuel liquids, such as coal-to-liquids and gas-to-liquids

For example, the IEA's reported all liquids production of 85.9Mb/d in November 2009 would include:

- roughly 73Mb/d (85 percent) of crude and lease condensate
- around 8.4Mb/d (10 percent) of natural gas liquids
- 2.3Mb/d (3 percent) of other liquids
- 2.2Mb/d (3 percent) of processing gain (the volume of products after refining exceeds the volume of crude input by the processing gain)

The typical production profile for a single field is shown diagrammatically in **Fig 2.3**(a). Production rises quite quickly to a peak, and then subsides at a 'depletion rate' which varies from field-to-field, depending on geology and production strategy. Peak production will be established when, typically, around 25-30 percent of the total reserve has been extracted. (Note, however, that the last 25-30 percent of the reserve will be extremely difficult to extract, so the reserve position at peak is not as rosy as it sounds). If we aggregate this information for all known, and planned, fields we can estimate world-wide future flow rates. An exercise of this type forms the basis for the opinion expressed in Section 3 of this report.

An interesting characteristic of oil production is that a collection of fields (in a single region, for example) will almost always demonstrate a collective 'peaky' behaviour. If we assume that the largest fields are tapped first, and that subsequent fields are progressively smaller, and are accessed at successive time intervals, the aggregated characteristic is shown in **Fig 2.3**(b) - no matter how many subsequent, smaller, finds are added, it is not possible to remove the peak - there will come a point where production moves into decline.

The prediction of future flows is not a precise science. However, the analysis presented in last year's report from ITPOES, and reinforced in Section 3 of this report, suggests that global supply rates are currently at, or near, their peak and cannot

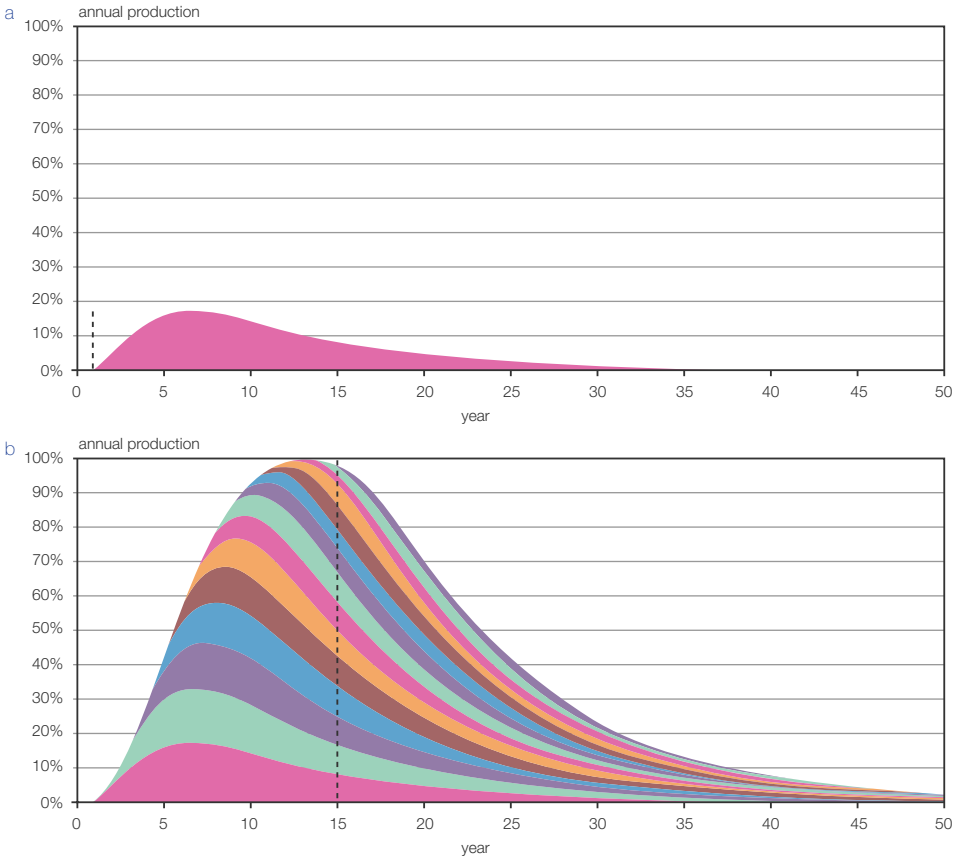

Fig 2.3 (a) The typical production profile for a single field. **(b)** The production from a single region made up from the aggregation of progressively smaller fields. This shows 15 fields, one field brought into production each year, each successive field being 10 percent smaller than the previous. However the overall peak is at 12 years, a date unchanged by further fields brought into production. (Source: UKERC "Global oil depletion" 2009)

rise significantly above 92Mb/d (million barrels per day) unless some unforeseen giant, and easily accessible, finds are reported very soon. In our view, this is extremely unlikely.

The weak point in such analyses, historically, has been the difficulty in predicting depletion rates and, in particular, some uncertainty over the veracity of the stated reserves in the OPEC countries. These reserves are, officially, very high - and this assertion leads to the conclusion that if demand rises, pumping rates can be easily increased. However, the inability of oil producers to keep up with the rising demands of 2007-8, and the statements from some Middle Eastern producers that the oil is more valuable left in the ground as a legacy for their future generations, casts some serious doubt over the conventional 'abundant future production' scenario.

The real question is whether significant new supplies of readily accessible, cheap, oil are available. The answer is 'certainly not' - from the viewpoint of the world's oil majors, at least. Whilst all the major oil companies are reporting new finds, the accessibility of these finds means that the cost of producing oil will be very high in most cases. Or there may be other problems, as with the great resources of the tar sands. This is an energy-intensive and, therefore,

expensive process. It is also likely to be very carbon-intensive. But there is also a physical limit to how fast the oil can be extracted from these sands. So, even if the reserves are abundant, the maximum extraction rates are likely to be limited, thus constraining the tar sands from becoming the mainstay of future production.

Fig 2.4 illustrates the range in costs of extraction of oil found in different locations at today's prices; it is clear that we need to find more oil at Middle-Eastern-like prices if our historic position of cheap oil is to be maintained.

New finds at Middle-Eastern-like prices are very unlikely to be delivered by the world's oil majors. However those players no longer dominate the world scene. The ten largest quoted oil companies currently produce only about 20 percent of the world's oil between them. **Fig 2.5** shows that they produced only 17.5Mb/d in 2008 (out of a total of around 82Mb/d in **Fig. 2.2**). It also shows that this aggregated production volume has been relatively flat for the past six years and is currently in decline (although production at two very important companies, Petrobras and PetroChina, is expanding).

If the largest, strongest, and best financed companies are having difficulty in maintaining (let alone expanding) production, then the idea that the world is coming close to an oil supply crunch is not as unreasonable as it might first appear.

It is a fact that the discovery of abundant, easily accessible, new sources of supply will come (if at all)

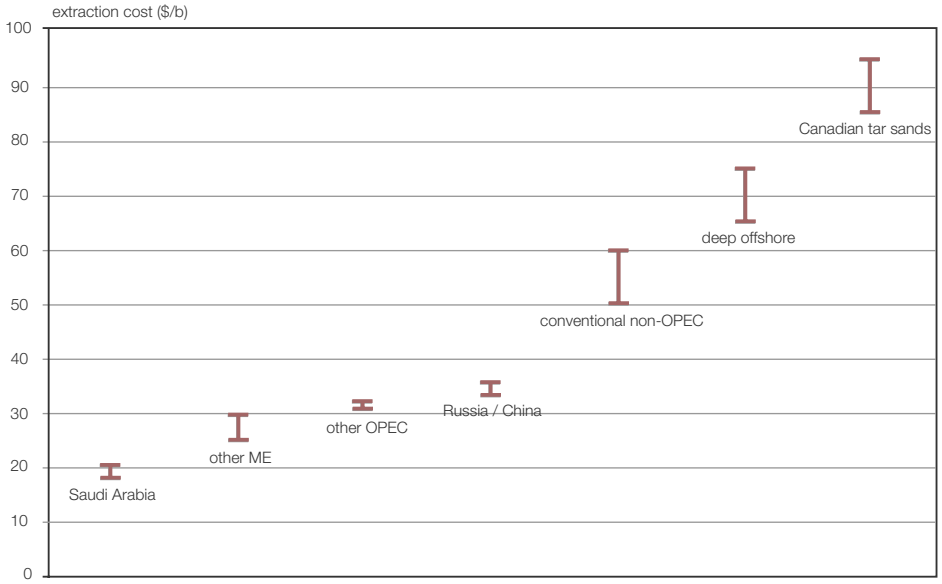

Fig 2.4 For a range of oil sources, comparison of extraction costs. (ME: Middle East countries) (Source: Peak Oil Consulting)

from the National Oil Companies who dominate today's production scene. These oil-producing nations (some Middle-Eastern, some not) could find new low-cost sources of oil in the near future and this would change the outlook dramatically. Iraq is principal amongst these, where it is certain that vast reserves of low-cost oil are readily available. But the military and

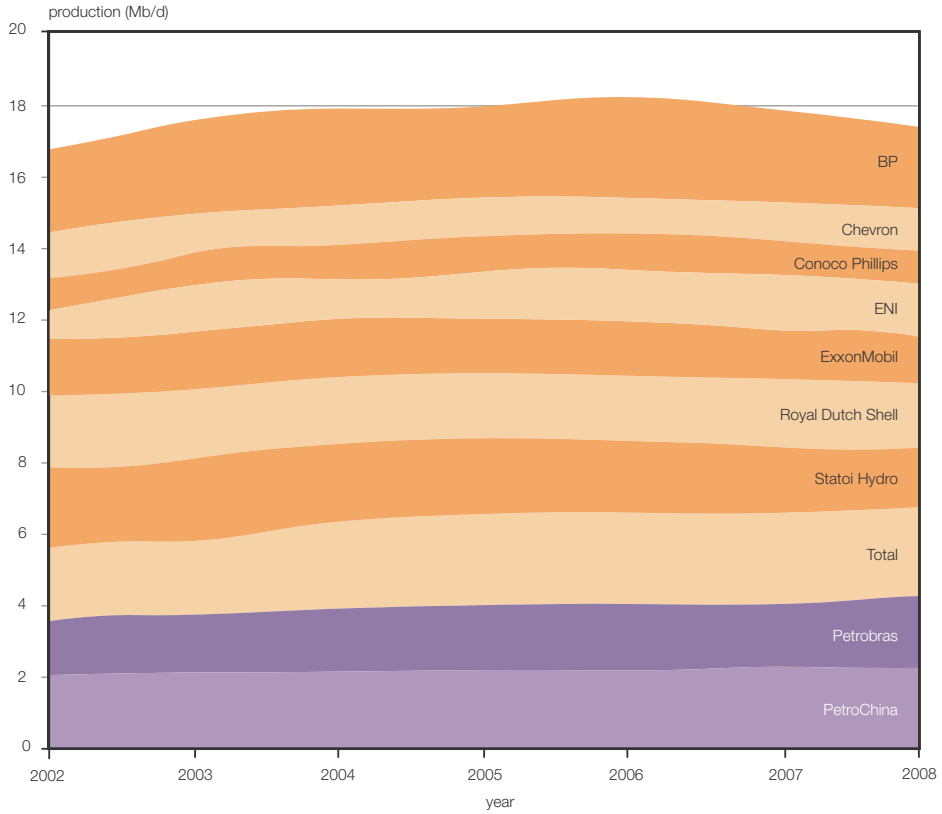

Fig 2.5 Aggregated production for the world's ten largest quoted oil companies. (Source: Peak Oil Consulting)

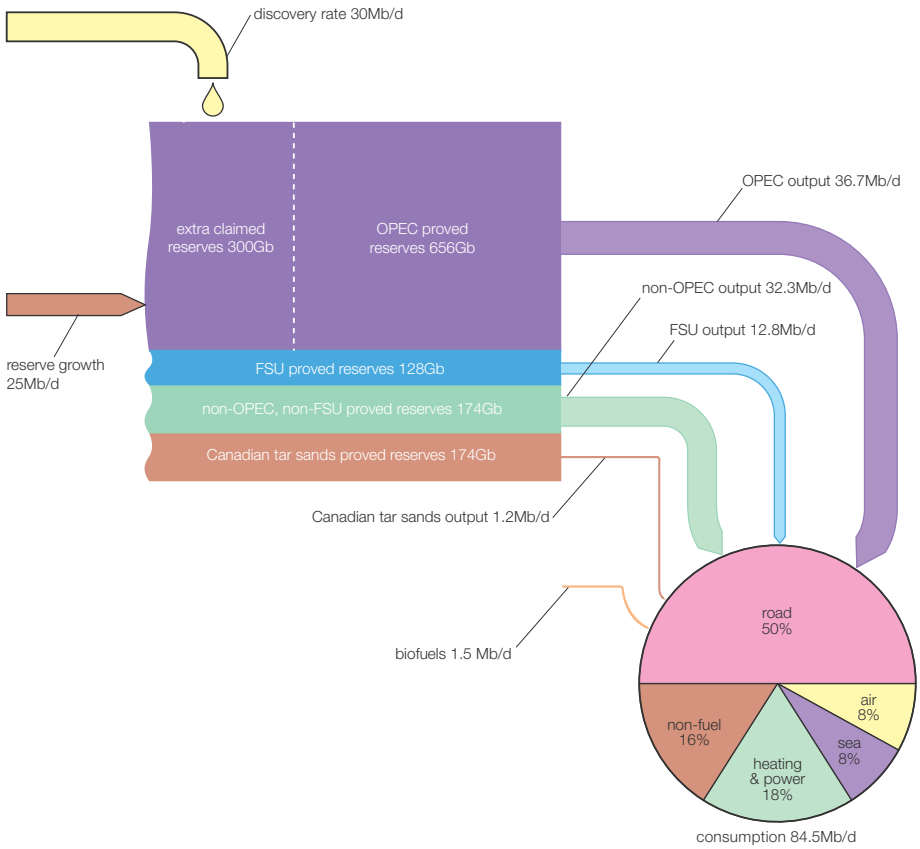

Fig 2.6 Schematic of the size of oil reserves, supply and demand in today's market. Non-fuel consumption includes chemicals, solvents, lubricants and asphalt. (Source: Peak Oil Consulting)

political difficulties in Iraq rule out any simple predictions of future supply from this theatre. And real knowledge of most other National Oil Company assets is cloudy, at best.

A simple summary of today's picture of reserves, supply, and demand, is presented in **Fig 2.6** showing the relative scale of the components, including biofuels. (For more details about biofuels, see Appendix C.)

2.3 Global demand - is it really set to rise?

It seems reasonable to assume that world demand for oil will continue to rise for the foreseeable future. It has, after all, risen fairly continuously for the last 100 years (**Fig 2.2**). A simple extrapolation of this line would suggest that world demand could reach 120Mb/d by 2050, a very similar figure to that predicted by an extrapolation of the IEA's 2009 predictions for demand in 2030. But a simple extrapolation of historic demand could be deceptive, because world economic development, in the future, will be systemically different from the past. To date, the vast majority of world demand for oil has come from the OECD countries (the so-called 'Western world'). But, in future, the principal growth in demand will come from the non-OECD countries (the so-called 'developing world'). The non-OECD countries comprise the vast majority of the world's population (some 5 billion people of the world's current population of 6 billion), so the consequences of a steady growth in per capita oil-demand in these nations need no further elaboration.

The forces of globalisation, now unlocked, will be very powerful and will probably change our outlook on future oil demand from a fundamental point of view. Nevertheless, in the short-term (within the context of the next decade, at least), there are arguments both for, and against, a continued strong growth in global oil demand.

On the side of the 'weak growth' argument, the underlying trend of unfettered growth among the OECD countries has been modified by the oil shocks of the 70's, a general maturing of demand in the last two decades, and the recent economic collapse. If we ignore short-term economic volatilities (economic cycles come and go), the underlying maturing of the OECD economies suggests that future growth in oil demand might be expected to flatten off. Indeed, there are even signs that it is beginning to decline, as prices rise and nations and consumers become more careful in their use of natural resources. The current economic downturn has

accentuated this pattern and the drop in demand over the past 18 months has been dramatic. When economic recovery arrives, will demand rise back to the earlier growth trend very quickly, or will some demand have been permanently destroyed? It is conceivable that the demand from the Western world will never again rise to the levels seen in 2008, and the current excess of capacity will turn into a glut.

Another argument which puts a limit on global demand is that oil prices, when they rise above a certain threshold ($120/b at today's prices?), automatically trigger an economic recession. This deflates demand, thus putting an automatic cap on the maximum required rate of production. Some argue that this happened in 2008.

The counter to these arguments lies in the rate of development of the non-OECD countries. Historically, demand from these countries has been very low (or even non-existent) but, as suggested previously, a rise in per-capita demand from these populations could have an explosive effect on the global market for oil. For these reasons, it can be argued that the next phase of demand growth will be structurally different from the past 50 years. Globalisation has opened up markets and expectations that were previously unthinkable, so the flattening demand patterns of the late 20th century in the OECD countries cannot be used as a basis for future extrapolation. Likewise, the 'recessionary trigger' argument may not be valid. There is no reason to believe that the strong emerging

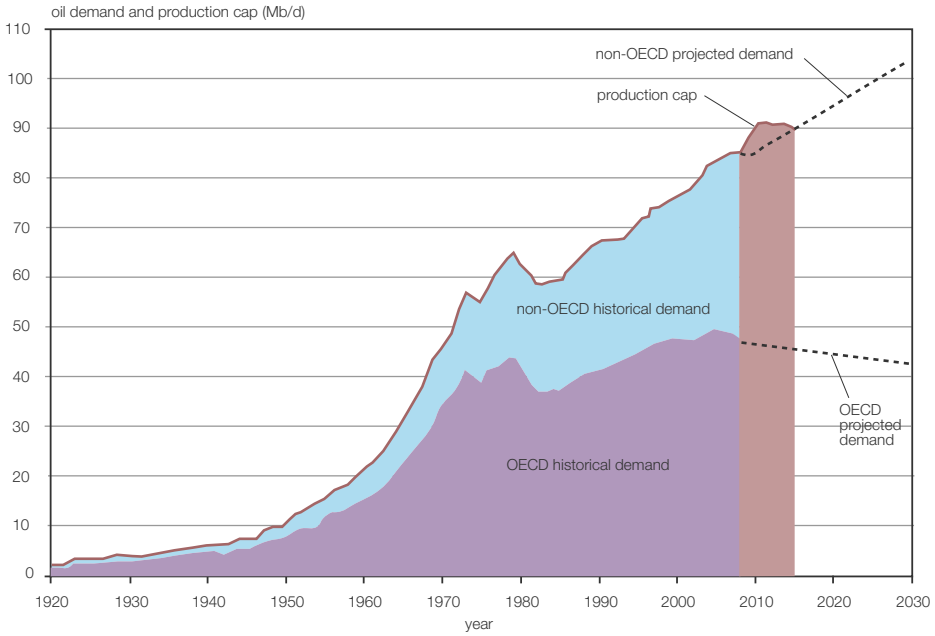

Fig 2.7 Oil demand by region for the historical period 1920-2008 and extrapolation to 2030 according to the IEA's projected 1%/y global growth within which we suggest a 0.5%/y OECD decline. Also shown is the production cap to 2015 according to the megaprojects/depletion analysis of Opinion A (Fig 3.2). (Source: BP Statistical Review of World Energy)

economies of the developing world cannot live with oil prices in excess of $120/b - indeed, their economic systems are currently evolving in a climate of higher oil prices and therefore might be relatively immune to it (whereas the OECD economies did not, and are not).

