# THE EIGHT SCENARIOS
## Developed by the
## TYNDALL INTEGRATED SCENARIOS PROJECT

**As discussed at the first project workshop on November 30th 2004**
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# 90a

## UK picture

90a is one of two low energy demand scenarios. It differs from scenario 90b by virtue of a lower rate of economic growth where activity within sectors continues along current trends. As a consequence of a continued decline of manufacturing, the UK has become ever more a service economy where a reduction in energy consumption is, in part, a consequence of the slow down in economic growth.

Curbs in personnel mobility may have been achieved through a variety of mechanisms such as economic instruments, a greater awareness of the environmental impacts of transport or a general acceptance that increasing congestion has made private car use unpleasant. Equally, in a low growth economy travel may simply be too expensive.

The acceptance of nuclear energy and coal fired generation without widespread carbon capture and storage is potentially unlikely without a collectivist rather than individualist approach since government will need to take the lead and widespread consent will be required. This is potentially a low innovation scenario where decreasing energy intensity may be the result of cost cutting measures; the hydrogen economy has not developed.

The scenario is consistent with stagnating economy or a positive sustainability striving society where low economic growth is deliberate in order for society to become more sustainable. In such a society, a declining public sector may not mean a declining quality of life, but instead more bottom-up activity and strong community networks. The scenario is also consistent with more individualist social relations but with more collectivist-type decision making and solutions.

Figure 1. Scenario economic and energy demand summary

| Module | Consumption (Mtoe) | % of consumption | Carbon (MtC) | % of carbon | % of GDP |
|---|---|---|---|---|---|
| Household | 23.1 | 25.9% | 15.6 | 24.2% | |
| Industry (Intensive) | 6.1 | 6.8% | 3.5 | 5.4% | 1.9% |
| Industry (other) | 10.6 | 11.9% | 6.8 | 10.5% | 12.0% |
| Public Administration | 2.7 | 3.0% | 1.2 | 1.9% | 10.8% |
| Commercial | 9.0 | 10.1% | 3.8 | 5.8% | 68.2% |
| Aviation domestic | 0.6 | 0.7% | 0.5 | 0.8% | |
| Aviation international | 5.8 | 6.5% | 4.7 | 7.2% | |
| Rail | 0.9 | 1.0% | 0.6 | 1.0% | |
| Road Freight | 8.7 | 9.8% | 5.3 | 8.2% | |
| Road Passenger (Private) | 10.1 | 11.3% | 8.0 | 12.4% | |
| Road Passenger (Public) | 0.9 | 1.1% | 0.7 | 1.1% | |
| Water Domestic | 0.5 | 0.6% | 0.4 | 0.6% | |
| Water International | 8.7 | 9.7% | 7.0 | 10.8% | |
| **Total Transport** | **36.3** | **40.6%** | **27.2** | **42.2%** | |
| Agriculture | 0.9 | 1.0% | **0.7** | 1.0% | 0.8% |
| Construction | 0.5 | 0.6% | 0.3 | 0.4% | 6.3% |
| **Total consumption** | **89.3** | 100.0% | **59.1** | - | **1.05%** |
| Energy industry use | 8.3 | 6.2% | 5.5 | 9% | |
| **Total primary demand** | **134.6** | - | **64.6** | - | **£1,669** |

### *Shape of the economy*

Economic growth is slower than in the early 2000's with low growth experienced across each of the productive sectors; that said the economy is nearly twice as large as today. The contribution to the economy from energy intensive industries, such as minerals and chemicals, has declined with the chemical industry in particular suffering a continued period of very slow growth in contrast to its previously strong performance. The commercial sector is the strongest performing sector of the economy, though its contribution to national prosperity has declined with improving performance within non energy intensive industries. The public administration sector is of less importance as a result of zero growth in output.

### *Demand characteristics*

Energy consumption within society is at about half current levels with demand for electricity increasing and demand for other energy decreasing. This shift has occurred across all sectors of society with increased use of electricity for meeting needs such as space and water heating. In general, current trends showing a reduction in energy intensity have been maintained, with the exception of the commercial sector where recent increases in energy intensity have been reversed and the energy intensity is not improving.

**Services and Industry**

Wealth creating sectors of the economy have undergone a sustained period of slow economic growth, and this has had a constraining effect on energy consumption. Energy intensity has continued to decrease across all sectors at similar rates to current trends, with the exception of energy intensive industries where the rate of decrease has declined. In a low growth economy, investment in energy efficiency may be on a small scale and focused on low cost measures.

**Households**

The total number of households remains at current levels, around 25 million, and energy consumption within the home has reduced by a half. This improvement has been brought about a reduction in energy intensity, i.e. the amount of energy consumed per capita in provision of household services such as heating, cooling, cooking, etc. per unit of consumer expenditure, slightly greater than the current trend. This change may have been brought about by changing behaviour and expectations, technical improvements in the way in which energy is used within the home, including improvements to building fabric or combinations of the two.

**Transport**

Growth in passenger transport has been curbed, with levels of mobility the same as today. Overall, there is zero growth in private road transport with a shift to public transport where passenger distances travelled by public transport, both road and rail, have doubled. This modal shift has resulted from a break in the historical relationship between increased consumer expenditure and more private road transport. For road passenger transport, both private and public, energy intensity has decreased faster than currently trends. In the rail sector, the very high rate of decrease in energy intensity has not been maintained, though is still improving.

Within the aviation sector, current high growths rate in mobility have been significantly curbed, with no increase in passenger kilometres travelled compared to today. Energy intensity within both domestic and international aviation sectors has significantly decreased, against current trends for increasing energy intensity.

For all forms of passenger transport, a decrease in energy intensity can be brought about through a combination of fuel efficiency, increased level of occupancy and other operational factors.

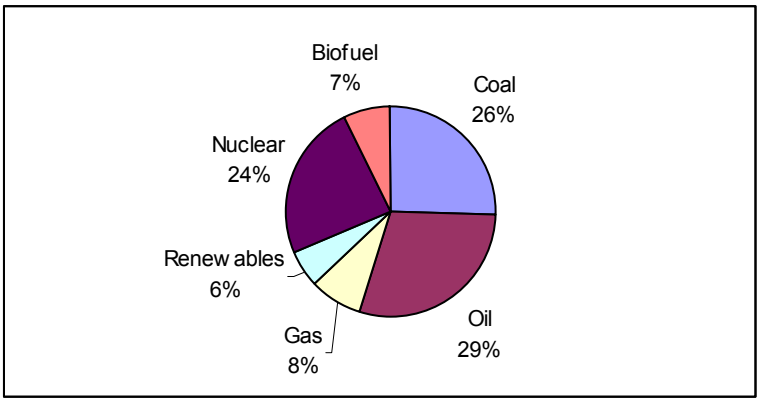
### *Supply side*

Table 2. Electricity sources

| Source | Electricity use (Mtoe) | % of grid supply | % of total electricity supply |
|---|---|---|---|
| CF | 9.8 | 33% | 26% |
| CCGT | 1.2 | 4% | 3% |
| NU (Grid) | 14.7 | 49% | 38% |
| NU (H2) | - | - | 0% |
| RENEW (Grid) | 1.2 | 4% | 3% |
| RENEW (h2) | - | - | 0% |
| CCS | 2.4 | 8% | 6% |
| BIO | 0.5 | 2% | 1% |
| C-CHP | 2.0 | - | 5% |
| G-CHP | 2.1 | - | 5% |
| B-CHP | 1.1 | - | 3% |
| ON-REN | 3.2 | - | 8% |
| **TOTAL** | **38.1** | | |

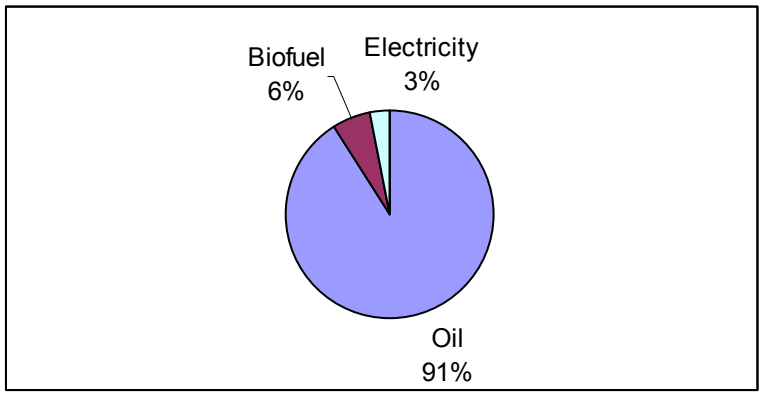
The electricity grid is dominated by coal and nuclear power. Coal is burnt in conventional power stations; the reduced energy demand allows space within a carbon dioxide emission budget so that carbon capture and storage is not necessary across all generating plant. Renewable energy has maintained its current contribution to the grid and has shown a strong growth in direct electricity supply for commercial and industrial end users. Biofuels are directly combusted to supply the grid; this could be in co-generation plants.

Figure 1. Primary energy demand




CHP has penetrated the market, meeting one tenth of energy needs; coal CHP supplies half the demand with biomass and gas supplying the remainder. A fifth of energy needs within the home are met through combined heat and power schemes. Over half of the CHP capacity is fuelled by gas; this could either be in the form of micro-CHP systems, or district heating schemes. Coal is used to fuel district CHP schemes where size of systems allows the economies of scale for adequate flue gas clean up. Alternatively, clean up systems may have developed which allow flue clean up at the scale of the household or business. Coal and biofuels are important fuels for CHP within the energy intensive industry sector where waste may form the biofuel element, and coal CHP may link in to the industrial plant gaseous effluent treatment systems.

Figure 2. Transport fuel mix




Oil is the dominant transport fuel, with biofuels supplying low carbon fuel to international aviation, road freight and passenger transport. Over half of rail is powered by electricity.

The hydrogen economy has not taken off. The biofuel demand is of a scale such that all needs should be met through UK supply.

# 90b

**UK picture**

90b is one of two low energy demand scenarios, differentiated from 90a by the size and make up of its economy. Although the UK remains a service economy there has been improving manufacturing output, particularly in non energy intensive and chemical industries. Overall growth is high yet there has been a significant reduction in consumption. This pattern of a reduction in energy intensity of goods and services points to high innovation and technological development. Much of this innovation has focused on hydrogen as a fuel, a move potentially prompted by, or causing, the phasing out of nuclear power. There is a large focus on self sufficiency of supply, many firms have on-site renewables and gas use is limited.

Whilst the population is likely to be more affluent than today, mobility patterns have changed with a shift from private to public transport and a large decrease in aviation. In addition, energy consumption in the household has greatly reduced. Such changes may be the result of a number of factors, some prompted by government such as strong environmental regulation or personnel carbon quotas. Alternatively society may be responding to external factors such as international conflict or worsening climate change impacts.