It seems reasonable, on balance, to expect that the growth in oil demand from the non-OECD countries over the next few decades will outweigh any shrinkage in demand from the OECD countries. This view is in line with the projections of the IEA, whose most recent World Energy Outlook (2009) predicts global oil demand at levels of 105Mb/d by 2030 in their "Reference" scenario. The demand line associated with this view is shown in **Fig 2.7**, along with a production cap which represents the current predictions of the ITPOES members (Section 3). We will argue in Section 6 that the IEA prediction for demand growth is possibly too low, but, for scene-setting purposes, it provides a reputable, and conservative, starting position.

2.4 So what is the likely effect on oil prices and availability?

Based on the foregoing arguments, it seems inevitable that global demand will move to a point where it consistently exceeds supply. The effect must be a structural increase in oil prices, coupled with the prospects of oil shortages and a consequent increase in market volatility. The only questions are "how soon, and by how much?"

3. Opinion A: Chris Skrebowski

Peak Oil Consulting

3.1 Introduction

There are now serious concerns that the free flow of relatively low cost oil, which has underpinned OECD countries economic growth since 1945, may not be sustainable for very much longer. It will be shown in this section that low-cost (under $25/b) oil supplies effectively ended in early 2005 and are unlikely to return. The actual global supply of oil is now expected to be limited to 91-92Mb/d (million barrels per day) of capacity that will be in place by end 2010/early 2011. Global capacity will then remain in the 91-92Mb/d range until 2015 from which time depletion will more than offset capacity growth from then onwards.

Between July 2008 and January 2009 virtually all the world's economies went from vigorous growth to economic recession. This has radically changed the short-term outlook for energy demand in general and oil demand in particular. The recession has changed the market dynamics and potentially moved the 'oil crunch' point (when demand exceeds production capacity) out by around two years. This in turn provides one of the few positive aspects to the recession - it gives companies and individuals more time to prepare and adapt to the coming oil supply crunch. The great risk is that as prices may remain fairly low for the next year or so, and complacency may set in thereby postponing decisions on making adaptive investments being postponed until oil prices start spiking again.

The next major supply constraint, along with spiking oil prices, will not occur until recession-hit demand grows to the point that it removes the current excess oil stocks and the large spare capacity held by OPEC. However, once these are removed, possibly as early as 2012/2013 and no later than 2014/2015, oil prices are likely to spike, imperilling economic growth and causing economic dislocation.

Oil supply over the next five to six years is predictable owing to the slow-moving nature of oil supply and the long lead times for major projects. The primary risk is from supply shortfalls caused by project delays over and above those already announced. The demand side is rather less predictable as the path of economic recovery from the recession is uncertain and because 80-90 percent of future demand is expected to come from non-OECD countries such as China and India where consumption data is rather less reliable. In contrast OECD demand, which makes up 55 percent of global demand, is expected to see little demand growth going forward and may even decline.

The last 15 months have seen unparalleled levels of price volatility in the three main hydrocarbon fuels. Oil prices have swung from $147 in July 2008 to $32 in late December 2008 and then back up to $70-80 from late August 2009.

As both UK Prime Minister Gordon Brown and French President Nicholas Sarkozy have publicly observed in their calls for greater price stability, this sort of volatility is very damaging

to economic activity and one that is becoming increasingly expensive for companies to hedge against. It is also true that great price volatility makes investment by both end users and energy suppliers more difficult.

As this section will make clear, energy price volatility is set to continue for some time simply because small mismatches in energy supply and demand produce wide price swings as there is no economic actor strong enough to absorb and damp the mismatches. When the 'Seven Sisters'[1] dominated global oil supplies in the 1960s, they were in a position to ensure price stability. Now there is no group in this position in terms of oil or energy supply. OPEC has limited pricing power but only when it holds capacity off the market and this requires key players, usually Saudi Arabia, to hold spare capacity to enforce discipline. As demand rises and spare capacity disappears, OPEC has to cede pricing power to the market as happened in mid-2008.

The UK, because it is now a net and rising importer of oil, gas and coal, is becoming increasingly exposed to competition for supplies from other energy importers. The insulation from international supply pressures provided when the UK was self-sufficient in oil and gas supply is now eroding quite quickly. This is likely to put pressure on the UK balance of payments and in a world of floating exchange rates is also likely to put downward pressure on the valuation of the pound sterling. In other words the positive benefits to the valuation of the pound as a petrocurrency are now disappearing.

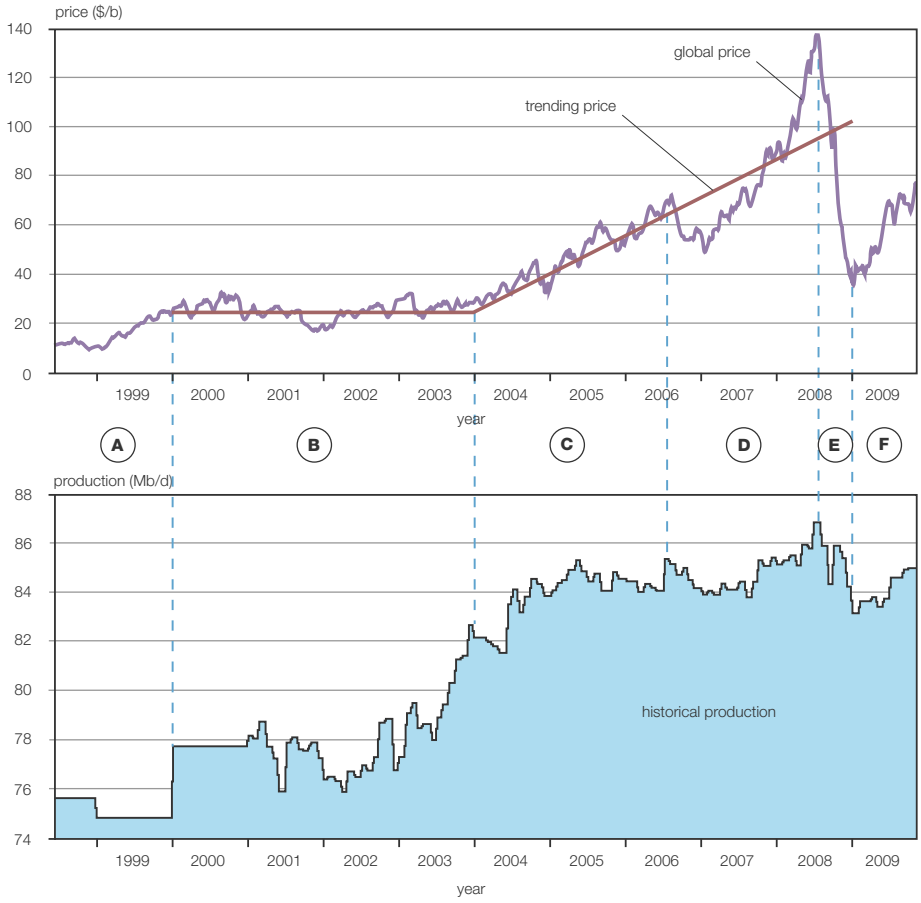

Fig 3.1 Global price and historical production for crude oil in the last decade showing the basic forces acting on the industry since 2000. (Source: EIA production and prices)

A Oil prices recovering steadily from a $10/b low caused by the Asian financial crisis.

B Supply and demand are well balanced. Prices moving in a narrow range around $25/b. Production and price dip in 2001 associated with the shallow dotcom recession.

C Prices start to rise steadily initially producing additional supply but then acting as a rationing mechanism for an essentially flat supply. Rationing trend extrapolated.

D Promises of additional Saudi supply produce price setback, but absence of additional supply produces rapid price escalation to peak in mid-July 2008.

E Prices and production fall as recession and banking crisis develop. Prices fall to marginal cost of highest cost producer -Canadian tar sands - as the OPEC cutback is seen as inadequate.

F Prices rise steadily on announcement of large OPEC production cutback and abating recession, reaching Saudi target price of $75/b in the third quarter 2009.

[1] The 'Seven Sisters' refers to the seven oil companies that dominated oil production, refining, and distribution in the mid 20th century, these being: BP, Chevron, Exxon, Gulf Oil, Mobil, Royal Dutch Shell, Texaco. Later mergers reduced the original seven down to four following formation of ChevronTexaco (including Gulf Oil) and ExxonMobil.

3.2 Impact of the recent recession

In terms of the energy market, the immediate impact of an economic recession is to depress demand, either in a temporary or more sustained way, and for this to be reflected in lower prices. This is exactly what was seen between the third quarter of 2008 and the first quarter of 2009 (**Fig 3.1**, period E). Prices peaked in July 2008 at $147 before falling steadily to a low by the end of December. There was a slow recovery thereafter, largely driven by OPEC's agreement to restrict production and its success after January 2009 in doing so (**Fig 3.1**, period F). Once oil prices were seen to be on an upward trend, and significant financial funds started to invest in oil, both in terms of buying physical cargoes and selling them later at higher prices and in terms of paper transactions on the futures markets (**Fig 3.1**, period F). This self-fulfilling momentum took prices all the way up to the OPEC target price of $75/b in August 2009. Since that date prices have moved in a narrow range awaiting clear evidence of a strong revival in oil demand and reacting to changes in the value of the US dollar but have not to date exceeded $81/b.

Although OPEC announced its first production cutback in September 2008 this was generally seen as inadequate and was followed by a prolonged standoff between OPEC and non-OPEC producers as to who would cut production to balance the market. As a result and in conformity with economic theory, the oil price fell all the way to the marginal cost of the highest cost producer - the Canadian tar sands. More or less at the point when producers would have had to close in tar sands production (because out of pocket expenditures would have exceeded revenues), OPEC made it clear that it was prepared to shut in enough capacity to strengthen oil prices. The formal output cuts announced by OPEC in January 2009 were seen as enough to put oil prices back on a rising trend which then gathered momentum reaching $75/b in August 2009.

Recession also impacts on the supply side making the sanctioning of new oil field investment more difficult particularly if the immediate outlook is for prices to remain relatively low. A low price expectation also renders a number of potential projects uneconomic and subject to cancellation, delay or complete re-budgeting. Again this is exactly what has occurred. It should be noted, however, that with large capital projects such as major oil field developments, it is usually cheaper to complete those already well underway - even if this may have negative consequences for oil prices. Relatively few oil developments due on stream in 2009 and 2010 have been delayed or cancelled but without a strong demand recovery these will add to the current overcapacity and may depress prices or restrain upward price pressures.

The credit crunch, the collapse of oil prices and uncertainty about the length and depth of recession mean that analysis now has to look at the costs of existing and incremental oil production, the availability of resources to be developed and the likely impact of recession and price on the trajectory of oil demand growth.

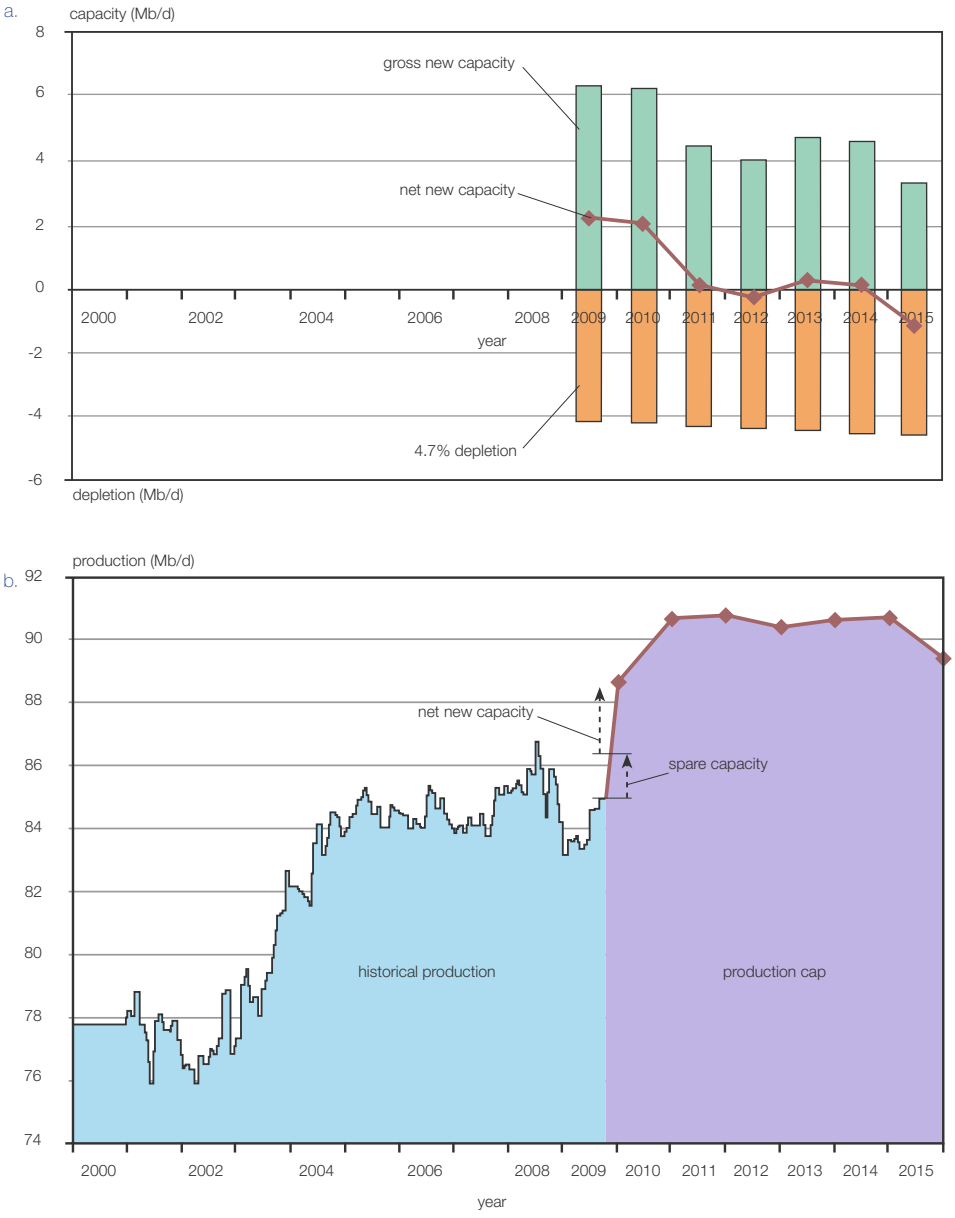

Fig 3.2 Derivation of the maximum future production capacity or "production cap".
(a) Annual values of gross new capacity, as summarised in the megaprojects listing in Table 3.1, together with annual depletion of total current production.
(b) Historical production projected into the future using first the current spare capacity, then each annual value of net new capacity (net of depletion) as shown in (a).

3.3 Supply to 2015 - megaprojects analysis

Increases in oil supply up to six years hence are largely dictated by the long lead times for major projects, so an analysis of these projects gives a calculation of the maximum supply-side capacity high confidence.

Table 3.1 shows all projects with a peak flow of 40,000 b/d or greater in each year - that is, the megaprojects - separating them into OPEC and non-OPEC and listing the gross new capacity. Allowances have been made for the contribution of smaller projects of below 40,000 b/d, operational uptime as well an average project slippage. From these data we see there is a clear bulge in new projects and incremental capacity in 2009 and 2010 and a rather lower level from 2011 to 2013.

A widely accepted assessment of current depletion rates is that it accounts for 4.7 percent of current liquids production. Breaking this down, Peak Oil Consulting puts current depletion rates at 1.5Mb/d and 2.5Mb/d for OPEC and non-OPEC respectively giving a total annual loss of capacity of 4.0Mb/d or 4.7 percent of current total liquids production of 84.5Mb/d.

The final column in **Table 3.1** is net of depletion. In terms of net new capacity, this is overwhelmingly concentrated in 2009 and 2010 with minimal additions thereafter.

Each annual gross new capacity and depletion combine in **Fig. 3.2**(a) to form net new capacity each year which go on to derive the production cap, the limit of production capacity, to 2015 in **Fig 3.2**(b). This shows production as no higher than 92Mb/d. (For a discussion of possible disruptive events to oil production capacity that might reduce this production cap, see Appendix B.)

3.4 Limited discovery and high-cost reserves

One of the many challenges faced by the industry is that discovery rates have over the last decade averaged a little over 30Mb/d while demand has grown steadily reaching nearly 85Mb/d in 2008. This in turn means the world's store of 'discovered and in production' oil is now being run

Year of project completion	OPEC projects completed	Non-OPEC projects completed	Total projects completed	Annual gross new capacity to be brought on stream	Annual net new capacity to be brought on stream
2009	26	24	50	6.2Mb/d	2.2Mb/d
2010	14	25	39	5.7Mb/d	2.1Mb/d
2011	6	17	23	3.2Mb/d	0.2Mb/d
2012	24	18	42	3.4Mb/d	-0.2Mb/d
2013	14	25	39	4.4Mb/d	0.3Mb/d
2014	15	6	21	4.2Mb/d	0.2Mb/d
2015	4	6	10	2.4Mb/d	-1.2Mb/d

Table 3.1 Megaprojects listing of the incremental supply coming on stream in each year for 2009-2015. The gross new capacity figures have been corrected with a delay to account for an unannounced three-month project slippage and 10 percent reduction to account for the typical operational uptime for a project of 90 percent. The net new capacity figures take account of loss to depletion. (Source: Peak Oil Consulting)

down at an annual rate of up to 55Mb/d. (The additions to reserves made when companies revise estimates for discovered fields should be treated with some caution as they extend field life but only rarely expand production capacity.) The world's reserves of both developed and undeveloped oil are large but the challenge of expanding output further is becoming ever harder to meet. If oil prices remain relatively low over the next few years, it will be virtually impossible to sanction investments in high-cost resources, such as deepwater offshore oil, offshore Arctic oil and Canadian tar sands.

Fig 3.1 shows that despite an ever increasing financial incentive in the form of higher oil prices from around May 2005 to mid 2008, there was little or no increase in supply which moved in a narrow range at just over 84Mb/d.

Fig 3.3 shows the oil cost split by the volumes of production capacity. It is possible to divide current global oil production of around 85Mb/d into three tranches. The first comprises production onshore in the Middle East, Russia and China. This has full cycle (investment and production) costs of under $30/b. This is highly profitable and has some, relatively limited, expansion potential over and above the 4Mb/d of spare capacity OPEC currently has. (For an in-depth analysis of spare capacity, see Appendix A.) Low-cost onshore OPEC plus onshore Russia and China currently accounts for around 55Mb/d of global production including the OPEC spare capacity. The large supra-normal profits earned by this group support massive government expenditures. In the case of the Middle East this allows minimal taxation and large education, health and welfare benefits for the population.

The next tranche essentially comprises all other onshore production in the world and the relatively shallow water production from Mexico, the North Sea and other continental shelves. Here fully built-up costs are in the $50-60/b range. Production from this group currently amounts to about 30Mb/d, again with some limited expansion potential.

This means that essentially the world has around 80Mb/d of production capacity and 5Mb/d of spare capacity which is profitable providing prices are above $60/b and even at this price level new investment can be justified.

The real challenge is that the final 5-10Mb/d of global capacity comes from the third tranche high-cost sources - predominantly deepwater developments off the West African coast, in the Gulf of Mexico and offshore Brazil as well as Canadian tar sands. Fully built-up costs at the levels required to justify new investments range from $70/b to $100/b. Some commentators have claimed that in the light of recent price volatility, companies would need to see prices as high as $120/b before sanctioning new investment for these high-cost, multi-billion dollar projects. This is the group that has the largest expansion potential and the group from which most of the incremental production is expected to come from. Existing production is profitable at current prices of around $75/b but incremental investments are hard to justify unless oil prices are in the $100-120/b range.