This is potentially a high tech sustainability world with a mixture of large-scale and smaller-scale technologies. A strong government has managed to curb personnel energy use in the home and for mobility, putting in place policies to drive innovation in low carbon supply technologies. Alternatively, sustainability might have been achieved by accident rather than design with external factors, such as security, driving the search for self-sufficiency and an inward focused UK.

Figure 1. Scenario economic and energy demand summary

| Module | Consumption (Mtoe) | % of consumption | Carbon (MtC) | % of carbon | % of GDP |
|---|---|---|---|---|---|
| Household | 19.0 | 20.9% | 12.3 | 18.9% | |
| Industry (Intensive) | 8.0 | 8.8% | 5.9 | 9.1% | 1.4% |
| Industry (other) | 13.0 | 14.3% | 8.2 | 12.6% | 9.5% |
| Public Administration | 2.1 | 2.3% | 1.3 | 2.0% | 4.9% |
| Commercial | 12.2 | 13.5% | 8.0 | 12.2% | 78.0% |
| Aviation domestic | 0.5 | 0.5% | 0.4 | 0.6% | |
| Aviation international | 8.6 | 9.4% | 6.9 | 10.5% | |
| Rail | 1.3 | 1.4% | 1.2 | 1.8% | |
| Road Freight | 6.9 | 7.5% | 5.5 | 8.4% | |
| Road Passenger (Private) | 7.9 | 8.7% | 3.1 | 4.8% | |
| Road Passenger (Public) | 1.8 | 1.9% | 0.7 | 1.0% | |
| Water Domestic | 0.8 | 0.9% | 0.3 | 0.4% | |
| Water International | 8.3 | 9.1% | 5.8 | 8.9% | |
| **Total Transport** | **36.0** | **39.6%** | **23.9** | **36.6%** | |
| Agriculture | 0.3 | 0.3% | **0.2** | 0.3% | 0.4% |
| Construction | 0.3 | 0.3% | 0.2 | 0.4% | 5.7% |
| **Total consumption** | **90.9** | 100.0% | **60.1** | **-** | **3.25%** |
| Energy industry use | 7.9 | 5.4% | 5.2 | 8% | |
| **Total primary demand** | **145.9** | **-** | **65.3** | **-** | **£4,693** |

### *Shape of the economy*

Well above current average growth results in an economy four times bigger than today. Continued high growth in the commercial sector, sees it consolidate its position as the most important contributor to the economy. Of the traditional energy intensive industries, the chemical industry continues to experience growth, albeit slower than the historical trend, and the previously declining metals sector is experiencing a sustained period of recovery. There has been conspicuously slow growth in the public administration sector, and its importance within the economy has declined as a consequence.

### *Demand characteristics*

Annual energy intensity reductions are above current levels, with the exception of energy intensive industries. This has lead to an overall energy demand half the current level despite high economic growth. Substitution of other energy by electricity across many sectors, particularly within public administration and industry, results in roughly equal proportions of demand being met through electricity and other energy.

**Services and Industry**

Reductions in energy intensity have occurred across all the wealth creating sectors of the economy; with the exception of energy intensive industries, reductions have occurred at rates higher than current trends. The high level of economic growth may have enabled large investments in improving the energy efficiency of equipment and processes; alternatively high energy prices and security issues may have prompted businesses to focus their attention on cost reductions or such a focus may have been driven by a strong government pushing the country towards sustainability.

**Households**

Household numbers have increased to 27.5 million by 2050, though enormous reductions in the energy intensity of the sector has led to a drop in household energy consumption to 40% of current levels. Such changes have been brought about by improvements in the efficiency with which energy is used in the home and changes to the ways in which householders use energy. Three quarters of energy needs are met through the use of electricity; the majority of this is supplied by the grid with the remainder from direct supply from on-site renewables. Hydrogen is an important fuel within the home and solar heating of living space and hot water is widespread.

**Transport**

There has been a big curb in the growth in international aviation though the sector is still twice as big as at present; energy intensity reductions are significant and higher than IPCC estimate. Growth in domestic aviation has ceased, with a shift towards other forms of public transport. Overall, the public transport sector is 10 times larger than today. Private road traffic has dropped by a quarter with energy intensity decreasing significantly higher than current trends. Energy intensity may be reduced in many ways as a consequence of passenger behaviour, government regulation or increases in the technical efficiency of vehicles themselves, as a result of fuel cell powered vehicles for example. In terms of passenger kilometres, there is nearly twice the level of mobility of today but there has been a break in the relationship between income and mobility with a decrease in mobility in relation to income.

Road freight drops by a third, in contrast marine freight experiences strong growth for both international and domestic movements. Energy intensity reductions are substantial; these could result from increasing the technical efficiency of engines, through the use of hydrogen powered fuel cell for example, improving operational practices or combinations of both.