The challenge is that if oil prices reach the levels necessary to justify these high-cost investments, economic growth may be imperilled. This results from the higher cost of oil and the fact the first production group (OPEC plus onshore Russia and China) is making massive supra-normal profits. Because these extra profits are not readily absorbed, they

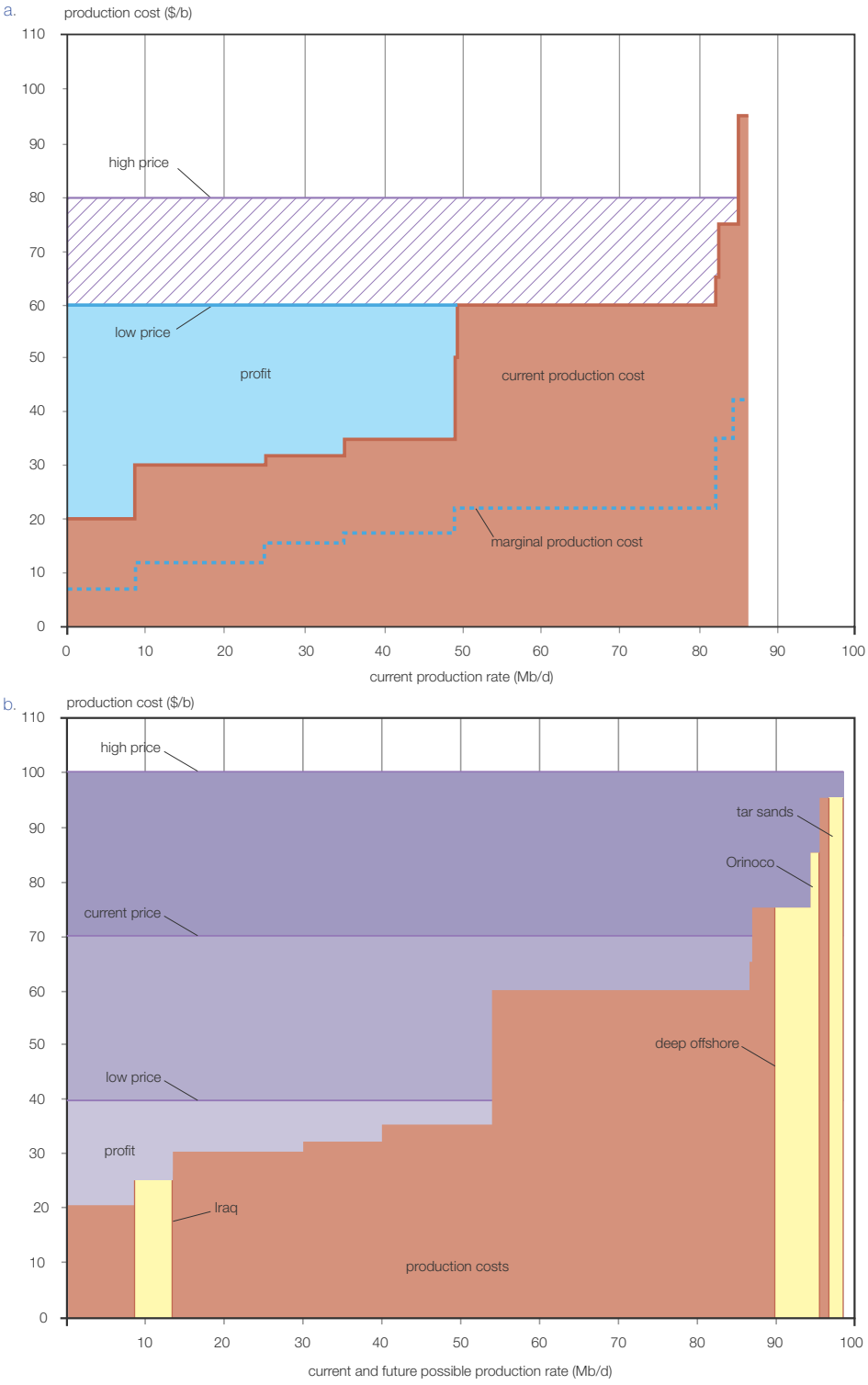

Fig 3.3 Progressively higher production costs ($/b) related to global capacity (Mb/d). (Source: Peak Oil Consulting)
(a) Analysis of current production with a price range, $60-80/b, that allows most production types to be profitable. If the price were to go much lower than $60/b, the marginal production costs show how much production would be viable, though covering only direct costs and operating at a loss.
(b) Addition of possible new production from 2015 with extra investment in: Iraq, deep offshore (Brazil), Orinoco (Venezuela) and tar sands (Canada). Horizontal lines representing low $40, current $70 and high $100 oil prices show both the viability for production from high-cost types as well as the degree of profit from low cost types.

are usually partly remitted to the banking centres of London and New York. This is the classic petrodollar recycling which led to the South American debt crisis in the 1980s and arguably was a key contributor to the financial crisis of 2008.

It therefore appears that there may be real constraints to the widely held idea that shortfalls in oil supply can be met by mobilising high-cost reserves.

3.5 Recent history reconciling static supply and rising demand

Between 2004 and 2008 Chinese demand grew by 1.2Mb/d and Indian demand by 0.3Mb/d. As there was only a very limited expansion of supply in this period, supply and demand had to be reconciled by using high prices to depress demand in the OECD area. Rapid Asian demand growth was met by depressing US, European and Japanese demand by over 1.5Mb/d from 2004 to 2008. The effect was accentuated because much of the rapidly growing Middle East and Asian demand enjoyed subsidised, low oil products prices while OECD countries generally experienced the full rise in oil prices

Another way of understanding what happened between 2004 and 2008 might be to consider the marginal utility or the marginal productivity of an extra barrel of oil. This may be much higher in fast growing but relatively poor non-OECD countries than it is in much richer OECD countries. This would lead to the

apparently non-intuitive conclusion that because additional oil supply brought greater benefits, the developing countries could afford high oil prices more readily than richer developed economies.

The global supply demand behaviour in the 2005-2008 period immediately begs a number of important questions. The first is whether the demand decline in the OECD area will reverse in the face of sustained lower prices and easier supply conditions? Or whether a fundamental change to a declining demand trajectory has occurred? A further key question is whether fuel subsidies are a valid or an invalid policy tool? And if invalid, how could and should countries be dissuaded from their use? Finally and at a more profound level should the richest countries encourage efficiency in use in order to depress their own oil demand in order to free up oil supplies for the rapidly growing developing economies of the non-OECD countries?

While all of these questions really start to apply as we approach the oil crunch or peak, addressing them earlier could make adaptation to peaking oil supplies rather less disruptive to economic activity, growth and employment.

Although there has been some suggestion that the July 2008 production of 87.0Mb/d represents the peak oil output, this report shows that this is unlikely. At a time of depressed demand it is more useful to think of the size of production capacity. It has been shown that this reaches 91-92Mb/d by end 2010/early 2011 and then maintains a plateau capacity in this range until mid-2015. This is when capacity starts to be overwhelmed by depletion and lack of new capacity additions, and consequently declines. The oil crunch or peak occurs when demand reaches 91-92Mb/d or somewhat less if after mid-2015 when capacity is declining.

3.6 Future supply-demand dynamic

The long lead times for major oil developments and the attempt to bring on new supplies quickly led to huge inflation in all oil field costs which doubled between 2005 and 2008. This required ever higher oil prices to justify the ever higher cost of investment. In 2009 costs have eased back a little declining by around 20 percent from the 2008 highs. The general expectation is that prices will soften while few contracts are being awarded but will inflate again once more contracts start to be awarded.

The general assumption had been that there would be smooth transition to higher cost oil supplies and that these higher prices for oil would be acceptable in the end markets. What the events of 2008 brutally demonstrated was that if oil prices move too high too quickly the only economic adaptation is recession.

There is no accepted idea of what oil price is absorbable and what level causes recessions. Recent work done in the US shows that high oil prices and recessions are linked. The work showed that rapid price rises with oil costs reaching 4 percent of US GNP have been associated with every US recession since 1960 apart from the one after the dotcom bubble burst. Association does not prove causality but this close association is highly suggestive. At the moment 4 percent of US GNP would equate to $80/b oil. It also suggests there is an oil price level too high to be afforded without negative economic consequences.

Fig. 3.4 overlays the global production cap derived from the megaprojects analysis above with projections of global demand. Projected demand exceeding the production cap gives an indication of when the price crunch will begin.

The demand projections in **Fig. 3.4** are all from the IEA's Oil Market Reports (OMR) but from different times to illustrate the difficulties inherent in such predictions. The oldest projection shown is from the Medium-Term OMR of July 2008. A year later, the Medium-Term OMR of July 2009 shows the effect of the recession, indicating much reduced demand and cross over with the production cap out to 2015. However since late summer 2009 the IEA has been steadily revising demand projections upwards for 2009 and 2010. It would now appear that, in terms of the impact on oil demand, the recession has been much less severe than earlier anticipated.

In the December 2009 Oil Market Report, the IEA offered two demand scenarios. The first is for annual oil demand growth of 1.4 percent for 2009-2014 which gives an oil crunch in 2014, little changed from the projected date in the ITPOES report

of 2008, or a semi-recessionary growth of just 0.5 percent which postpones the oil crunch to some time after 2015 (see **Fig 3.4**).

3.7 Review of future over four time periods

The foregoing discussion has derived a production cap to 2015 and discussed interaction with demand. This can now be reviewed by considering how both supply and prices might develop over four time periods with reference to **Fig. 3.5** considering also the forces that could alter their impact and duration. Prices are ultimately going to reflect underlying supply/demand balances although speculative pressures or OPEC actions have the ability to move price levels away from fundamentals, sometimes for extended periods.

3.7.1 Low prices during recovery to 2011

The first period is to 2011 when supply is likely to be adequate and prices relatively low. How low will largely depend on how successful OPEC is in both defending prices around the preferred $75/b level and in ensuring they don't rise too far above this level in order to minimise the risk to recovering economic growth.

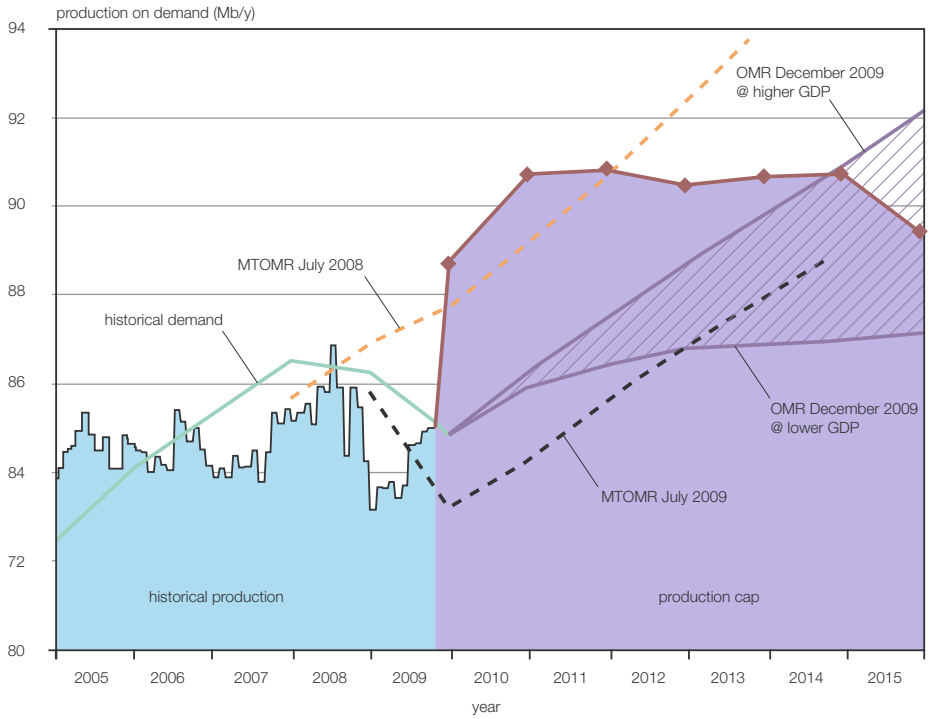

Fig 3.4 Comparing predictions of demand to production capacity, as derived in Fig 3.2, to 2015. The 'oil crunch' occurs at the point when demand matches or exceeds the production cap. The most recent projected demand trend (IEA Oil Market Report December 2009) is given for higher and lower GDP growth outlooks. Older projected demand trends (IEA Medium-Term Oil Market Reports) are shown for July 2009 and July 2008. Also shown are historical production and historical demand.

3.7.2 Supply satisfies economic growth, 2011-2013

The second period is 2011-2013 when economic recovery from the recession should be complete and economic growth re-established around the world. As a result, oil demand would be expected to be growing strongly with prices starting to rise and supply to begin tightening.

For the 2011-2013 period prices are likely to increase as rising demand absorbs the spare capacity overhang. The danger is anticipation by producers leading to excess oil coming onto the market ahead of demand growth and leading to lower prices. The counter pressure will be financial market activity attempting to engender an upward price momentum as supply tightens or appears to tighten. Prices are likely to be higher than in the earlier period in the $70-90/b range but could also be quite volatile.

3.7.3 Tightening oil supplies, 2014-2015

The third time period would be 2014-2015 when the oil market would be starting to experience rapidly rising prices and tightening oil supplies. As these trends establish themselves increasing amounts of money will seek a return invested in oil - in companies, and in oil futures and as physical oil contracts. In effect this could easily become a repetition of what happened in 2008 and is the period in which the oil crunch

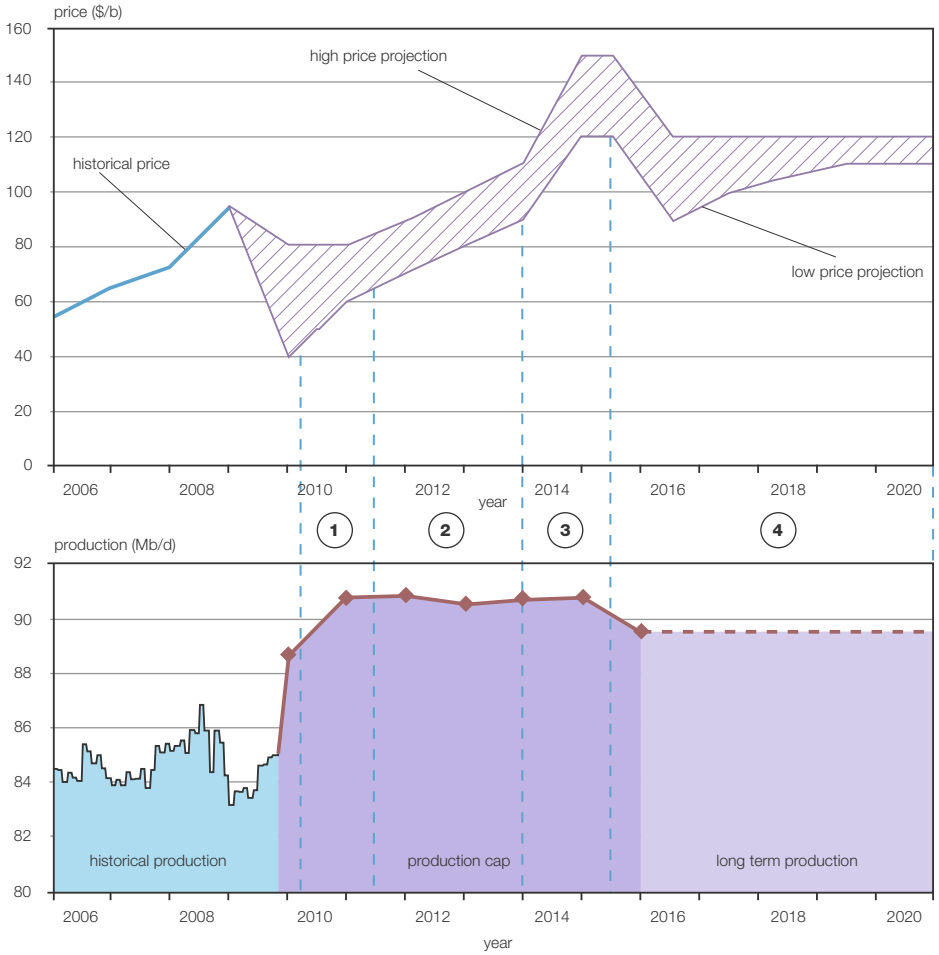

Fig 3.5 Prices and global production projections for the period 2009-2020. Historical data is shown for 2006-2009. The production cap to 2015 is based on megaprojects currently in build, as derived in Fig 3.2. The production projection beyond 2015 is shown as a plateau.

is most likely to occur. It is notable that the CEO of Total, Christophe de Margerie, is already warning of such an outcome in the 2014/15 period.

For the UK, this is exactly the period when the next UK government will be seeking re-election.

In the 2014-2015 period it is expected that demand will start to outrun immediately available supply with prices advancing strongly. All parties will wish to avoid a repetition of 2008. Their ability to do so largely depends on how far the fuel mix has changed and how responsive demand is to rising prices. This means there is potentially a relatively benign outcome in which prices rise above $100 but economies are broadly able to absorb this. There is also the oil crunch outcome in which oil prices are bid up to levels that produce a recession and we get a repetition of 2008-2011.

3.7.4 Recessionary forces with volatile prices from 2015 on

The fourth time period is 2015-2020 when we would expect a repetition of the post-2008 experience - a rapid price fall caused by recessionary forces followed by a price recovery. Unlike 2009-2010 where there is spare OPEC capacity and large volumes of incremental capacity coming on stream, after 2015 depletion will be eroding capacity steadily with only limited new capacity coming on stream. The expectation will be that companies will make heroic efforts to bring on new capacity although it is unlikely that this will be sufficient to fully offset depletion. A possible outcome is an undulating production plateau at around 90Mb/d, as indicated in **Fig. 3.5**.

There is, however, a plausible alternative scenario for this period. Here, adaptation and new technology will have reached the point where declining usage of oil in the OECD area and not-too-rapid non-OECD growth are just enough to reconcile supply and demand at around 90Mb/d even though production capacity is likely to be declining. Oil prices are likely to be fairly high to maintain the pressure to minimise usage. This relatively benign outlook becomes less likely if non-OECD growth proceeds at over 3 percent and OECD growth reappears as this would give overall growth approaching 2 percent per year. (OECD and non-OECD are likely each to take half of global supply by around 2013.)

3.8 Gas - the wild card

There has been much recent discussion of the undoubted development success of US shale gas reserves and the possibility that this success can be repeated around the world allowing a partial transition to gas to offset potential shortfalls in oil supply. This is a development that would also lower the cost of energy as the calorific cost of gas is around half that of oil. The associated possibility is that relatively cheap gas will pressure and reduce oil prices.

Over the last five years aggressive development of unconventional gas reserves has reversed the US gas supply decline and boosted US gas reserves. Most notable has been the Barnett shale in Texas as well as the more conventional 'unconventional gas' reserves such as coal bed methane. Between end 1998 and end 2008, US gas reserves grew by 2.08tn cm or 44.7 percent with most of the increase coming from unconventional gas resources. This in turn has allowed a 7.5 percent increase in production in 2007-2008 alone taking US gas production to a record high. The short-term consequence has been to drive US gas prices down to levels not seen since the start of the decade as winter gas storage filled early and recession hit demand failed to take up the slack. This is likely to rebalance as demand rises and excess stocks clear.

Companies are now scouring the globe to identify and exploit shale gas reserves. In Canada where both gas reserves and gas production have been in sustained decline, since 1996 and 2002 respectively, the discovery of the Horn River shale gas accumulation provides the first hard evidence that Canada may be able to the repeat the US gas turnaround. Potential shale gas reserves have also been identified in Spain and Poland, France and Germany and at least among some companies there are high hopes that significant European shale gas resources will be identified. The rest of the world appears to be on the cusp of a scramble for shale gas.