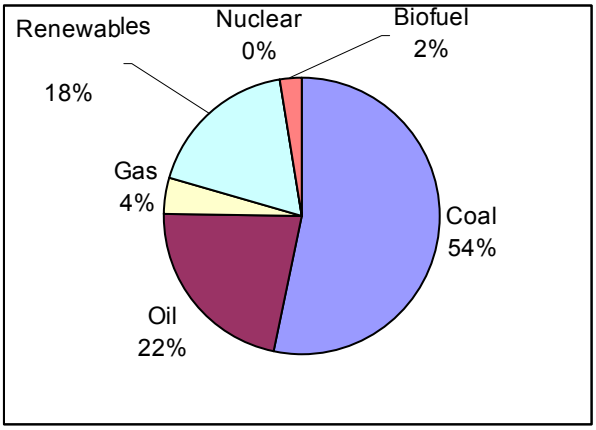
### *Supply side*

Table 2. Electricity sources

| Source | Electricity use (Mtoe) | % of grid supply | % of total electricity supply |
|---|---|---|---|
| CF | 17.7 | 48% | 35% |
| CCGT | - | 0% | 0% |
| NU (Grid) | - | 0% | 0% |
| NU (H2) | - | - | 0% |
| RENEW (Grid) | 8.9 | 24% | 17% |
| RENEW (h2) | 8.5 | - | 17% |
| CCS | 8.9 | 24% | 17% |
| BIO | 1.5 | 4% | 3% |
| C-CHP | - | - | 0% |
| G-CHP | 2.5 | - | 5% |
| B-CHP | 0.1 | - | 0% |
| ON-REN | 3.2 | - | 6% |
| **TOTAL** | **51.3** | | |

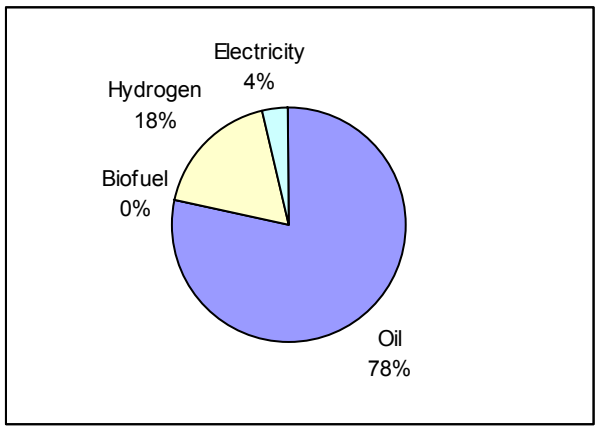
There is a large electricity grid and a strong preference for indigenous energy sources for generation. Half of electricity is supplied by coal burnt in conventional power stations; the remaining contribution comes from equal proportions of coal with carbon capture and storage and renewable energy. Nuclear power and gas have been phased out. Supply from on-site renewables has grown strongly in the domestic, public, commercial and non energy intensive industry sectors.

Figure 1. Primary energy demand




Hydrogen is an important energy source, particularly for the transport sector where a fifth of energy consumed comes from hydrogen. Fuel cell technology has developed stationary applications for hydrogen, particularly within the household and non energy intensive industry sectors. Electrolysis from renewable energy and gasification of coal with CCS supply equal proportions of hydrogen production. The scale of energy demand met by hydrogen implies a widespread infrastructure for supply, storage and distribution in place.

Figure 2. Transport fuel mix




End use technology within the transport sector, and a hydrogen supply infrastructure, has developed to the extent that it is an important fuel for road passenger transport, though limited distributed refuelling opportunities, along major motorways for example, mean that it has not made the same penetrations within road freight. Hydrogen use is not feasible for aviation. Biofuels are not used within transport.

CHP supplies 5% of energy needs, with coal an important fuel, with gas and limited biofuel firing. CHP use is concentrated within industrial and productive sectors. Use of biofuels is limited and confined to heat and power applications.

# 130a

**UK picture**

The 130a scenario is a medium-low demand scenario. It has a higher level of economic growth than the other 130 Mtoe demand scenario with economic trends continuing as today.

Developments of renewables and carbon capture and storage suggest some preference for indigenous supply, with the exception being continued use of oil within the transport sector. Technological innovation has been required to enable the widespread use of hydrogen across both stationary and transport applications. Nuclear power has been phased out; this could be due to concerns over environmental impacts and waste disposal, or for economic reasons as developments in other areas such as hydrogen have impacted on the market share.

There have been efforts to control growth in passenger transport and reductions in energy intensity across all sectors. In a growth scenario, such changes may be the result of successful use economic instruments with citizens and businesses paying attention to the 'bottom line'. Overall this scenario is possibly a 'middle way' where there is a compromise between sustainability and the market.

Figure 1. Economy and energy demand summary

| Module | Consumption (Mtoe) | % of consumption | Carbon (MtC) | % of carbon | % of GDP |
|---|---|---|---|---|---|
| Household | 29.5 | 22.7% | 7.4 | 11.5% | |
| Industry (Intensive) | 6.5 | 5.0% | 2.9 | 4.5% | 0.8% |
| Industry (other) | 5.7 | 4.4% | 2.2 | 3.4% | 4.7% |
| Public Administration | 3.4 | 2.6% | 1.2 | 1.9% | 10.1% |
| Commercial | 14.1 | 10.9% | 2.6 | 4.0% | 79.4% |
| Aviation domestic | 0.8 | 0.6% | 0.7 | 1.0% | |
| Aviation international | 19.3 | 14.9% | 14.7 | 22.7% | |
| Rail | 2.7 | 2.1% | 0.3 | 0.5% | |
| Road Freight | 8.7 | 6.7% | 4.8 | 7.5% | |
| Road Passenger (Private) | 12.9 | 9.9% | 7.9 | 12.3% | |
| Road Passenger (Public) | 1.8 | 1.4% | 0.1 | 0.2% | |
| Water Domestic | 0.4 | 0.3% | 0.3 | 0.5% | |
| Water International | 22.7 | 17.5% | 14.4 | 22.4% | |
| **Total Transport** | **69.4** | **53.4%** | **43.3** | **67.0%** | |
| Agriculture | 0.4 | 0.3% | **0.1** | 0.1% | 0.4% |
| Construction | 0.8 | 0.7% | 0.4 | 0.6% | 4.6% |
| **Total consumption** | **129.8** | 100.0% | **60.0** | **-** | **2.72%** |
| Energy industry use | 9.8 | 5.3% | 4.5 | 7% | |
| **Total primary demand** | **185.7** | **-** | **64.6** | **-** | **£3,661** |