Already the global gas market is in upheaval thanks to the US shale gas success. In addition the last year has seen a massive increase in liquified natural gas (LNG) supplies with the start up of massive trains in Qatar, Sakhalin, Irian Jaya (Indonesia) and most recently Yemen. 2010 will see even more LNG export capacity coming on stream from Qatar, Peru and Yemen.

In one sense the timing could not be worse as economic recession has hit gas demand globally while US shale gas has already backed out LNG supplies into the US. In 2007 US LNG imports were 21.82bn cm but these fell to 9.94bn cm in 2008 - a 54.4 percent decline which took utilisation of recently expanded US LNG import capacity down to just 8 percent. This diverted LNG supply has increased LNG availability in Asian and European markets which now enjoy LNG costs of around $6-8 mn BTU, roughly a third of the levels paid in early 2008.

It is widely accepted that gas prices in the $6-9 range would allow profitable development of both LNG resources and the unconventional gas reserves such as shale gas and coal bed methane. On a calorific equivalence basis gas at $6-9mn BTU is equivalent to oil prices of $36-54/b. Historically oil has commanded a 20 percent premium to the strict calorific equivalence which would translate to $43.2-64.8/b.

In terms of primary energy supply the proportion of gas in the energy mix varies widely. In the UK gas constitutes 39.9 percent of primary energy a little ahead of oil's 37.2 percent share. Probably the most gas-dependent economy is Russia with a 55.2 percent share for gas. In sharp contrast the two Asian giants - China and India - have minimal gas utilisation with primary energy shares of 3.6 percent and 8.6 percent respectively. Australia despite its abundant gas resources only achieves a 17.9 percent share for gas. Asia's two largest LNG importers - Japan and South Korea - also have a remarkably low gas utilisation in their energy mix at 16.6 percent and 14.9 percent respectively. What this clearly indicates is there is enormous potential for gas to capture market share driven by its economic attraction versus oil and its lower CO_2 emissions versus both oil and coal.

Because gas has the potential to be so disruptive of energy markets it has attracted rather strident advocates and detractors. The advocates claim it as the fuel of the future, pointing out that the world hasn't really been explored for shale gas and other unconventional gas supplies, and that huge volumes are potentially available at prices rather below current oil prices. In addition ever greater quantities of remote or stranded gas can be mobilised as LNG particularly as the new floating LNG technology has the potential to mobilise smaller gas accumulations which to date have been uneconomic but are actually very numerous around the world. They also suggest that greater gas utilisation could reduce dependence on oil imports from OPEC countries and restrict OPEC's and Russia's power. The advocates also suggest that a determined move to utilise gas in transport would both drive the utilisation of gas and reduce the dependence on oil for transport across the world.

The detractors point out that the economics of shale gas are suspect because production falls off between 50 percent and 65 percent in the first year with an economic production limit for each well of 10 years and maybe as little as five years. The counter to this is that even if the decline curves are very sharp and development drilling has to be almost continuous that doesn't mean it is uneconomic, just that it requires a very different approach from conventional gas fields. There have also been water supply and water contamination problems associated with the hydrofraccing that is the key to shale gas development with the detractors seeing this as a fundamental constraint and the advocates as a learning curve problem. Detractors also believe it would be dangerous to depend on a new and not fully proven resource particularly as the quality and producibility varies widely between gas shale formations.

For the large quoted oil companies gas presents a great challenge. Almost all have shale gas and LNG investments but if plentiful gas supply keeps oil prices down they will be unable to develop their high-cost deepwater, Arctic and tar sand reserves. The challenge is whether they can make gas as profitable as oil.

The recent takeover of the largest US independent shale gas producer XTO Energy by ExxonMobil for $31 billion and the buy-ins of shale gas acreage and production from Chesapeake Energy by BP and Total strongly suggest the oil supermajors now see unconventional gas as a growth area for them. Whether the development of unconventional gas supplies is fast enough to have an impact on the oil crunch remains to be seen. It is clear, however, that unconventional gas will be a key incremental energy supply in ameliorating the impact of the oil crunch.

3.9 Conclusion

The recession caused by the credit crunch and the 2008 price spike has delayed the oil crunch by at least two years.

There has been much recent discussion that the undoubted development success of US shale gas reserves and the possibility this success can be repeated around the world allowing a partial transition to gas to offset potential shortfalls in oil supply. This is a development that would also lower the cost of energy as the calorific cost of gas is around half that of oil. The associated possibility is that relatively cheap gas will pressure and reduce oil prices.

The danger is that a period of relatively low oil prices by recent standards may induce complacency and inhibit investment in both adaptive technologies and incremental oil production capacity.

The severity and impact of the oil crunch in terms of economic disruption will be largely determined by the degree to which the period to 2014 is used to plan and adapt to the real threat of restricted oil supplies.

Potentially greater gas utilisation offers an amelioration of the oil supply challenge. It should be remembered however, that fuel supply changeovers take time and investment even when there is a clear economic incentive. Companies will want to see more gas reserves proved up and the attractive price differential maintained before they are prepared to invest in a large-scale move to gas.

4. Opinion B: Dr Robert Falkner

London School of Economics (Department of International Relations)

4.1 Introduction

For the UK, 'peak oil' is no longer a matter of theoretical debate. Ever since oil production in the North Sea started to decline just over a decade ago, the prospect of continuously dwindling petroleum reserves has become part of the country's new economic reality. As the UK is becoming more dependent on energy imports, the parameters of energy policy are shifting. Peak oil has emerged from the fringes of political and economic debate, and security of energy supply has risen to the top of the political agenda. Will the next government face up to this new reality?

4.2 Beyond the peak: the UK experience

Few analysts doubt that the UK passed its regional oil peak in 1999. Annual oil production in the North Sea has since fallen from 137 million tonnes to 72 million tonnes in less than a decade. Responding to this challenge is as much an international as a national issue. As the UK is facing growing dependence on oil imports (it became a net importer of crude oil in 2005), it will have to tackle the growing global supply constraints head on, with an ever smaller cushion of a safe source of domestic oil. Not only will this put pressure on the country's balance of payments, but it will also turn energy policy firmly into a foreign policy concern. As more and more global oil reserves are concentrated in countries that are either unstable or unpalatable, hard choices will have to be made to fill the growing gap in the country's oil trade balance.

Is Britain facing a knock-out blow from peak oil? A future tightening of oil supply conditions is unlikely to produce a sudden and catastrophic effect in the short-term (5 years) to medium term (10 years) term, and the global economic recession has delayed the 'oil crunch' point by at least two years. Still, the short-term consequences, i.e. over the likely lifetime of the next government, are serious enough and will be felt in important sectors of the economy, as well as among some of the poorest parts of society. As the world begins to feel the consequences of tightening supply conditions, the UK may have to deal with a toxic mix of greater oil import dependence, rising yet volatile oil prices, inflationary pressures and the risk of sudden disruptions to the transport system.

4.3 Economic consequences for the UK

Of all the different sectors of the British economy, transport is most exposed to the effects of global supply constraints and price shocks. Despite efforts to promote energy efficiency and the use of alternative fuels, ground and air transport remain stubbornly dependent on petrol, diesel and kerosene. These oil-based liquid fuels simply cannot be substituted in the short to medium term. Biofuels, for example, currently only account for 2.6 percent of the fuel supplied for road transport in the UK (for more details about biofuels, see Appendix C). If anything, current trends in the growth of air travel and

road haulage suggest that future demand growth will more than compensate for any energy-saving or oil-substitution measures. Global supply restrictions and price volatility will therefore pose a growing threat to the UK's transport sector as the global oil crunch hits home.

The vulnerability of the transport sector has important knock-on effects throughout the UK economy. A wide range of businesses, from supermarkets to manufacturers, has come to rely on a highly integrated transport system that delivers goods in a time-sensitive manner. The adoption of so-called 'just-in-time' business models has led to a situation where companies have reduced inventories to minimal levels and intermediate and final goods are delivered at more rapid and frequent rates, be it to producers or consumers. Any disruption to this complex distribution network would have far-reaching economic consequences, as the fuel protests of 2000 vividly illustrate. Back then, supermarkets ran out of essential food products as supplies dried up and consumers resorted to panic-driven hoarding. (For more details about possible disruption to oil supplies, see Appendix B.)

The lesson from this experience is clear. Sudden supply-side shocks generated by oil supply restrictions or hikes in oil prices would not be isolated economic events. They would quickly reverberate throughout the UK's supply chain, affecting many more companies that are not directly dependent on oil. Even if the UK continues to gradually move away from energy-intensive manufacturing, the central importance of oil-dependent transport to the economy will tie its economic fortunes to the future of the 'black gold'.

Vulnerability to oil-related shocks would continue to pose a threat even if oil consumption continues to fall in the UK as it has done in recent years. This is because the downward trend in oil demand masks a structural shift in energy consumption. While electricity generation and heating have been moving away from oil and towards gas, the transport sector is consuming an ever larger share of the UK's oil-based energy demand. Official statistics show that from the time of the first oil shock in 1973 to today, domestic households, industry and services have been able to reduce their reliance on oil products. Not so in the case of transport. Road and air transport's share of oil demand in the UK has been rising steadily, exceeding 50 percent of overall consumption in 2008. Air travel and road haulage are now the key reasons behind our dangerous addiction to oil.

Continued dependence on oil, coupled with a more uncertain global energy environment and fluctuating oil prices, will cost the UK economy dearly. The recent rollercoaster ride of oil prices marks a significant increase in price volatility and is set to continue in the coming years as supply constraints become a more permanent feature of the oil market. While key sectors of the economy remain highly dependent on a secure and stable supply of oil at predictable prices, the return to boom-and-bust cycles in which commodity price rallies give way to periods of economic downturn would significantly increase the costs of doing business in the UK. The uncertainty about future prices will drive up the costs of capital and raise hurdles for investment.

The effects of increased price volatility will be felt throughout society. With ever more consumer products being delivered through oil-dependent and vulnerable transport systems in the retail sector, sudden oil price hikes can feed quickly through the supply chain into higher prices for consumables.

Where food is concerned, the poorest households will be particularly hard hit. They have already felt the pinch of rising energy prices in the last five years, as is evident from the dramatic rise in the numbers of households trapped in fuel poverty. Because oil and gas prices have been closely linked in the past, the recent price rally in the oil market has driven up this number to an estimated 4.6 million in 2009. The Office of Gas and Electricity Markets (Ofgem), the

government's energy regulator, warns that domestic energy bills may rise by up to 25 percent by 2020 due to rising commodity prices with up to £200 billion needed for energy infrastructure investment.

The current glut in global gas markets and a widely predicted de-coupling of gas and oil prices should mitigate against further dramatic increases in domestic fuel costs. This would offer a welcome reprieve to the most hard-pressed households in the UK. Nevertheless, a rise in living costs - in the form of higher travel and transport costs and consumer prices - is firmly on the agenda.

Are we likely to see a re-run of the 1970s scenario, when two OPEC-induced oil shocks drove up the oil price and double-digit inflation rates ensued in many industrialised countries? To some extent, circumstances are more favourable today. The monetary policy environment has changed and is likely to keep inflationary expectations lower than they were in the 1970s and 1980s, and the UK economy's overall oil intensity has declined.

But the experience of the most recent hike in oil prices nevertheless offers a sobering lesson. Rising oil and food prices pushed up consumer prices well above the Bank of England's 2 percent inflation target to a peak of 5.2 percent in September 2008. While this inflationary push was comparatively lower than in past decades, a sustained rise in oil prices over the next five to ten years will eventually feed through into higher price levels overall. Economic recovery after the recession and a decline in the current output gap will soon return the UK economy to a situation where sudden and persistent oil price rises require monetary authorities to apply a bitter medicine, with a further economic downturn and rising unemployment in tow.

4.4 UK energy policy: ready for the coming oil crunch?

The once fashionable view that energy is just another commodity that is subject only to the forces of the free market no longer holds. Securing energy supply and managing energy demand have become eminently political questions again as countries race to secure their future energy needs. The rise of resource nationalism in the world's leading oil-producing regions, combined with the geological constraints of an ultimately limited petroleum base, is redefining the global politics of energy. Total oil consumption may be levelling off or declining in the leading industrialised countries; but this partial easing on the demand side will be more than compensated for by the growing energy consumption in the BRIC countries (Brazil, Russia, India and China) and other populous and energy-hungry emerging economies. If anything, an oil peak will only accelerate the dramatic reconfiguration of the global energy order that has been underway for the last decade.

Critics of the 'peak oil' scenario often point out that, while plentiful reserves await further exploitation, global demand for oil has recently reached its own peak. This is only partially true. Oil demand in the industrialised countries has levelled off in most, and has been falling in some, of the leading Western economies. But while these countries have achieved a partial de-coupling of economic growth and oil demand, the two remain closely linked in the developing world.

Economic analysis suggests that developing country growth translates into an equivalent increase in oil demand of between 70 and 100 percent (compared to 40 to 50 percent in industrialised countries). In fact, the sharp rise in demand for oil in China, India and other emerging economies has been a critical factor behind the oil price rise since 2000. As their economies pick up speed again after the global recession, their economic growth will again drive up oil demand worldwide. The IEA's World Energy Outlook expects 80 percent of the world's increase in demand for liquid fuels to come from the nations of non-OECD Asia and Middle East, with the transportation sector accounting for 80 percent of this increase. The new economic powerhouses of the South will thus be the main drivers of global oil demand in the foreseeable future.

The explosive mixture of upward demand pressure, restrained investment in oil production and geopolitical risks is set to cause instability in the global oil market. Short-term price inelasticity ensures that even small supply shocks result in a large rise of oil prices. Demand is known to be price inelastic because of the inability, particularly of the transport sector, to replace oil-based liquid fuels in the short run. Likewise, supply is inelastic as it takes many years for an increase in the price of oil to feed into higher investment in production capacity and an eventual increase in output. The two forms of price inelasticity combined create a powerful multiplier effect in the global oil market, which economists estimate to be in the region of factor ten.

In other words, a physical supply shock (as happened in Iraq, Venezuela and Nigeria prior to the 2008 price hike) would cause a price rise about ten times as large in the short run as would normally happen if demand and supply were elastic. Small shocks will thus have ever larger price effects as the world edges closer to its 'peak oil' point.

The politicisation of energy is evident not least in the change in tone in recent government pronouncements on this topic. The UK Energy Review of 2006 and White Paper of 2007 established security of supply alongside climate change as the main challenge for future energy policy. This recognition is clearly good news.

However, while energy security may have risen on the political agenda, the government has remained upbeat about the future of global oil reserves despite the growing signs of a looming supply-side oil crunch. In the latest government-commissioned review of energy security, former energy minister Malcolm Wicks MP acknowledges peak oil but merely states that oil production "has already peaked in most non-OPEC countries and will peak in most others before 2030". Government policy is starting to change, but still has a long way to go to acknowledge the urgency of taking action now.

4.5 Climate change policy: help or hindrance?

Could the threat of climate change help bring about a speedier change in UK energy policy? Or will the focus on reducing greenhouse gas emissions further complicate the search for a solution to the looming peak oil problem?

Climate change policy is driving investment in renewable energy sources and energy efficiency measures. Weaning companies and households off their oil dependence will thus have positive effects on energy security. But there are important conflicts between these two objectives that cannot be ignored. In the medium term, the need to reduce greenhouse gas emissions will limit the options available in dealing with the effects of peak oil. Replacing dwindling reserves of conventional oil with more expensive and carbon-intensive alternative fuels (e.g. tar sands and coal-to-liquids) will be an environmentally damaging course. And banking on renewable resources (e.g. biofuels) alone simply won't provide an adequate solution. (For more details on biofuels, see Appendix C.)

Even if the government's target to derive 15 percent of energy from renewable sources by 2020 is met, an estimated 70 percent of energy will still be supplied by oil and gas at that time. A much more rapid transition to low-carbon energy sources - whether wind, solar or nuclear - would thus have to be achieved if the UK is to respond more effectively to the twin threats of global warming and peak oil.

What is to be done? As a first step, the next government will need to acknowledge that the era of cheap oil is over. This will need to be followed by rapid decisions on how to ease potential energy supply constraints and accelerate the transition to low-carbon alternatives. On this, governmental rhetoric has been admirable so far, but not implementation.

No silver bullet exists; instead a multitude of approaches will need to be pursued. Investment in current oil production capacity will have to increase to keep the lights on while renewable energy sources are brought online. But the latter will not happen unless more innovative and decisive steps are taken to drive up energy efficiency and develop low-carbon technologies. Will the next government have the mettle to take tough, and early, decisions?

5. Other points of view

2009 has seen release of a number of reports, either specifically on peak oil or covering important aspects of world or UK energy. Some argue all is OK while others agree with the Taskforce outlook.

This section summarises the main publications in chronological order.

5.1 Wicks' Review

On 5 August 2009, the government published a review of the UK's energy security situation called *"Energy Security: A national challenge in a changing world"*. The report was specifically commissioned by the UK Prime Minister, Gordon Brown, of Malcolm Wicks, a former energy minister.

Wicks focuses on the changing UK and global energy picture, pointing out that even with ambitious climate change targets, the world is still likely to be reliant on coal, oil and gas to meet over two-thirds of its energy needs by 2030.

On the specific subject of peak oil, Wicks notes, "Few authors advocating an imminent peak take account of factors such as the role of prices in stimulating exploration, investment, technological development and changes in consumer behaviour." (This observation cannot be levelled at the Taskforce where our Report 1 in 2008 examined all these aspects extensively and rigorously.) He goes on to comment, "proven reserves are equal to over 40 years of current production". The sum of Wicks' recommendations specific to oil imports are: "to improve transparency in the oil market, support short-term efforts to facilitate production in states capable of increasing production levels, and reduce our reliance upon oil in the longer-term."

5.2 Macquarie Bank report

Macquarie Group Limited is the pre-eminent Australian investment bank and has its global headquarters located in Sydney.

Their research report of 16 September 2009, *"The Big Oil Picture: We're not running out, but that doesn't mean we'll have enough"*, sees global oil production capacity topping out at 89.6Mb/d this year, a far more pessimistic view than most other banks or traditional forecasters. Iain Reid, Macquarie's head of European oil and gas, who worked for 16 years at Shell and Amerada Hess, says in the report that, "Capacity has pretty much peaked in the sense that declines equal new resources."

He expects the current spare-capacity cushion of around 5.2 million barrels to be wiped out by 2012 and global production capacity to fall to 87.3Mb/d by 2015. Global oil demand is expected to rise to 90.9Mb/d by 2015 from 84.2Mb/d today. He adds that, "Adding sufficient productive capacity on time is nearly impossible."

5.3 IHS Herold study

IHS Herold is a leading, independent research firm serving a global client base with analysis of companies, transactions, and trends in the global energy industry.

In their *"The 2009 Global Upstream Performance Review"* published 23 September they note that investment in finding new oil is falling this year. Exploration spending by listed oil companies rose 21 percent and development spending 23 percent in 2008, but the average cost of replacing a barrel of oil equivalent rose 70 percent to $23.44/b. Total reserves fell 3 percent, including a 5.2 billion barrel decline. Despite record development spending, up 23 percent from 2007, worldwide oil and gas finding and development replacement rates fell in 2008 to 88 percent of production, the first year since 2004 in which production was not replaced.

5.4 UKERC report

The UK Energy Research Centre (UKERC) is the focal point for UK research on sustainable energy. It acts as a bridge between the UK energy research community and the wider world, and is the centrepiece of the Research Councils' Energy Programme.

Its most recent major research report *"Global Oil Depletion"* launched on 7 October 2009 concludes that there is "a significant risk of a peak before 2020." It notes:

"….Although there are around 70,000 oil fields in the world, approximately 25 fields account for one quarter of the global production of crude oil, 100 fields account for half of production and up to 500 fields account for two thirds of cumulative discoveries. ….The average rate of decline from fields that are past their peak of production is at least 6.5 percent per year globally, while the corresponding rate of decline from all currently-producing fields is at least 4 percent per year. This implies that approximately 3Mb/d of new capacity must be added each year, simply to maintain production at current levels - equivalent to a new Saudi Arabia coming on stream every three years. ….More than two thirds of current crude oil production capacity may need to be replaced by 2030, simply to prevent production from falling. At best, this is likely to prove extremely challenging. ….