### *Shape of the economy*

The shape of the economy in 2050 remains much as it is today with overall economic growth continuing at the same rate at the present day, resulting in an economy four times larger. Wealth creating sectors remain similar, with strong economic performance from the commercial sector. Non energy intensive industries and the chemical sector grow, albeit very slowly, and there is continuing decline for other energy intensive sectors such as metals and minerals.

***General Demand characteristics***

In spite of strong economic performance, energy demand is three quarters of today's level. There has been a substantial shift towards electricity consumption as opposed to direct combustion for meeting space and other heating needs.

**Services and Industry**

Within the traditional energy intensive manufacturing sectors, energy intensity continues to decrease, though the rate of improvement has slowed considerably compared to current trends, this could be due to increased automation for example. Declining energy consumption within the sector, as a proportion ok UK consumption, is largely a consequence of declining activity. The picture is different within the non energy intensive industrial sector where huge reductions are being made in energy intensity, potentially through operational changes and low cost measures, since growth remains tentative.

Despite huge reductions in energy intensity, which see a complete reversal of current trends, energy consumption in the commercial sector increases with respect to today's level as a consequence of the high level of economic growth in this sector.

**Households**

There is no overall increase in the number of households, though significant improvements in energy intensity and a shift to greater use of electricity, over other energy sources, within the home is potentially a result of a turnover in the building stock as well as changing consumer behaviour.

**Transport**

Passenger transport continues to grow, though there has been a slow down in private road transport and international aviation in comparison to trends seen today. By contrast, there has been increased growth in public modes of transport such as bus and trains. Energy intensity has reduced across the spectrum of passenger transport modes, with the largest improvements seem in the domestic aviation and private road transport. In the case of aviation, such reductions are a reversal of current trends.

Road freight continues to grow, though more slowly than economic output. With no growth in domestic water freight with respect to today, either the economy is becoming increasingly 'weightless' or a greater proportion of goods are imported and exported as implied by a growth in international marine, though given the importance of coal, imports would rely on marine freight transport to the UK. Energy intensity across the road freight sector decreases considerably; such changes may be the result of operational practices, or improvements in energy efficiency.

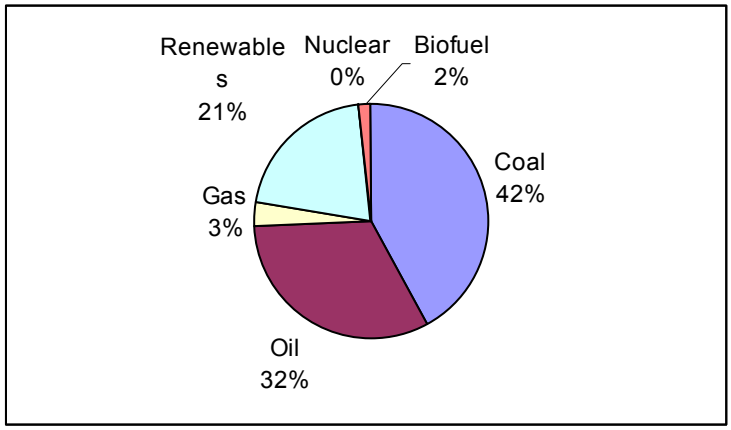
### *Supply side*

Table 2. Electricity sources

| Source | Electricity use (Mtoe) | % of grid supply | % of total electricity supply |
|---|---|---|---|
| CF | 2.4 | 8% | 4% |
| CCGT | - | 0% | 0% |
| NU (Grid) | - | 0% | 0% |
| NU (H2) | - | - | 0% |
| RENEW (Grid) | 14.5 | 46% | 27% |
| RENEW (h2) | 11.3 | - | 21% |
| CCS | 14.5 | 46% | 27% |
| BIO | - | 0% | 0% |
| C-CHP | 3.1 | - | 6% |
| G-CHP | 1.6 | - | 3% |
| B-CHP | 1.2 | - | 2% |
| ON-REN | 6.1 | - | 11% |
| **TOTAL** | **54.6** | | |

The grid is entirely supplied by renewable energy and coal with widespread carbon capture and storage. Nuclear power has been phased out, with no contribution to the grid from gas or combustion of biofuels. Overall, 83% of total energy is from fossil fuels. Renewables are also important for on-site supply of both electricity and other energy, most notably in the domestic and commercial sectors.