"….For a wide range of assumptions about the global URR [ultimately recoverable reserves] of conventional oil and the shape of the future production cycle, the date of peak production can be estimated to lie between 2009 and 2031. Although this range appears wide in the light of forecasts of an imminent peak, it may be a relatively narrow window in terms of the lead time to develop substitute fuels."

5.5 Ofgem report

The Office of Gas and Electricity Markets (Ofgem) is the government regulator for the electricity and downstream natural gas markets in Great Britain. It was formed by the merger of the Office of Electricity Regulation (OFFER) and Office of Gas Supply (Ofgas), themselves formed when gas and electricity was privatised in the 1980s. Its primary duty is to protect consumers by promoting competition, wherever appropriate, and regulating the monopoly companies which run the gas and electricity networks.

Ofgem is undertaking a comprehensive review of Britain's energy supplies, called *"Project Discovery"*. 9 October 2009 saw publication of their initial report outlining challenges for Britain's energy industry over the next 10 -15 years. It drew up four energy scenarios to assess the energy security risks noting volatile world energy prices and Britain's increasing dependence on gas imports.

The report implies that real increases of up to 25 percent in energy bills are likely due to rising commodity prices and up to £200 billion investment in energy infrastructure by 2020.
It suggests that the additional costs projected for electricity consumers by 2020 are least in the two "green" scenarios presented as opposed to the higher energy bill costs projected for the "slow growth" and "dash for energy" scenarios.

The two "green" scenarios both assume 30 percent renewable electricity by 2020, including feed-in tariffs for sub-5MW renewables set to attract investors, while the "slow growth" and "dash for energy" scenarios both assume only 15 percent renewable electricity by 2020.

5.6 ASPO annual conference

The Association for the Study of Peak Oil (ASPO) is a global network of scientists and others, having an interest in determining the date and impact of the peak and decline of the world's production of oil and gas, due to resource constraints.

The association's international conference for 2009 was held in October in Denver, CO, USA. Analyst Chris Nelder compares the results of this conference with the first of this series in 2005: "We now know that conventional crude did in fact hit its peak-plateau in 2005, having remained around the 74Mb/d level ever since. The expected growth from non-OPEC mostly failed to materialize, as depletion of mature fields took its toll and the cost of new projects soared—especially for deepwater and production from marginal sources. More pessimistic observers now think the 87Mb/d all-liquids peak recorded at the height of the 2008 boom was the peak, and the more optimistic ones have cut their expectations to under 100Mb/d, with 90Mb/d looking more likely. ….. Most observers believe the globally averaged depletion rate has risen from 4.5 percent per year in 2007 to about 5.0 - 5.5 percent now, which will accelerate to around 6.5 percent per year by 2014. This is more or less in line with the average rates from IEA's report last year."

5.7 Global Witness report

Global Witness is an international NGO established in 1993, now based in London and Washington, that works through investigations and campaigns to break the links between natural resource exploitation, conflict, poverty, corruption, and human rights abuses worldwide. It has become a leading authority on identifying and addressing issues concerning how the unaccountable exploitation of natural resources has driven human suffering.

Their report published on 20 October 2009 argues that governments have failed to acknowledge a looming oil supply crunch. The report outlines four underlying oil production factors: declining output, declining discoveries, increasing demand and insufficient projects in the pipeline

These they state clearly show how the world is facing an imminent oil supply crunch. Some of these factors have been apparent for many years. Thus the report concludes that the collective failure by governments means we have lost a decade in which action could have been taken.

5.8 IEA's World Energy Outlook 2009

The International Energy Agency (IEA) is an intergovernmental organisation based in Paris which acts as energy policy advisor to 28 member countries in their effort to ensure reliable, affordable and clean energy for their citizens. Founded during the oil crisis of 1973-74, the IEA's initial role was to co-ordinate measures in times of oil supply emergencies. As energy markets have changed, its mandate has broadened to incorporate the "Three E's" of balanced energy policy making, these being: energy security, economic development and environmental protection.

The IEA's annual "*World Energy Outlook for 2009"* was released on 10 November. It provides updated projections that take into account the implications of the global credit crisis, the economic slowdown and the recent slump in the prices of oil and other forms of energy. The Outlook notes that "global energy use is set to fall in 2009 - for the first time since 1981 on any significant scale - as a result of the financial and economic crisis; but, on current policies, it would quickly resume its long-term upward trend once economic recovery is underway." In their Reference Scenario, world primary energy demand is projected to increase by 1.5 percent per year between 2007 and 2030. Oil demand is projected to grow by 1 percent per year on average over the projection period, from 85Mb/d in 2008 to 105Mb/d in 2030, and oil prices are assumed to rebound with the economic recovery to reach $100/b by 2020 and $115/b by 2030 (in year-2008 dollars).

Whilst this is all about demand, there is little analysis in the Outlook on capacity to meet this demand apart from noting "energy investment worldwide has plunged over the past year" and that "energy companies are drilling fewer oil and gas wells". Simply noting that the investment needed is a significant proportion of GDP implies this is the only limitation.

Release of the Outlook was preceded by controversy. *The Guardian* newspaper reported from an un-named senior IEA official that the decline of existing reserves is being underplayed, and the prospects of finding more overplayed, in order to stop panic buying. Their source claims, "Many inside the organisation believe that maintaining oil supplies at even 90 to 95Mb/d would be impossible but there are fears that panic could spread on the financial markets if the figures were brought down further. And the Americans fear the end of oil supremacy because it would threaten their power over access to oil resources."

5.9 IHS CERA report

Cambridge Energy Research Associates, also known as CERA, is an international consulting company headquartered in Massachusetts, USA, that specialises in advising governments and private companies on energy markets, geopolitics, industry trends, and strategy. CERA has research and consulting staff across the globe and covers the oil, gas, power, and coal markets worldwide. The company was formed in 1983 and acquired by IHS Energy in 2004.

CERA's latest report *"The Future of Global Oil Supply: Understanding the Building Blocks"* published on 17 November sees no oil peak through 2030 thanks to technology. The report's lead author, Peter Jackson, comments: "It would be easy to interpret the market and oil price trends from 2003 through 2009 in isolation to support the belief that a peak in global supply has passed or is imminent. But this only illustrates that the market continues to act as the shock absorber of major volatility." Beyond 115Mb/d at 2030, the report says, production will stay on an undulating plateau through 2050. Of more than 1,000 fields examined in detail for the study, 60 percent were found to have production levels that were either steady or climbing. While they estimate decline rate of all fields currently in production to be 4.5 percent, Jackson notes, "Supply evolution through 2030 is not a question of resource availability. The crucial issue lies not belowground. It is the aboveground factors that will dictate the ultimate shape of the supply curve."

Clearly this report is considerably more bullish than the IEA's WEO 2009 earlier in the month. CERA regards all limiting factors to their reference scenario as being above ground rather than below, although they allow themselves an extremely broad set of 'aboveground driver' caveats to explain any degree of variance in the future.

6. Taskforce view

6.1 Since last year

Clearly, a lot has happened since the first ITPOES Report was published in 2008. Much of this has already been remarked upon in Sections 3 and 4, and requires no further elaboration here. The reports issued by others (summarised in Section 5) underline the growing interest in the peak oil proposition, and several of those publications support the general thrust of the ITPOES argument. However, it remains the case that UK Government policies and attitudes are dismissive of these possibilities.

Of all the reports mentioned in the previous section, the Wicks Review is notable because it gives an insight into government thinking. Peak oil is mentioned only once. The relevant passage concludes: "Few authors advocating an imminent peak take account of factors such as the role of prices in stimulating exploration, investment, technological development and changes in consumer behaviour."

The Taskforce report of 2008 ignored none of these factors. Prices do stimulate exploration but - we argued - not quickly enough. We discussed the intervals between oil discoveries and bringing capacity to the market. We discussed investment, and concluded that there have been dangerous shortfalls even when prices have been high. We discussed technological developments, such as enhanced oil recovery, and concluded that they tend only to slow depletion rates. We discussed changes in consumer behaviour and worried that they will not be sufficient, especially in India and China, to shrink the growth in global demand and keep it in line with supply.

Very little of substance has occurred in the intervening year between the first and second ITPOES reports to change our concerns. There is, therefore, a fundamental difference between the ITPOES members and the government's advisor (Wicks). The following analysis seeks to explain the Taskforce's position.

6.2 Taskforce analysis

In this section, we interpret the opinions offered in Sections 3 and 4, and respond from the perspectives of the Taskforce members.

Oil is a key commodity within the UK economy, and business activity is affected by large swings in the oil price and oil availability. The consequence of the very high oil prices, and the shortages of supply, in the 70s and 80s was that the national economy fell into recession on both occasions (**Fig 6.1**). The implication from our research is that high and volatile oil prices, coupled with supply uncertainties, are likely to become a characteristic of future world oil markets.

Today, the aftermath of the financial crisis has already kicked the national economy into one of the severest recessions on record. Oil price uncertainties over the coming few years could make economic recovery for the UK particularly difficult.

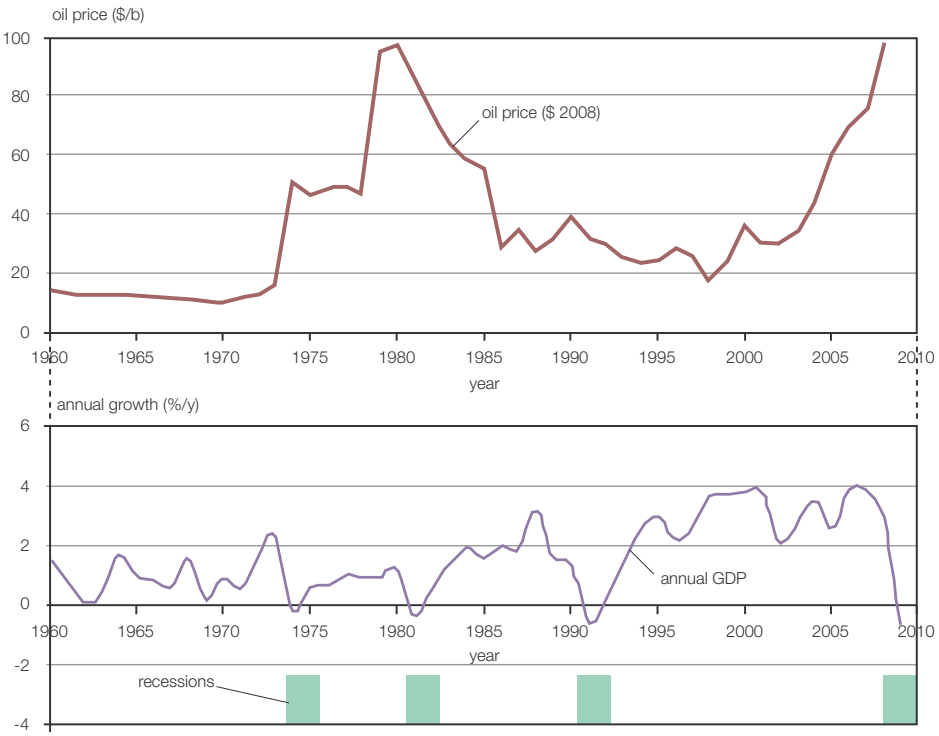

Fig 6.1 UK annual GDP growth and oil price from 1960 to the present with periods of recession marked by shading. (Sources: ONS and BP Statistical Review)

6.3 Where will oil prices go in the next few years?

The heady peaks of oil price in 2008 deflated very rapidly a year ago with the onset of the recession, and prices sank from a peak of nearly $150/b to a figure below $40/b. An oil price collapse is what we might expect in a recession (although this one was pretty dramatic), but prices have subsequently bounced back more quickly than we might have expected. With today's prices firmly lodged around $80/b, oil is again at very high prices by historical standards, even though the world is still struggling with recessionary forces. This is unusual, and very few pundits predicted it 12 months ago. So, we are already in unusual territory.

The future movement in oil prices will depend, in particular, on demand from the non-OECD countries (as argued in Section 2). These are dominated by the BRIC countries whose recent growth compared to the G7 economies, shown in **Fig 6.2**, suggests that the picture of growing world demand, fuelled by the growth of the non-OECD nations, seems to be being developing without serious interruption from the financial crisis. Coupling GDP projections to oil demand leads to the conclusion that demand could soon be back beyond the 86.4Mb/d seen in the first half of 2008. Unless extraction rates can be lifted to meet this level of demand before it becomes a reality (unlikely, as previously argued), the general level of prices should be expected to rise again quite soon - certainly within the lifetime of the next government.

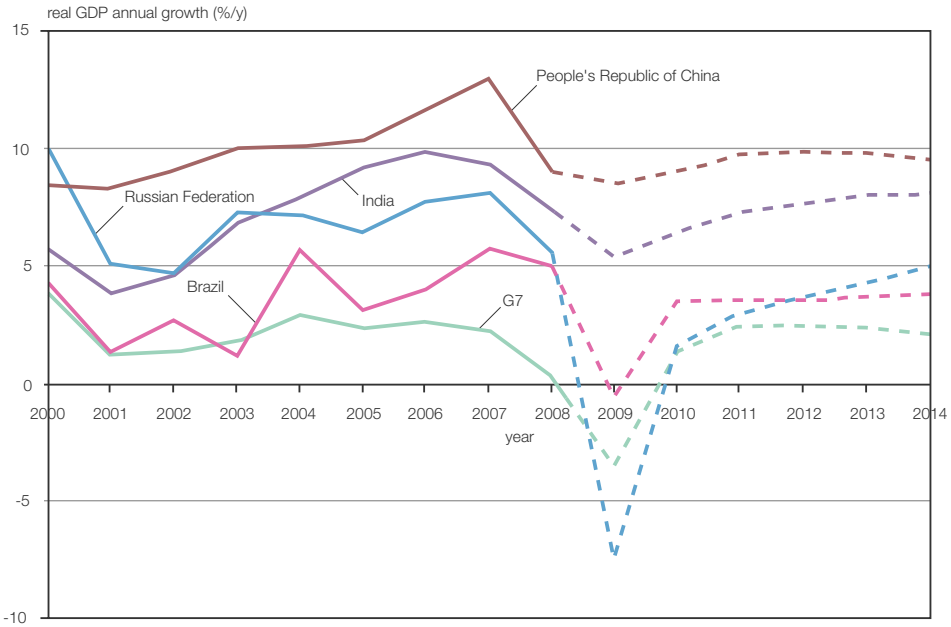

Fig 6.2 Actual real annual GDP growth of the BRIC and the G7 group of developed economies for 2000-2008 and with estimates and projections to 2010. (Source: IMF)

Some may say that the recent recovery in oil prices has been encouraged by OPEC's decision to reduce flows (a move that was designed to achieve precisely that goal). It is argued that, once demand recovers, flows will be increased again and price increases will be ameliorated. But this argument misses a crucial point. Once world demand returns to pre-crisis levels (around 87Mb/d), it will be the inability to extract faster that will cause the problem, not an absolute lack of oil. Extracting oil faster will require new fields to be brought on stream, and this is where the problem really lies.

On a positive note, there has been some very good news in the past year with regards to new production. The pre-salt finds in the Gulf of Mexico and offshore Brazil are significant, indicating the continued ability of the industry to find new sources of oil. The potential return of Iraqi oil to the world markets is also very significant. In the long-run these two sources, alone, could add more than another 10-15Mb/d to global capacity, but this is unlikely to materialise very quickly.

However, the problem with both these sources is time: the pre-salt oil is difficult to access and will take 5-7 years to bring into full production. Even then, the oil will be expensive, as suggested in **Fig 2.4** for deep offshore, so it is unlikely to make an appearance at less than $80/b, as shown in **Fig 3.3**(b). And the political uncertainties in Iraq will inevitably slow down developments in that country - as witnessed by the complex manoeuvrings in the recent rounds of negotiations between the Iraqi authorities and the bidders for their development contracts. So, significantly increased flows at low prices from either of these new

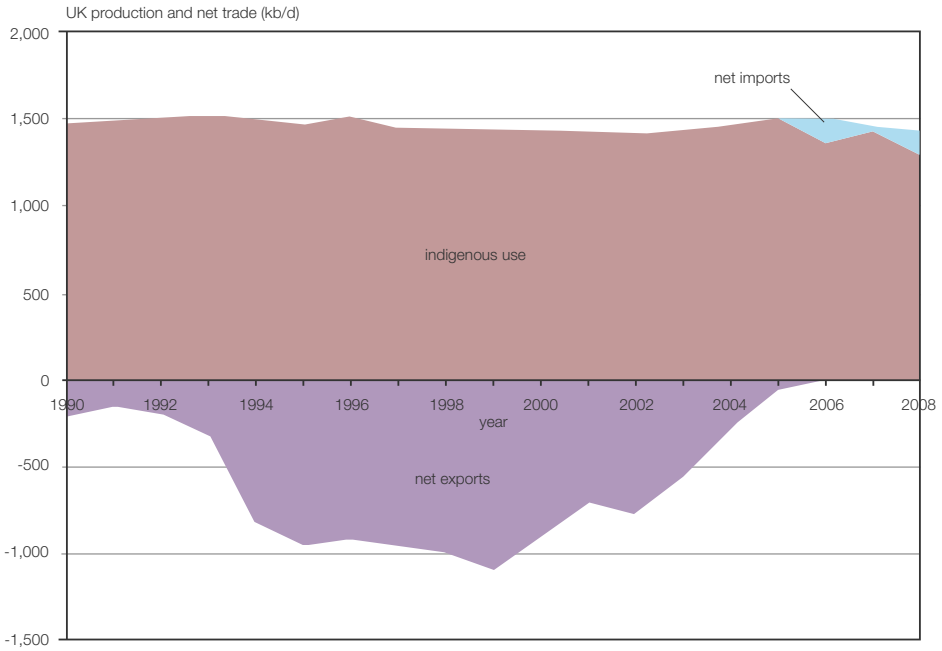

Fig 6.3 The import and export of oil from the UK. (Source: DUKES)

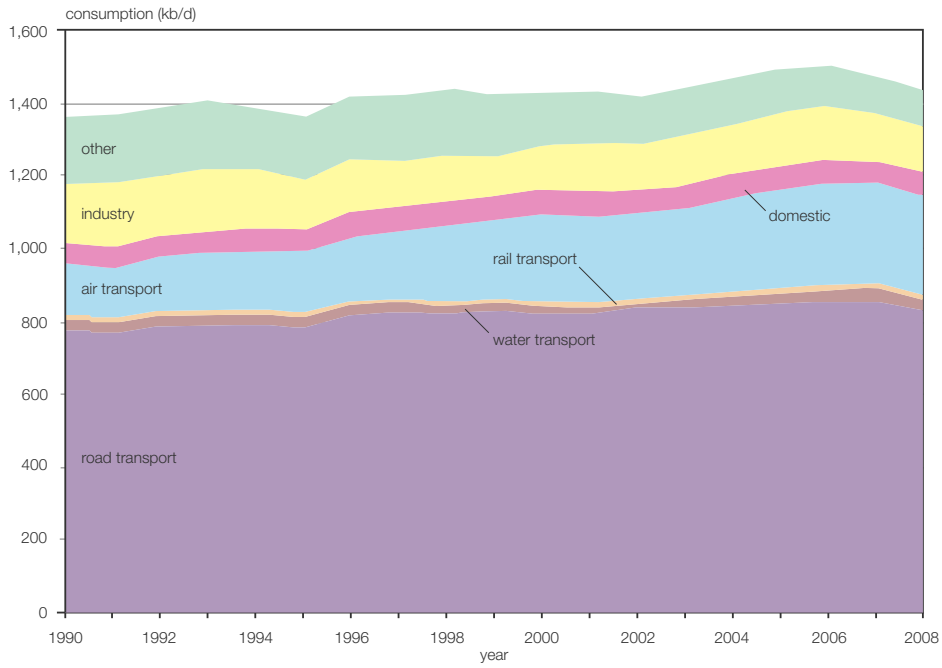

Fig 6.4 UK consumption of oil by sector. ("air transport" covers total inland deliveries in the UK to international and other airlines, British and foreign Governments including armed services, and for private flying.) (Source: DUKES)

sources seem very unlikely to occur within the next few years.

When these sources do eventually come on stream, it will be a question of whether the depletion of existing wells will have reduced flow-rates at that stage by more than the increase from the incremental finds. The expert Opinion A offered in Section 3 concludes that this will, indeed, be the case. According to this analysis, peak extraction capacity will be reached within the next few years (if it hasn't already been reached). Against the background of rising world (non-OECD) demand, this can only mean that oil prices will rise well beyond current levels, and remain high until extraction rates can be increased to meet these rising levels of demand.

So, the 'crunch' is most likely upon us. Massive, easily accessible, new finds could restore the medium-long term outlook (5-10 years), but there is little that can be seen that will prevent the short-term problem other than the continued contraction of demand in the OECD nations and an immediate flattening of demand in the non-OECD countries.

This combination may allow prices to ease in the immediate future (2-3 years), but the long-term trend of growth in demand from the non-OECD countries looks set to overtake this temporary decline comfortably within the next five years. In the longer term, the IEA's prediction is that global demand will reach 105Mb/d by 2030 (a figure that is well beyond our current expectations of the world's ability to deliver). However, in our view, this figure could easily be exceeded. A few simple calculations serve to underline this suggestion.

The current global split of oil usage is shown in **Fig 2.6**. We can make some simple predictions for the likely rise in demand within each of the main categories of use, as follows.

Ground transportation

It is projected that the number of vehicles in the world will triple to around two billion vehicles by 2050. If we postulate that oil demand will rise in a manner that reflects this growth (but make some allowances for improving fuel efficiency and the introduction of electric vehicles), simple calculations suggest that world oil demand for ground transportation will be cruising towards 100Mb/d by 2050.

'Other uses'

We could postulate that the demand for all other uses (for example, heating, petrochemical feedstocks and hydrocarbon-based materials) will rise in proportion to the rising standard of living associated with the world's urban population. Around 750 million people in the OECD countries consume the vast majority of today's 'other uses' (most of them in the urban context), and this yields a consumption rate of around 35Mb/d per billion urban-dwellers.

It is reckoned that around 7 billion people will live in cities by 2050. Let us now postulate that the demand from the OECD urban populations will stabilise, and that the demand from the non-OECD urban populations will head towards 25 percent of the comparable OECD figure (i.e. about 9Mb/d per billion urban dwellers). This suggests that oil demand under this heading could rise to around 80Mb/d by 2050.

Adding these components together suggests that world demand in 2050 could be in the region of 180Mb/d.

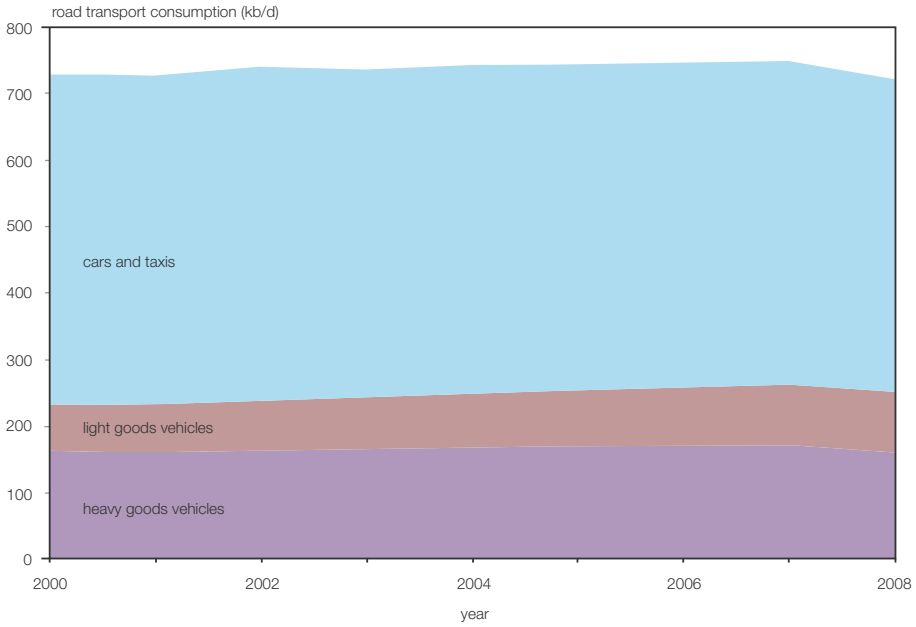

Fig 6.5 Breakdown of transport usage. (Source: DUKES)

Working backwards from this, we might expect demand levels to exceed 120Mb/d by 2030, a figure which is comfortably in excess of the IEA's latest projection of 105Mb/d (the 'Reference' scenario).

These estimates, of course, assume a fairly rapid rate of growth for the developing world. But the economic growth records for some of the non-OECD countries (particularly the BRIC countries) over the past decade, as shown in **Fig. 6.2**, suggest that sustained high rates of growth in the developing nations must be noted and included.

The potential mismatch between world oil supply and demand is shown in **Fig 6.6**. This diagram shows the ITPOES postulation to 2050, alongside the IEA projection to 2030. It also shows the corresponding ITPOES and IEA supply curve predictions. It is clear that there is no realistic vision of future oil production that will meet the expected levels of demand at anywhere near historic oil prices. Short of a series of super-giant, easily accessible finds in the next few years, it looks like we are headed for a sharp and permanent increase in oil prices. Market prices well in excess of $100/b (maybe $150/b), plus inflation, should be anticipated within the next decade.

For the UK, at least, this could represent a structural change in the shape of our economy. The only medium-term restorative possibility is that aggregated world demand will continue to drop - but this requires such a sharp reduction in growth amongst the non-OECD nations that it seems a very unlikely scenario. And, if it does happen, the world will be plunged into even deeper recession. So this is not something we should wish for!

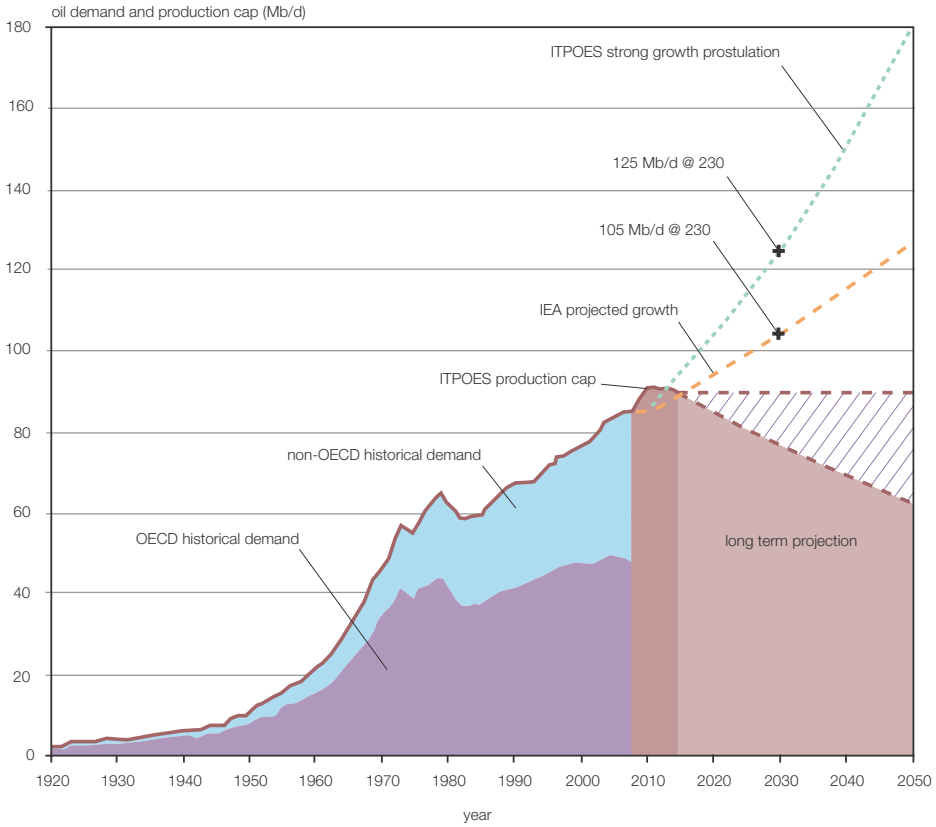

Fig 6.6 Oil demand for the historical period 1920-2008, with extrapolations to 2050 for the IEA 'Reference Case' (1% growth rate) and the ITPOES 'strong growth' case as described in the text. Also shown are two projections for production: a plateau (based on Shell's paper in the first ITPOES Oil Crunch Report, 2008), and the ITPOES production cap (Section 3) followed by a 1 percent per annum net depletion rate. (Sources: BP Statistical Review of World Energy and the IEA's World Energy Outlook 2009)

6.4 Consequences of a high oil price for the UK

The possible shock to the UK economy of higher oil prices must be set in context. On the one hand, the national consumption picture is much better now than it was in the 70s and 80s. Oil is no longer used as a significant source of electricity generation; it was replaced in this role by coal, nuclear, and gas during the early 80s, precisely because of the oil price spikes and availability uncertainties which dominated that era. This is good news.

However, on the other hand, the national supply picture is much worse. North Sea oil was just coming on stream in the late 70s, and this turned the UK into an oil exporter for the next 25 years. That era has now come to an end and the UK is, once again, a net importer of oil (**Fig 6.3**). The reversion to importing oil, and the spike in world prices, represents an unpleasant 'double whammy' for the UK economy.

Today within the UK, despite the focus on renewables and alternative fuels, oil still turns the wheels of the transport sector (**Fig 6.4**). Furthermore 97 percent of transport energy consumption is from petroleum products. In addition to cars, public transport operators depend on diesel to run their bus and coach networks and many of their rail services.

However, the role of transport in the economy has mushroomed. People travel for business, social, domestic and pleasure purposes, and the sustained level of oil consumption associated with transport since 2000, despite improvements in engine efficiency, is shown in **Fig 6.5** (which also sub-divides small and large vehicles).

The freight component of light and heavy goods vehicles, though smaller than cars and taxis, must not be ignored. Manufacturing and retail businesses widely depend on just-in-time business models, and transport is fundamental to this approach (as has been remarked in Section 4). This means that the prices of most goods on the retail shelves have a significant transport component in their build-up, and availability on the shelves is acutely vulnerable to oil supply shortages. Thus, a hike in oil prices will quickly find its way through to the shelves, and into people's weekly shopping bills. A shortage of oil will likewise be quickly felt as a shortage of goods in the shops (again, as remarked previously). These problems apply all the more when goods are brought in from abroad.

Apart from transport, the other sectors of the UK economy which have vital oil-based ingredients are farming and materials manufacturing, such as plastics. In both cases, while the absolute volumes of oil consumed are relatively small, but, in both cases, the prices of the products for sale in the shops are directly affected by the cost and availability of oil.

Based on this assessment, we might expect to see the following effects reflected in our economy within the term of the next government:

- Markedly higher prices for all forms of travel (air, sea, rail and road)
- Increased food prices
- Increased general retail prices
- Increased domestic utility bills for heating and power

It is an unfortunate by-product of these factors that the disadvantaged members of society are likely to be hit first, and hardest.

Our concern, therefore, centres around a situation on which it seems that future oil prices will be significantly higher, in real terms, than they have ever been in the past, and in which disruptions to oil supply cannot be ruled out.

(Some scenario work on consequences for the UK of higher imports of increasingly expensive fossil fuels is briefly described in Appendix D.)

6.5 Restatement of underlying issues

Although the immediate slow-down in the global economy has removed short-term pressures on oil consumption, the underlying issues highlighted in last year's report have not changed. These underlying issues we identified in 2008 were:

- We are surprised that the industry has not discovered more giant fields, given that oil prices have been high for several years and investment has been "affordable".
- We are concerned by the infrastructure problems, underskilling and underinvestment in new exploration, which have become evident throughout the oil industry.
- 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.
- We are disappointed, given the long lead times of oil production infrastructure, that the net flow rate data which shows a slow down in 2011-13 and a reduction thereafter, has not galvanised a more active response from governments and industry.

There is a real need for more integration of sustainable transport policies with land use planning.

In terms of contingency planning, Government needs to ensure that, as well as prioritising key worker groups in times of fuel shortage or disruptions to oil supply, public transport is also prioritised, bearing in mind its ability to move large numbers of people extremely efficiently. Public transport is well placed to deliver the low-cost, quick win solutions that we need.

All of this requires partnership between transport operators and local authorities. It also needs brave politicians with long-term vision. Technology will take us some way along the road. But behavioural change, modal shift to greener, smarter bus, coach and train travel and measures to support these modes will make or break our efforts to deliver a reduced oil-dependant, low carbon transport future.

7. Possible countermeasures

We concluded in the last section that we probably face a future in which oil prices are significantly higher, in real terms, than they have ever been in the past, and in which disruptions to oil supply cannot be ruled out.

In this section we draw upon the experience of the Taskforce members to suggest possible countermeasures.

7.1 Transport

We all have a legitimate need to travel and transport is key to the economy and so many aspects of society and our daily lives. Yet we cannot escape the fact that the sector faces two massive converging challenges - oil depletion and climate change - both of which require significant changes.

Lower carbon technology for cars is advancing rapidly, with mainstream hybrids and a push for mass-market electric vehicles with a supporting plug-in charging network. Buses and coaches are also benefiting from advances developed for cars. The first hybrids are on the road today. We are also seeing cleaner engines, trials of sustainable biofuels, fuel-efficient driver training programmes and in-cab technology, as well as steps to reduce the weight of vehicles.

Rail is already a relatively energy efficient mode of transport, with a lower environmental impact than other modes and a good combination of high speed and efficiency. However, the long lead times for rail improvements mean we need to plan ahead now for tomorrow's railway, particularly for new lines. There needs to be a long term strategy which looks beyond the current five-year programme to a time when the public and private sectors can invest in increased capacity and enhancements which encourage people to switch from cars and planes. Ongoing electrification must be a priority, as well as greater use of regenerative braking and designs for more efficient rolling stock. High-speed rail could deliver modal shift from domestic airlines as we have already seen on the West Coast main line in recent years. However, the cost is significant - anything from £34 billion to £69 billion. In addition, the timescales are 20 years away and passenger projections already point to some rail lines being full up by 2020 or 2025.

But there is a real danger that the focus on technological advances in cars is making consumers and government complacent. New technologies in cars - or buses - will not be a complete solution. Central to our transport revolution has to be a package of measures to deliver behavioural change and secure modal shift. We also have to take steps to redress the balance of the relative cost versus convenience of different transport modes. Importantly, politicians have to be brave in pursuing pro-public transport taxation and funding regimes and in allocating road space based on the most fuel and carbon efficient modes for the transport journeys we are looking to undertake.

Commuter and business travel account for nearly 40 percent of all miles driven by car. Even switching to public transport one or two days a week can have a huge impact in this area. Workplace travel plans can also cut business costs, improve staff retention and reduce commuter car travel by 10 to 30 percent.

Bus and coach park-and-ride also has a proven track record in reducing journey times, a major influence on commuter transport choices. For every 1,000 park and ride spaces, research suggests there follow 250,000 fewer car journeys per year.

Rural areas, due to the demographics of remoteness, present a particular challenge. Tailored solutions, such as demand responsive transport, are better than a regular but virtually empty bus service at present.

There is a real need for more integration of sustainable transport policies with land use planning.

In terms of contingency planning, government needs to ensure that, as well as prioritising key worker groups in times of fuel shortage or disruptions to oil supply, public transport is also prioritised, bearing in mind its ability to move large numbers of people extremely efficiently. Public transport is well placed to deliver the low-cost, quick win solutions that we need.

All of this requires partnership between transport operators and local authorities. It also needs brave politicians with long-term vision. Technology will take us some way along the road. But behavioural change, modal shift to greener, smarter bus, coach and train travel and measures to support these modes will make or break our efforts to deliver a reduced oil-dependant, low-carbon transport future.

Finally, in the current challenging economic environment, it is vital that government investment in public transport is maintained.

On the railways, there is a need for more rolling stock, infrastructure work to lengthen platforms to take longer trains and investigation of the potential for new lines (particularly for high-speed rail). Government must also take a long-term view of the wider economic, social and environmental benefits of bus, coach, tram and train travel, and the positive impact of major integrated transport infrastructure projects.

7.2 Power generation

In addition to the transport considerations described above, there will be impacts on the power generation sector. Extended electrification of the railways and the potential conversion of road vehicles to electric power will increase demand. This will be further compounded by the possible adoption of 'green electricity' for heating in response to climate change fears. Thus there will be major changes in the demand pattern for electricity on the nation's power-generation and transmission/ distribution infrastructure. This consideration, plus more general concerns about energy supply, prompted Ofgem (the Office of Gas and Electricity Markets) to initiate "Project Discovery", a comprehensive review of Britain's energy supplies. The Ofgem preliminary report was published in October 2009 (as referred to in Section 5), and presented four alternative scenarios.

The scenarios range in their required energy infrastructure investment from £95 billion to £200 billion. They all result in increases in domestic energy bills of between 14 percent and 25 percent by 2020 (from 2009 levels), and raise the possibility that wholesale price spikes could lead to an increase in domestic energy bills of up to 60 percent in the interim.

Apart from these headline figures to illustrate impact on end users, a number of key aspects must be addressed for the power industry to invest and deliver their side.

Over the next decade, significant investment will be required, not only in new renewable generation capacity, but also in the broad spectrum of established generation technologies to ensure that the UK continues to benefit from a balanced, flexible and efficient generation portfolio. Critical to this will be investment in new transmission infrastructure, both on and offshore. Delivery of this infrastructure will require a pro-investment regulatory and political climate. The single most important aspect for this investment will be for the UK government and Ofgem to provide a stable and attractive investment climate in the UK that will allow companies to finance their activities.

A common theme across the four Ofgem scenarios and stress tests is the necessity for flexible generation. As the penetration of wind-powered generation increases, load factors for conventional plants will on average fall and become more uncertain. Given these lower running times, conventional plants will require higher prices to cover fixed costs and to earn an adequate return on investment.

A stable market framework is fundamental to ensuring sufficient thermal plant investment is maintained during this period. In particular, it is important that wholesale price spikes which reflect supply and demand fundamentals during periods of low wind are not unduly restricted by regulation, since these will be crucial to allow thermal plants with low load factors to pay back their capital costs. Even the threat of potential restrictions on price spikes may be sufficient to deter investment.

A transmission charging regime which allows efficient sharing of capacity will become increasingly desirable as renewables penetration increases. In particular, the role of energy storage (e.g. pumped storage) needs to be recognised and encouraged. For these reasons the transmission charging regime is in serious need of review.

Smart grid technology could play a major role in maintaining the reliability of the electricity system in the future by helping to reduce peak demand and to manage fluctuations in renewables output. There are three key areas for focus in realising the potential of this technology:

1. Developing appliances and infrastructure which allow automated demand response.
2. Finding effective ways of co-ordinating the various parties involved in smart demand (i.e. customers, suppliers, network operators and generators).
3. Providing funding for the development of smart networks.