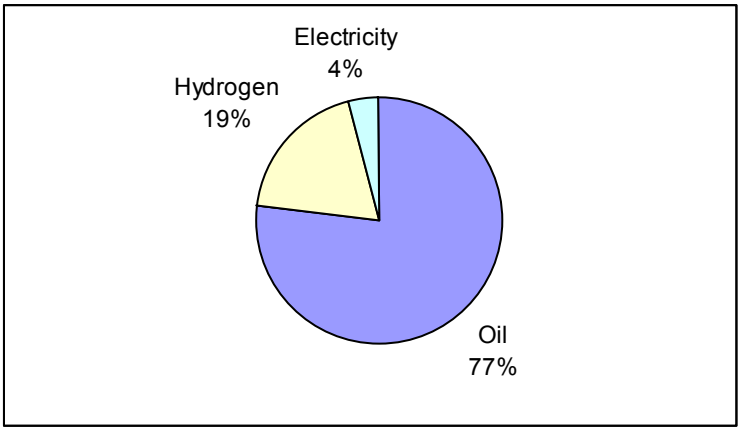
Figure 1. Primary energy demand




CHP has penetrated the UK market, across the domestic, industrial and service sectors. Coal is the most important fuel, with half the market share, the remainder coming from gas and biofuels. The large proportion of coal CHP implies a large number of district scale CHP schemes supplying a number of end users and of large enough scale to ensure economical flue gas cleaning, or potentially technological advancements which make smaller units viable. Coal and biofuel CHP, potentially from waste, is important in the context of industrial sectors.

Hydrogen is produced by coal gasification, with carbon capture and storage, and by electrolysis from renewables. Production of hydrogen through coal gasification and carbon capture requires a centralised system with associated storage and distribution. Without technological improvements which allow carbon capture and storage at a smaller scale than at present this potentially rules out local grids, supplying neighbourhoods and commercial districts, and implies greater use of cylinder delivery and replacement tanks. Renewable production may be more dispersed allowing local pipeline supply networks.

Figure 2. Transport fuel mix




Oil remains the most important transport fuel, with some hydrogen but no penetration of biofuels. Hydrogen technology has developed to allow hydrogen as a fuel across all forms of transport, including international aviation. Renewable generation of hydrogen may enable more widespread distribution of the fuel improving opportunities for hydrogen vehicles.

# 130b

**UK picture**

130b is a medium-low energy demand scenario with lower economic growth than the other 130 Mtoe demand scenario. There has been a shift in the make up of the economy, with strong growth in the public sector and a slowdown in the commercial sector. The growth in public administration may be due to increased activity in such as transport, energy supply or housing.

There is a strong focus on renewable forms of energy within this scenario, with on-site supply through renewables and CHP important. There is a mixture of small scale and large scale technologies, in a society where there has been a shift to public transport; this may imply a society with sustainability values, or change imposed by more prescriptive policies.

Society may be collectivist in decision making, with strong national government; such an approach would make use of national planning and regulation. An alternative view is for collectivist decision making, but with a bottom-up focus where there is greater local and regional participative decision-making. Consumer behaviour towards energy consumption has changed, with a shift to public transport; potentially a trade-off may have been made, through a quota system for example, which allows continued international air travel, or costs may have risen dramatically.

The growth in manufacturing might imply a more (large-scale) regionalist approach to production which is driven by trade barriers, global conflicts between major trading blocks, by renaissance in manufacturing sectors due to innovation or by restrictions on global transportation due to high associated costs.

Table 1. Economic and energy demand summary

| Module | Consumption (Mtoe) | % of consumption | Carbon (MtC) | % of carbon | % of GDP |
|---|---|---|---|---|---|
| Household | 18.1 | 13.9% | 3.0 | 4.7% | |
| Industry (Intensive) | 9.6 | 7.4% | 3.0 | 4.6% | 2.4% |
| Industry (other) | 19.2 | 14.7% | 2.5 | 3.9% | 12.5% |
| Public Administration | 8.6 | 6.6% | 1.8 | 2.8% | 33.3% |
| Commercial | 7.2 | 5.5% | 0.9 | 1.4% | 40.2% |
| Aviation domestic | 0.6 | 0.5% | 0.5 | 0.8% | |
| Aviation international | 33.9 | 25.9% | 27.2 | 42.3% | |
| Rail | 3.3 | 2.5% | 1.3 | 2.0% | |
| Road Freight | 6.9 | 5.2% | 5.5 | 8.5% | |
| Road Passenger (Private) | 4.8 | 3.7% | 3.9 | 6.0% | |
| Road Passenger (Public) | 4.5 | 3.5% | 2.1 | 3.2% | |
| Water Domestic | 0.4 | 0.3% | 0.2 | 0.4% | |
| Water International | 8.7 | 6.6% | 5.4 | 8.3% | |
| **Total Transport** | **63.1** | **48.3%** | **46.0** | **71.6%** | |
| Agriculture | 4.4 | 3.4% | **1.9** | 3.0% | 4.1% |
| Construction | 0.5 | 0.4% | 0.4 | 0.6% | 7.5% |
| **Total consumption** | **130.7** | 100.0% | **59.5** | **-** | **1.67%** |
| Energy industry use | 10.4 | 5.7% | 4.8 | 7% | |
| **Total primary demand** | **184.8** | **-** | **64.3** | **-** | **£2,236** |

### *Shape of the economy*

There is overall growth in the economy, but a change in the make up with declining growth within the commercial sector. Whilst there have been small upturns in previously declining sectors, such as metals and minerals, and growth in non energy intensive industries, this has not been able to compensate for the commercial downturn. The public administration sector has grown strongly, however it is the agricultural sector which has seen the greatest turnaround with output ten times higher than today

### *General Demand Characteristics*

Overall energy consumption is three quarters of levels today, and whilst some of this decrease is due to declining economic activity in the commercial sector, reductions in energy intensity have been made across all productive sectors of the economy.