Energy efficiency and microgeneration can also play vital roles in the policy response.

8. Recommendations

The next government will very likely need to steer the UK economy through a period of unusually high oil prices, with possible effects of the types such as those suggested in Sections 6 and 7. The members of ITPOES therefore recommend that all political parties actively consider the consequences of this and prepare themselves to weather a change in the UK economy driven by a volatile oil price which increasingly sits in the range $120-150/b.

Apart from driving new legislation, the new government will have an important role to play in incentivising private sector companies, public sector organisations and individuals, to change their behaviour in terms of reducing oil demand. A combination of legislation and 'encouragement' is therefore recommended, as follows.

8.1 General policies

- We call on the UK government, local government, businesses operating in the UK market and other key stakeholders to join us in an effort to appraise the risk from oil-supply difficulties, and plan proactive and reactive strategies - local and national - for facing up to the problem.
- Government policies (particularly those concerned with social, economic and financial matters) should explicitly acknowledge the potential for high oil prices and promote appropriate contingency planning.

8.2 Transport policies

Surface transport is the largest user of oil products. Petrol and diesel (with limited volumes of LPG) account for over 50 percent of all UK oil usage. The Taskforce members suggest the following:

- Continue measures to improve energy efficiency and wean transport from its dependence on oil. These include promoting technological developments such as hybrid engines, vehicle electrification and weight reduction, both for cars and public transport.
- Coordinate a package of measures to deliver behavioural change and secure modal shift from cars to sustainable public transport. These could include:
  - workplace travel plans to reduce long-distance commuting in cars as well as increasing their occupancy level,
  - support for the growth of car sharing,
  - measures to incentivise using public transport (for example by introducing fare structures that support home working, such as carnet-style ticketing products to complement weekly, monthly and annual tickets).
- Introduce fiscal measures to promote more carbon and fuel efficient modes of travel. For example, remove the current annual £9 billion tax break on fuel for domestic airlines and channel the income to public transport investment.
- Maintain short, medium and long-term public investment to support bus, coach and rail travel (even in the current challenging economic environment).
- Change the regulatory environment so that regulators are mandated to encourage the uptake of more fuel-efficient technologies. For example, giving the CAA a mandate to encourage the uptake of biofuels for aviation in a manner that parallels the mandate for the FAA in North America.

Within all of the above, transport policies designed to protect the disadvantaged members of society should be regarded as particularly important. Examples include the provision of better public and community transport services, and policies to help operators maintain affordable fares. Contingency planning is also essential in the event of fuel shortages to prioritise key work groups, public transport and essential deliveries.

8.3 Retail and agricultural policies

- The huge dependency on road freight for just-in-time delivery from centralised warehouses makes retail goods (particularly food) very vulnerable to fuel-related price rises and supply shortages. Government policies must plan to mitigate these effects (again, with particular reference to the disadvantaged).
- Farming is highly dependent on the use of oil-related products such as diesel fuel, soil improvers, crop treatments, and so on. Government will need to consider mechanisms for preventing unreasonable oil-driven price rises feeding through into the basic food supply chain.

8.4 Power generation and distribution policies

Further electrification of the railways and the potential conversion of road vehicles to electric power (plus the possible adoption of 'green electricity' for heating in response to climate change fears) will change the demand pattern for electricity on the nation's power-generation and transmission/distribution infrastructure.

- Government policies must plan to accommodate a significant upswing in electricity consumption and, in the short-term, must plan for the possibilities of price spikes and supply interruptions.
- The single most important aspect that will allow the UK to manage the above uncertainties and its 2020 vision for a low carbon economy is for the government to provide a stable and pro-investment regulatory and political climate in the UK that will allow companies to finance their activities.
- The 'cleantech revolution' in the use of renewable energy for generating electrical and motive power, and heating, requires continuing support. Although its short-term impact will be limited, UK plc can aspire to be a major player in the new industries that are being created, thus abating the long-term risks from peak oil, more general energy security, and climate change.

8.5 Heating policies including fuel poverty

- For those that still rely on oil, or oil-derived fuels, for domestic heating (mainly LPG), an increase in the fraction of the population caught in fuel poverty can be anticipated. The government needs to acknowledge this possibility and plan action to protect the disadvantaged. The programme to improve the energy efficiency of buildings must be accelerated.
- Encouraging the use of heat pumps is one solution. Based on the renewable heat scenarios published by DECC, heat pumps would increase electricity demand by 8TWh/y in 2020, but substitute for heat energy from primary fuels equivalent of up to 32TWh/y.

Appendix **A**: Spare capacity

Spare capacity is the key variable in terms of sustaining or undermining oil prices. When there is little or no operable spare capacity - as occurred in June and July of 2008 - oil prices become very inflationary. In contrast large quantities of spare capacity tend to undermine prices because holders of the excess or spare capacity have a financial incentive to 'leak out' additional cargoes. Initially an extra cargo or two does not undermine the price level but does bring a financial reward to the producer of the extra cargoes. Eventually once a number of producers are leaking out additional cargoes the oil price is undermined and falls.

This tendency to production 'leakage' has always been the key challenge to OPEC as an organisation. It occurs whenever OPEC tries to defend or establish a price level by restricting output by means of quotas. Currently OPEC appears to have an unofficial price target of $75/b. This is the price that King Abdullah of Saudi Arabia has announced represents a 'fair' price for both consumers and producers. To achieve this price OPEC has announced output cuts by its members totalling 4.2Mb/d. The $75/b target price was first achieved in August 2009. Since that date the price has held in the $70-$80 range. In the early summer OPEC compliance with the agreed output cuts of 4.2Mb/d had been around 70 percent but then gently eroded to 58 percent by November without undermining oil prices. Increased capacity coming on stream during the period to November meant that OPEC still had around 3Mb/d of operable spare capacity at year end 2009.

Spare capacity is defined by the IEA as the extra capacity that can be brought on stream within 30 days and sustained for 90 days. Since the 1970s spare capacity has essentially been an OPEC phenomenon as all the non-OPEC producers aim to produce as close as possible to capacity while only OPEC producers ration production to achieve price targets.

For this reason conventional analysis usually assumes that only OPEC holds any significant, non-transitory, spare capacity. Using the IEA data shows that OPEC spare capacity on the IEA's definition averaged 3.03Mb/d in 2006, 3.34Mb/d in 2007 and 2.64Mb/d in the first half of 2008. The lowest spare capacity recorded by the IEA was 2.35Mb/d in July 2008 - the month when oil prices peaked at $147/b and all producers were straining to maximise production. It is not clear if this 2.35Mb/d was unused because it represents not readily available spare capacity, or capacity that is commercially unattractive (unsaleable) because of its sulphur and metals content or whether it is regarded as an 'iron reserve' producers are reluctant to exploit. However in practical terms it represents an effective minimum OPEC producers do not go below. [Note that the lowest spare capacity recorded in the last three years was 2.12Mb/d in December 2007. It may be appropriate to regard this as the effective minimum for OPEC 'spare' production.]

The latest IEA figures (December 2009) give OPEC spare capacity as 6.24Mb/d which reduces to 5.35Mb/d once the notional spare capacity of Iraq, Nigeria and Venezuela are excluded. The reason for excluding these three is that Iraqi capacity is operated as flat out as the security situation will allow (over recent months it has been using virtually all its capacity). Nigerian production is

constrained by the security situation in the Niger Delta region. So Nigeria's large notional spare capacity has been inaccessible and possibly declining due to lack of maintenance access to the fields. The recent peace agreement with the rebels in the Delta region appears to be holding and production has been rising as field maintenance work recommences. This means more of Nigerian 'spare' capacity may now be brought into production. In the case of Venezuela a steady erosion of capacity has been seen since the Chavez government came to power in 2001. This will be slow and difficult to reverse as the Venezuelan government recently nationalised the oil field contractors to avoid paying the contractors' outstanding bills, while the earlier expropriation of a number of international oil company operations has continued to hold heavy oil production below its notional capacity. It has, however, just announced new bidding terms in November for an auction of joint venture partnerships in the to be held in the Orinoco Belt.

The conclusion, as at end 2009, is that after deducting the 2Mb/d of spare capacity below which OPEC does not go, the organisation has 3Mb/d of immediately operable spare capacity and a further 1-2Mb/d of spare capacity that given the right circumstances could potentially be brought to market.

However, spare capacity is a dynamic not a static phenomenon. In 2009, according to Peak Oil Consulting calculations, the net capacity (gross capacity additions minus depletion) addition is likely to be 2.3Mb/d made up of 1.9Mb/d for OPEC and 0.5Mb/d for non-OPEC.

Latest data suggests an oil demand growth of only 1Mb/d between the first quarter of 2009 and the fourth quarter of 2009. If the non-OPEC producers follow the usual pattern of utilising their capacity flat out then OPEC producers will have to increase their spare capacity by over 1Mb/d if they have brought all their new capacity on stream and want to defend prices in the $70-80 range.

Thus by year end 2009 OPEC is likely to have immediately operable spare capacity of over 3-4Mb/d with a further 1-2Mb/d of spare capacity which in the right circumstances could potentially be brought to market.

The year 2010 is unlikely to provide any alleviation as net (after allowing for depletion) new capacity is around 1.6Mb/d and essentially all OPEC. Only quite limited amounts of this could be delayed as the most of the increase is from fields brought on stream in 2009 building up output, Iranian developments and liquids associated with gas export (LNG) projects.

Latest oil demand growth estimates for 2010 over 2009 are 1.4Mb/d which means OPEC is likely to go into 2011 with as much spare capacity as it had at end 2009. Indirect confirmation of this weak outlook is provided by a recent interview on September 22, 2009, reported by Bloomberg with the Saudi Aramco CEO Khalid al-Falih. In this he indicated that they were prepared for the long haul and there was little chance of reactivating the 4Mb/d of idled Saudi production capacity in 2010 unless they saw an acceleration of economic recovery which he said is not yet apparent.

It seems fairly certain that OPEC will delay projects where it is economic to do so. As most projects are heavily front end loaded only a limited amount of incremental capacity is likely to be postponed

Appendix **B**: Major disruptive events to oil supplies

Major disruptive events are by their very nature unpredictable but there are always geopolitical tensions that have the potential to become major disruptive events. These are the possible events which could radically alter outcomes.

In the context of future oil supplies we can already identify a number of important areas of tension:

- Iran's nuclear ambitions and the consequent actions by the US and others determined to avoid Iran becoming a nuclear armed power. Iran as OPEC's second largest producer has a production capacity of just under 4Mb/d.
- Al Qaeda's ambition to destabilise and take over Saudi Arabia.
- The instability of Afghanistan/ Pakistan and the possible consequences in the event of partial or total takeover by Taliban/Al Qaeda groups.
- The civil war in Yemen and its possible spill over into Saudi Arabia.
- Assorted threats to the free passage of oil tankers both in restricted channels such as the Straits of Hormuz and the Malacca Straits and on the high seas from pirates or groups such as Al Qaeda.
- Continuing or escalating action by 'rebel' groups in areas such as Nigeria, Sudan or other areas where the central authority is weak in relation to regional ambitions with armed groups contesting the central authority.

There is also the potential for unexpected events in the oil fields. The world is heavily dependent on 120 oil fields that collectively account for 50 percent of world production and contain two thirds of the remaining reserves of fields in production. Their average age is 42 years and although the expectation is that their production will slowly decline in a predictable manner this is not always the case.

The Cantarell field offshore Mexico was one of the world's largest fields when it was discovered in 1975. Following the start of production in 1980, field production rose steadily and by 2000 it was producing over 1Mb/d. Nitrogen injection was used to enhance oil recovery from 2000 and in 2005 production peaked at 2.2Mb/d. At this point Cantarell was the second most productive oil field on earth only exceeded by Saudi Arabia's Ghawar field. However, in late 2005 a sustained and rapid decline in production started and has continued ever since. By August 2009 production from Cantarell was down to 0.65Mb/d amid hopes that production may finally be stabilising.

By global standards Cantarell is not an old field. Large numbers of still producing Middle East fields started up in the 1930s, 1940s and the early 1950s. The lesson to be drawn is that production from elderly oil fields may not be as reliable or as predictable as is generally supposed.

Appendix **C**: Biofuels

The promotion of the use of biofuels to increase self-sufficiency and to mitigate climate changing emissions is now established policy in much of the world and biofuels volumes are increasing quite rapidly. The use of biofuels additions to gasoline and diesel supplies impacts the oil industry in three ways. The loss of product sales volume impacts the requirement for crude production or crude purchase. The loss of refinery throughput impacts refinery profitability particularly as refinery capacity is currently greater than immediate requirements. The addition of a lower cost (or subsidised) biofuels blendstock tends to reduce the profitability of gasoline and diesel sales as oil companies usually have to buy in the biofuels rather than owning and creating them.

Total biofuels production reached 1.6Mb/d in 2009 and is expected to reach 1.8Mb/d by 2010 and 2.2Mb/d by 2014 according to the IEA. Although as discussed above biofuels exert a leveraged impact as a share of global liquids production, biofuels only accounts for 1.75 percent in 2008 and 2.4-2.5 percent in 2014.

There are three major threats to the increased output of biofuels. The first is changes to government subsidy regimes. This particularly applies to biofuels crops grown in temperate regions. The second is rising prices for the food use of the crop. Increased sugar prices are currently restricting the attractions of bioethanol production from sugar cane. Similarly high prices for cooking oil in Asia are a more profitable use for palm oil than biodiesel blendstock. Governments have recently become increasingly sensitive to the food versus fuel debate which may inhibit biofuels expansion hopes.

One of the key drivers in the expansion of biofuels supply particularly in temperate regions, has been government subsidy. The global recession has put many if not most government budgets under severe strain. It remains to be seen if governments see these subsidies as priorities or whether they will be seen as areas where expenditure cuts are acceptable.

Great hopes have been invested in the development of the so-called second generation biofuels - ones that come from non-food material such as wood waste - that do not compete with food supplies. To date this remains an experimental technology and one that is not fully proven technically or economically. Large scale investments are being made but any significant supplies are some years away.

The other much-promoted biotechnology is the use of algae to produce oils or even oil fuels such as diesel. Despite some promising experimental results this technology is at a very early stage of development. It is, however, attracting considerable investment finance, notably from ExxonMobil. Despite the investment and the numerous experimental facilities significant production is 5-10 years away at best.

Appendix **D**: Whole-economy scenarios for the UK to 2025

D.1 Introduction

This section briefly examines scenarios for the UK to 2025 using a socio-economic-energy framework developed at Arup known as *4see*. The primary purpose of the framework is to show what is physically possible - that is, the maximum physical envelope for any given future scenario. Two such constraining physical limits are the output of industry, which goes to supplying household consumption and reinvestment in the economy, and available energy. In reality, actual industry output can always be less, as during a recession when there is loss in confidence, but it can never be more than this physical limit. A unique feature of the *4see* framework is that the rate of growth does not have to be predetermined, as in most economic forecasting models, but is endogenous, generated by the *4see* framework itself.

The first scenario presented is based on business-as-usual behaviour of "reactive" policies, while the second scenario contrasts implementation of "proactive" policies. Both scenarios have a level of industrial activity and expansion of the service sector that continue economic growth, one benefit being to keep the level of unemployment in check. Both scenarios include decline of North Sea oil and gas production with the scenarios showing how the consequences of this on imports play out.

In the reactive scenario, demand for oil and gas continues to increase through economic growth typical of the last two decades. Increasing imports of these two fuels and at higher prices puts pressure on balance of payments. Using the *4see* framework with this scenario suggests that a reactive consequence could be continuous devaluation of sterling at an average of about 1 percent per year.

In the proactive scenario, a small proportion of the output of goods for personal consumption is diverted to other investments. Specifically, this investment is directed to increased implementation of energy efficiency on all buildings and growth of renewable energy as fast as reasonably possible. A policy to bring about this diversion could be taxation applied specifically to personal consumption of goods. There is no change in the total output of goods, just in their mix, but the consequence would be reduced demand for gas. Meanwhile, the historical trend of increasing personal transport by car is reversed by stick-and-carrot policies. The result of these policies would be to keep oil imports at a roughly constant level. Using the *4see* framework, the overall observation from this scenario suggests that, in contrast to the reactive scenario, the balance of payments would be sufficiently healthy for sterling not to devalue.

D.2 Overview of the *4see* framework

The *4see* framework aggregates the UK economy into just a few broad groupings of capital stocks (assets), these being: the energy supply sector, industry, the service sector, transportation, agriculture and the domestic sector (**Fig. D.1**). The framework also covers the main "flows", these being: energy, goods and services, interaction of these with the balance of payments, growth of capital stocks and utilisation of the working population.

The capital stocks interact through flows as shown in **Fig D.2**. One of the distinguishing features of the framework is that metrics for the capital stocks and flows are not money but, where possible, more resilient, physically related units. Flows of energy are in petajoules (10^{15} joules or PJ) per year. Capital stocks and flows of goods are both in embodied energy units (virtual petajoules or VPJ). Flows of services are kept in inflation-corrected pounds sterling for lack of any better metric that captures their innate value.

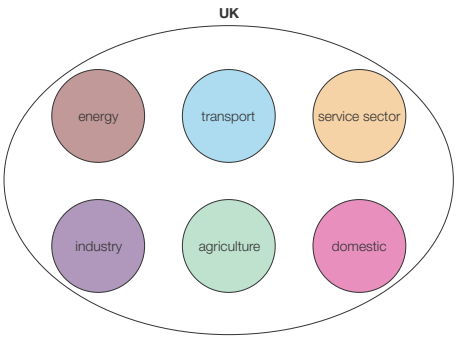

Fig D.1 Main capital stocks (assets) of the *4see* framework within the system boundary of the UK economy.

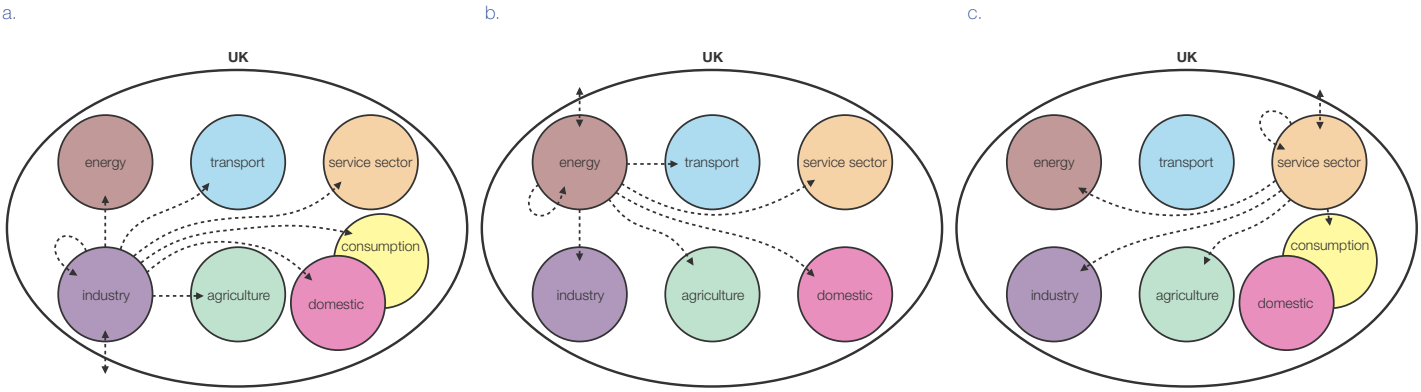

Fig D.2 The main interactions in the economy are shown as flows between the main sectors of the *4see* framework. (a) Flows of energy from the energy sector. (b) Flows of goods from industry. (c) Flows of service.

Double-ended arrows in **Fig D.2** crossing the UK system boundary represent international trade in the flows of energy, goods and services. Each of these flows has a related monetary transaction. These monetary transactions form part of the balance of payments that also includes other transactions on the current, capital and financial accounts.