**Services and industry**

Traditional energy intensive industries improved their performance above current trends and decreased their energy intensity, possibly as result of new capital investments as well as operational practices. Similar levels of improved growth in non energy intensive sector may have resulted from new products and processes which bring with them inherently more efficient manufacturing.

The public sector has seen a period of sustained expansion; with high public transport there is the potential for a degree of public ownership. Alternatively municipalities may now own their own generating plant, or have greater responsibility than at present for new housing and building projects.

Growth in the agricultural sector may come from greater indigenous food production, or production of fuel crops.

**Households**

There have been large reductions in household energy consumption, brought about by large decreases in energy intensity. With no net increase in the number of households, this improvement may have been brought about by stock turnover or improvement, changing behaviour or combinations of the two. Such changes may have been driven by the public sector, through energy efficiency programmes or compulsory energy efficiency measures for private house owners.

**Transport**

International aviation continues to grow, though more slowly than at present, whereas domestic aviation has stagnated. Whilst energy intensity has reduced within the domestic aviation sector, the converse is true in the case of international aviation, potentially as the result of falling passenger numbers or lack of improvements in engine efficiency. Efficiency in public transport, both rail and road has increased by a factor of 16 compared to today, this provides high levels of mobility despite a significant decrease in levels of private road transport. Despite declining passenger kilometres, energy intensity reductions are seen within the private road transport sector in contrast to both rail and public road.

Road freight is stagnant with growth in freight transferred to domestic waterways and rail.

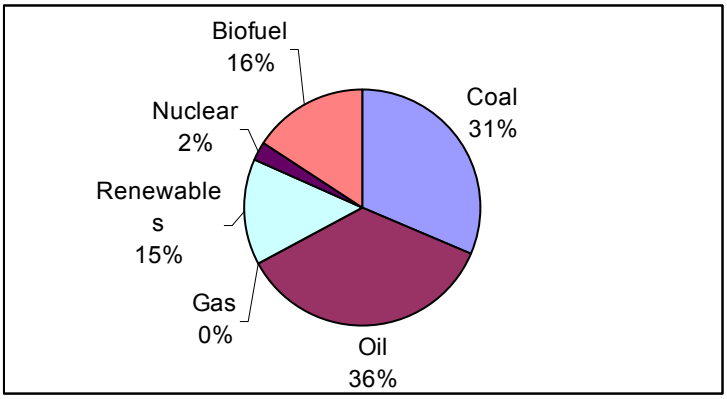
### *Supply side*

Table 2. Electricity sources

| Source | Electricity use (Mtoe) | % of grid supply | % of total electricity supply |
|---|---|---|---|
| CF | 2.7 | 11% | 6% |
| CCGT | - | 0% | 0% |
| NU (Grid) | 2.0 | 8% | 4% |
| NU (H2) | - | - | 0% |
| RENEW (Grid) | 8.0 | 32% | 18% |
| RENEW (h2) | 4.0 | - | 9% |
| CCS | 5.4 | 21% | 12% |
| BIO | 7.1 | 28% | 15% |
| C-CHP | 2.3 | - | 5% |
| G-CHP | - | - | 0% |
| B-CHP | 4.2 | - | 9% |
| ON-REN | 9.9 | - | 22% |
| **TOTAL** | **45.6** | | |

The electricity grid supplies approximately the same proportion of total energy needs as today, roughly one fifth, though in absolute terms the capacity is smaller. Whilst the make up of the grid is diverse, in the region of 60% of supply comes from renewable energy and biofuels, with coal generation, both with and without carbon capture and storage, contributing a third; the remainder comes from nuclear power. Gas is not utilised anywhere. The level of biomass penetration, for grid supply and CHP will require some imports, either as wood fuel or alternatively as liquid biofuels. On-site use for renewable energy for electricity generation is important in the industry and service sectors, along with space and hot water heating from renewables, particularly in the household and commercial sectors.

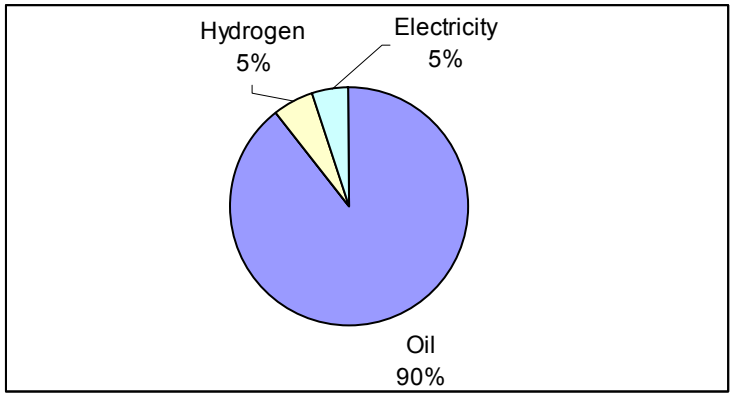
Figure 1. Primary energy demand




CHP has penetrated the UK market, fuelled by coal and biomass. Biomass CHP is the major fuel for plants supplying domestic and other industry, possibly in neighbourhood units within mixed used residential/new manufacturing industry zones. Coal is the fuel of choice for industrial CHP, where the size of units, and the potential for linking into other clean up systems provides the economies of scale for flue gas cleaning for gaseous pollutants, such as $SO_2$ and NOx, possibly including carbon capture for the removal of carbon dioxide.