The benefits of trade are the interchangeability of flows of energy, goods and services. For example, net exports of services can be "exchanged" for the net import of energy and goods, the balance of payments and exchange rate enabling this process.

In contrast, one of the principles of the *4see*-based view is to recognise and highlight the fundamental nature of energy, goods and services, and that within the economy they are not as easily interchangeable as they are in trade. For example, if we want to reduce the flow of fossil energy, either we have to reduce activity of the sectors to reduce their energy demand or we have to change the output of goods so as to invest in renewable energy capacity. Another example is that if household purchasing were to shift from shopping (consumption of goods) to leisure services, the services sector would have to be increased to cope with the additional demand. This might necessitate construction which would impact back on the flow of goods through the demand for construction goods.

Application of the *4see* framework first involves examining historical data (chosen to be for the period from 1990 to the present) in terms of the framework's groupings for capital stocks and flows, as quantified by the framework's metrics. Next, the sizes of flows are related to the sizes of capital stocks as a calibration process capturing the socio-economic behaviour. This calibrated socio-economic behaviour can then be applied to future scenarios as a form of sophisticated trend analysis working within the system dynamics represented by the flows in **Fig D.2**.

D.3 Business-as-usual assumptions

The reactive scenario, also known as business-as-usual, has policies essentially reacting to events. For instance, the historical period has shown substantial growth of the service sector. The *4see* framework derives relationships between sector demand for services and size of each sector. These relationships are extrapolated in the scenario to model the continuing growth in demand for services, and consequent growth in the service sector. For investment in industry and housing, this continues at the same roughly constant levels as in recent years. The resultant increase in goods and services shows as around 1 percent per year (annual GDP growth).

Other trends are assumed to continue. These include the low level of improvement of energy efficiency over the last decade (essentially through replacement of stock) and increase in travel in terms of passenger-km and freight-tonnes per year.

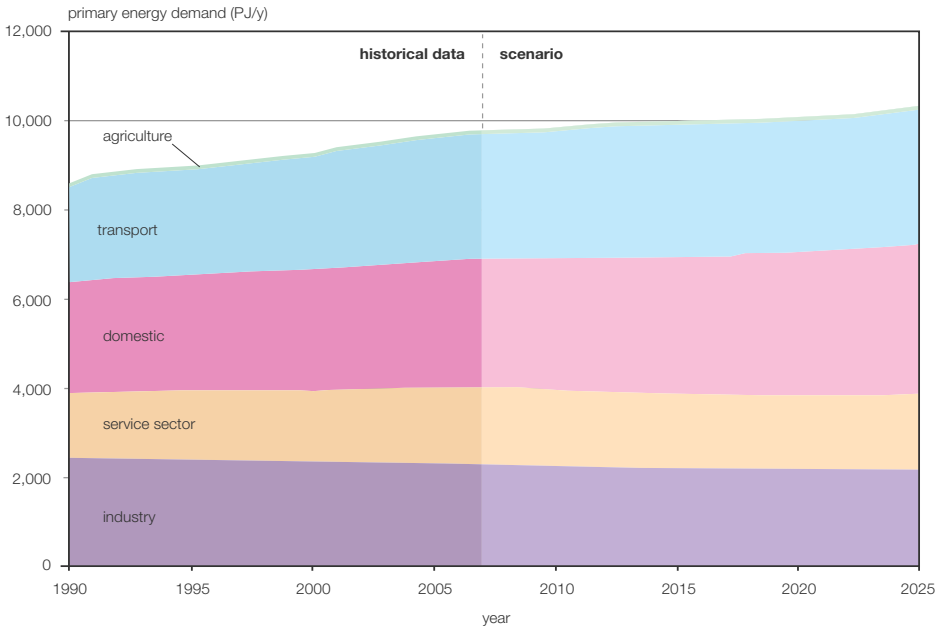

Fig D.3 Primary energy demand by sector (excluding utilities and mining) for the historical period to 2007 and projected to 2025 according to the proactive scenario.

A projection for the expected total energy demand can be derived from this set of conditions, shown in **Fig D.3**. The energy demand by 2025 in this scenario is over 10,000 PJ/y (in terms of total primary energy). This primary energy demand is dominated by fossil fuels with only small proportions of electricity from renewables and nuclear power.

Over the historical period, there has been a trend to reduce the number of staff employed per unit of assets, in both the service sector and industry. (Economists describe this phenomenon by its inverse, the increase of capital employed per unit of labour, a trend they encourage in order to achieve economic growth.) The downward trends of staff employed per unit of assets in the service sector and industry are assumed to continue for the scenario. Meanwhile the service sector is growing, as already mentioned, so these trends compensate to a degree and unemployment stays at around 4 percent.

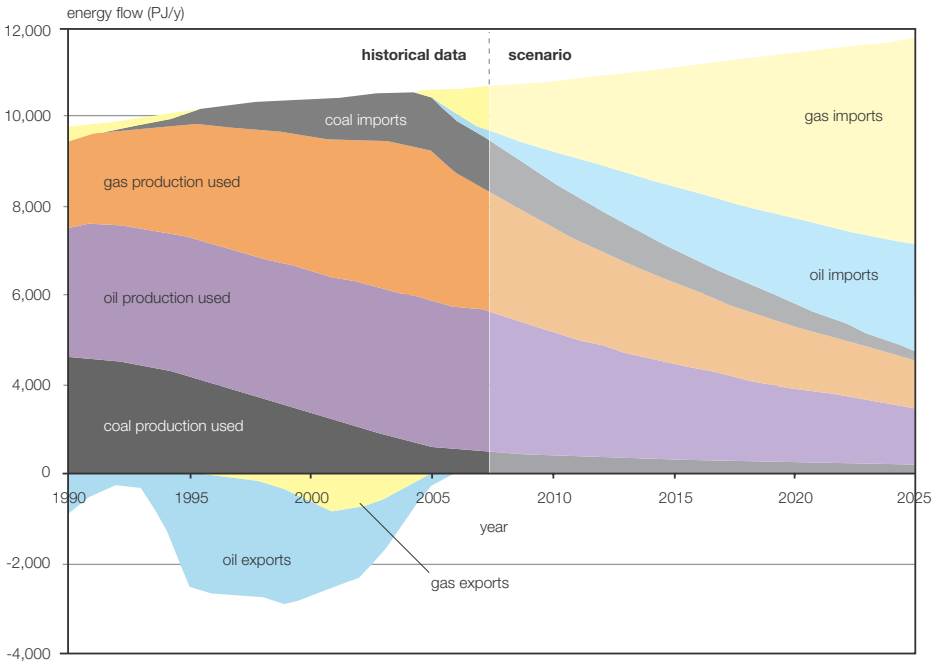

Fig D.4 Extraction, use and trade of coal, oil and gas for the historical period to 2007 and projected to 2025 according to the reactive scenario. Decline of North Sea oil and gas production into the future is shown at 5 percent per year.

D.4 North Sea output

Output of oil and gas from the North Sea is past its peak and that we are now set on a path of permanent decline is now generally accepted. A decline level of 5 percent per year for oil and gas is used for domestic production in **Fig D.4**.

Within the energy demand profile of the reactive scenario shown in **Fig D.3**, the shortfall in domestic oil production for the oil component will result in increasing imports. These could grow at about 10 percent per year, as shown in **Fig D.4**.

D.5 Reactive consequences to the business-as-usual scenario

At this point in developing a scenario (based on the assumptions above), we have to conjecture how this vision of the economy might respond to the unprecedented situation for the UK of becoming an overwhelmingly major energy importer.

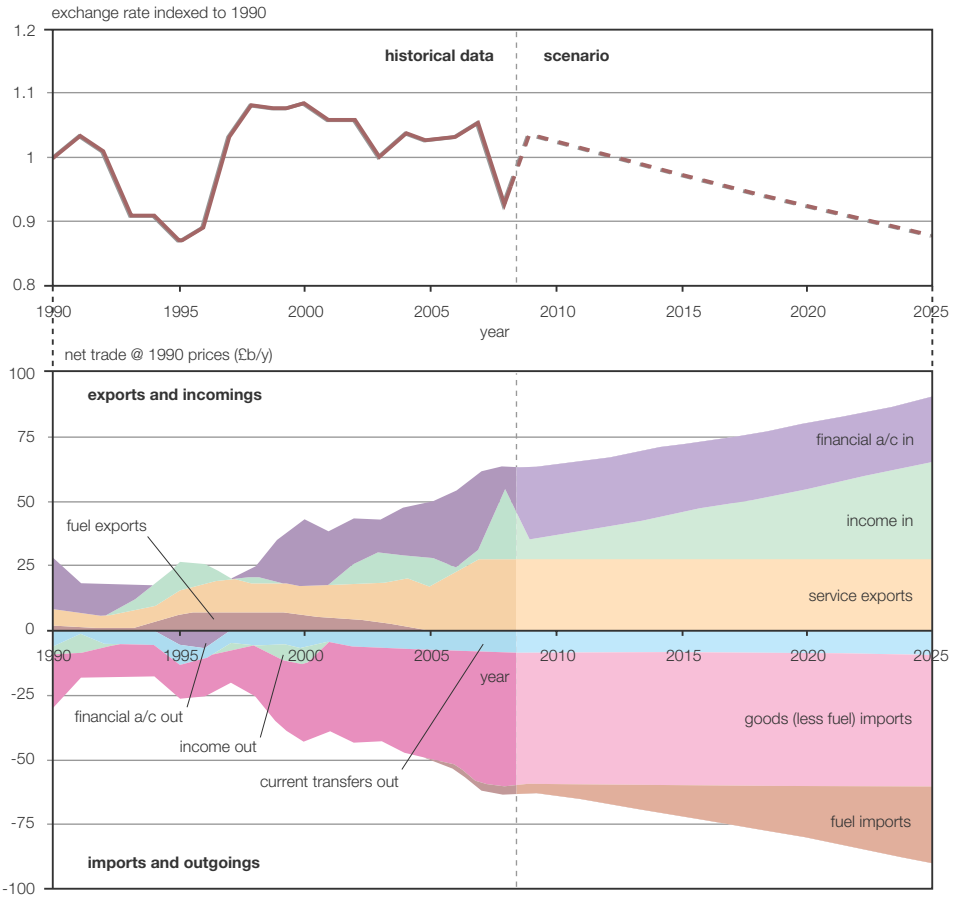

Fig D.5 Strength of sterling and balance of payments showing net components for the UK for 2007 with a projection to 2025 based on the reactive scenario with the change in strength of sterling shown.

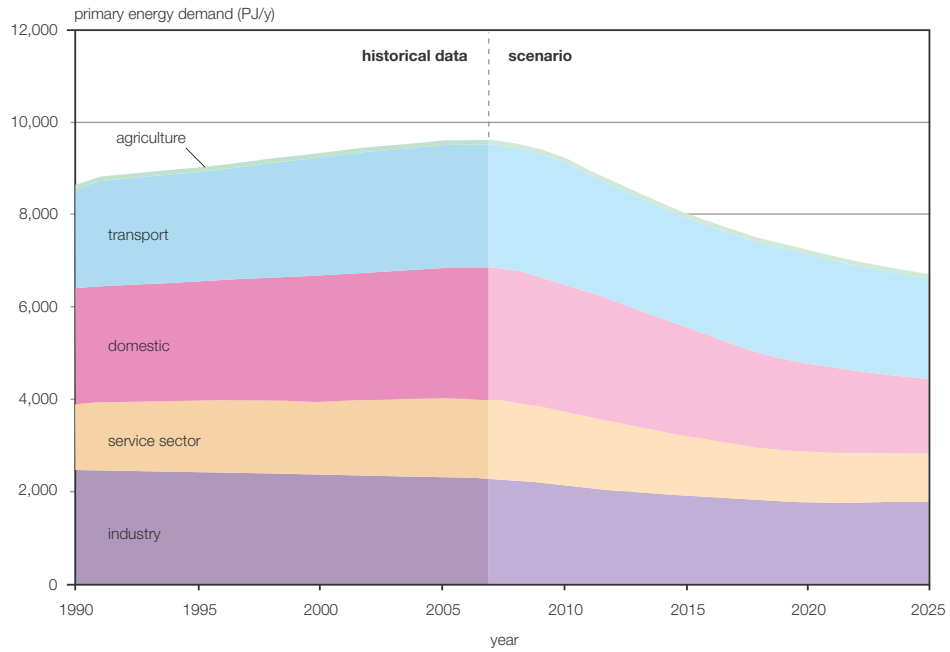

Fig D.6 Primary energy demand by sector (excluding utilities and mining) for the historical period to 2007 and projected to 2025 according to the proactive investment scenario.

At the same time as oil imports start to rise, a consequence of global peak oil is that the global price of oil is also likely to rise, and substantially. For the purposes of this scenario, the price is put at doubling by 2025 with the price of gas moving in tandem at a constant 50 percent of the oil price by energy content.

The net components making up the complete balance of payments are shown in **Fig. D.5**. The increasing dependence on imported fuel is clearly evident in the lower half for outgoing funds. This balance of payments projection includes the conjecture for the strength of sterling as it responds to events, shown in the upper part of **Fig D.5**. This is in no way intended to "predict" balance of payments to 2025, an impossible task, but simply to get a feel for the relative magnitude of balance of payments components.

So, **Fig D.5** shows the reaction as 1 percent devaluation each year. The explanation of this behaviour is that the valuation of sterling enables the "income in" (from UK owned foreign assets) to compensate or "pay for" fuel imports. Given that the scenario has 1 percent growth, the simultaneous devaluation of sterling by the same amount means that, seen from abroad, the UK as zero growth.

The key message to take from this scenario is that the features of the UK's balance of payments mean the UK could possibly "afford" an increasing fuel imports bill, but really this is not a situation to get into in the first place.

D.6 Proactive scenario

The alternative scenario investigated here proposed that some of the industrial output to consumer goods is diverted to investment in energy efficiency and renewable energy, as described above. By diverting industrial output in this way, other aspects of the scenario described earlier, of 4 percent unemployment and 1 percent growth, still apply.

To complete the scenario, a highly coordinated approach is proposed to reducing passenger car and freight consumption of oil. This might include higher pump prices, encouraging multi-occupant driving and a modal shift to rail.

The resulting effect on sector demand for primary energy is shown in **Fig D.6**, which shows a marked reduction in demand compared to **Fig D.3** of the reactive scenario.

The resulting reduction in fossil fuel demand, and thus fuel imports, is shown in **Fig D.7**.

Finally, the effect on balance of payments of this proactive investment scenario is shown in **Fig D.8**.

Compared to **Fig D.5** of the reactive scenario, the fuel component is much smaller and now comparable with variability of the other components of the balance of payments. A low likelihood of devaluation of sterling is the conclusion that can be drawn from this scenario. Both scenarios have the same growth and low unemployment of the reactive scenario, but the proactive scenario has much improved energy security.

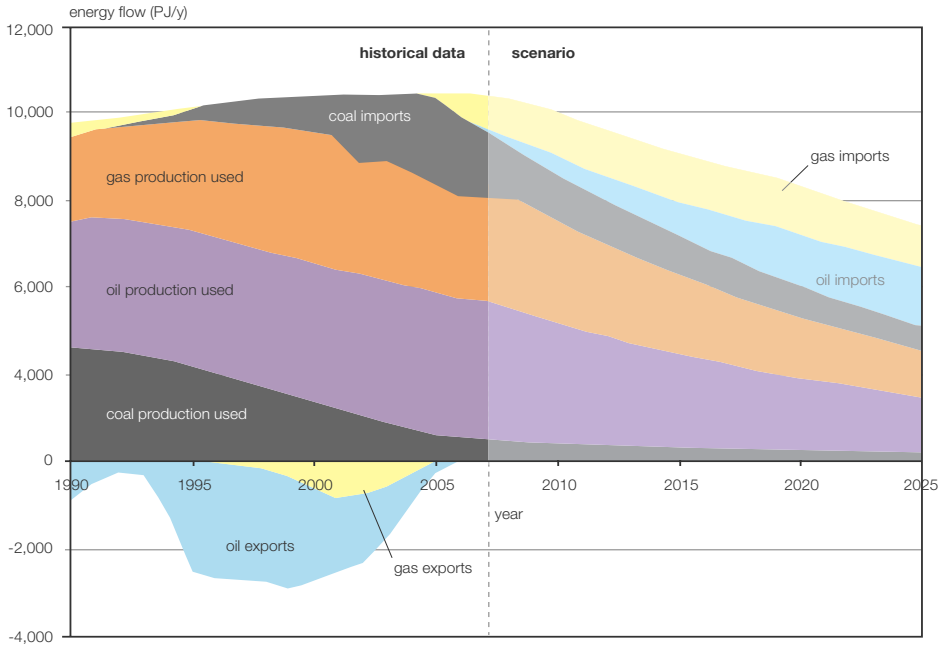

Fig D.7 Extraction, use and trade of coal, oil and gas for the historical period to 2007 and projected to 2025 according to the proactive investment scenario together with decline of North Sea oil and gas production at 5 percent per year.

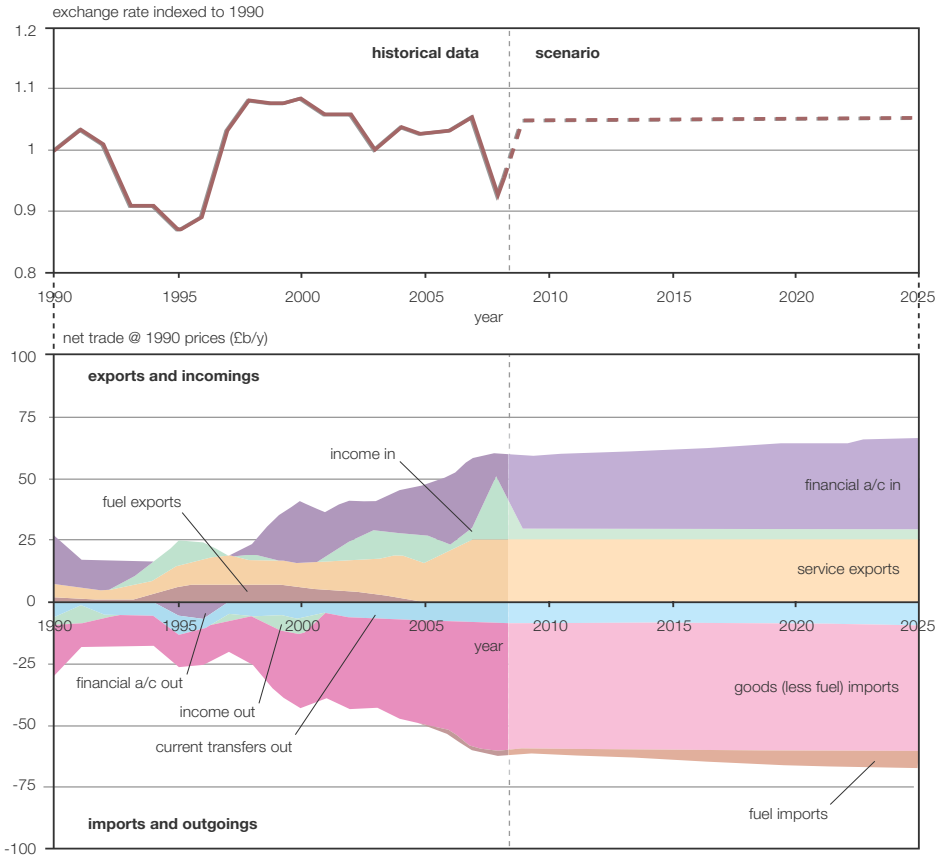

Fig D.8 Strength of sterling and balance of payments showing net components for the UK for 2007 with a projection to 2025 based on the proactive investment scenario with no change in strength of sterling.

Appendix **E**: Sources

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