Hydrogen technology has developed for primarily stationary applications, with limited use in transport. In the transport sector it is used for public passenger transport, namely rail and buses, where centralised refuelling can be provided. The technology has also developed for hydrogen to power marine transport, both international and domestic, where issues of the weight of fuel are less important than for other modes, such as aircraft. Four fifths of the hydrogen is produced by coal gasification, and the remainder from renewables. Such a system will necessitate centralisation of supply, and a distribution network to supply end users.

Figure 2. Transport fuel mix




Oil remains the major fuel for transport, fuelling aircraft and all road transport, with the exception of buses. Biofuels are used in limited quantities, and their use is confined to the agricultural sector where there is small scale on-site manufacture.

# 200 a

**UK picture**

Scenario 200a is one of two medium-high growth scenarios where energy demand is a third higher than today. This scenario differs from the 200b scenario in that it has lower levels of economic growth and an economy which is broadly similar to the present day in terms of the relative contributions to GDP from different sectors.

This moderate growth UK is potentially a place of moderate innovation. Innovation may be driven by rising costs of fuel imports pushing development of lower cost alternatives, or alternatively concerns over security of supply. The mix of energy supply is similar to the current mix though nuclear is replacing gas. Low carbon fuels are developed to allow the desire for mobility to be maintained.

Government is strong in implementing infrastructure changes, such as a new nuclear build programme, but less successful in motivating changes in behaviour with respect to personnel mobility and energy consumption in the home. Where changes have occurred, a shift towards public transport this has potentially been the result of market forces. Alternatively a strong energy industry has been able to offer a route to enable emission reduction targets to be met in the absence of a strong drive towards more sustainable consumption of energy.

Figure 1. Economy and energy demand summary

| Module | Consumption (Mtoe) | % of consumption | Carbon (MtC) | % of carbon | % of GDP |
|---|---|---|---|---|---|
| Household | 43.4 | 21.7% | 11.9 | 18.3% | |
| Industry (Intensive) | 19.2 | 9.6% | 4.2 | 6.4% | 2.7% |
| Industry (other) | 9.2 | 4.6% | 1.9 | 2.9% | 5.1% |
| Public Administration | 6.0 | 3.0% | 1.7 | 2.6% | 11.9% |
| Commercial | 17.4 | 8.7% | 3.4 | 5.2% | 67.5% |
| Aviation domestic | 1.3 | 0.7% | 1.0 | 1.6% | |
| Aviation international | 52.7 | 26.4% | 24.1 | 36.9% | |
| Rail | 0.6 | 0.3% | 0.1 | 0.2% | |
| Road Freight | 14.2 | 7.1% | 4.2 | 6.5% | |
| Road Passenger (Private) | 12.9 | 6.4% | 2.2 | 3.3% | |
| Road Passenger (Public) | 1.2 | 0.6% | 0.2 | 0.3% | |
| Water Domestic | 1.3 | 0.7% | 0.2 | 0.4% | |
| Water International | 17.9 | 8.9% | 4.3 | 6.5% | |
| **Total Transport** | **102.1** | **51.1%** | **36.4** | **55.7%** | |
| Agriculture | 0.3 | 0.2% | **0.0** | 0.0% | 0.4% |
| Construction | 2.1 | 1.1% | 0.5 | 0.7% | 12.5% |
| **Total consumption** | **199.8** | 100.0% | **59.9** | **-** | **2.57%** |
| Energy industry use | 17.8 | 5.6% | 5.3 | 8% | |
| **Total primary demand** | **317.3** | **-** | **65.3** | **-** | **£3,413** |

### *Shape of the economy*

Levels of economic growth are slightly lower than the present day, with growth of 2.3% between now and 2050. Structurally, the economy is similar to today with continued strong performance by the commercial sector and a continuing of current trends in the public sector and non energy intensive industries. There has been a period of sustained growth in the chemical sector, though no upturn in other energy intensive industries such as minerals. Overall, the size of the economy is 2.5 times bigger than today.

### *General Demand characteristics*

Energy demand is a third higher than today, with a large increase in electricity demand and a small fall in the demand for other energy types as more end user needs are met through the use of electricity. All sectors, with the exception of international aviation, achieve reductions in energy intensity at rates consistent with current trends.

**Services and industry**

Strong economic growth in the commercial sector leads to an energy consumption higher than the present day, despite continued reductions in energy intensity. All other productive sectors reduce their energy consumption in real terms, with the exception of the chemicals industry which experiences strong economic growth and is unable to maintain its current high rate of decrease in energy intensity.

**Households**

There is overall growth in the number of households, with a total of 27.5 million in 2050. The rate of energy intensity reduction in the household improves slightly compared to current trends, resulting in a slight fall in overall energy consumption over the period. There is a marked shift to electricity use within the home. These changes may be the result of refurbishment of current building stock and some behavioural change

**Transport**

There are moderate increases in distances travelled across passenger terrestrial transport, though no growth in private road transport with a shift to rail and public road. Overall levels of mobility are higher, though aviation expands more slowly than current trends. Energy intensity is decreasing across all forms of road transport, most noticeably in private cars. Such changes could be brought about through technological improvements, or changing behaviour, such as increasing the number of passengers travelling in a vehicle.

Road freight sees an increase in freight tonne kilometres, though less than would be expected given increase in GDP; transport on domestic waterways and international marine increases. These changes imply a potential increase in water movements, for chemicals and other products for example. There is a marked reduction in energy intensity for road freight transport which could be the result of improving fleet management and changing delivery patterns.

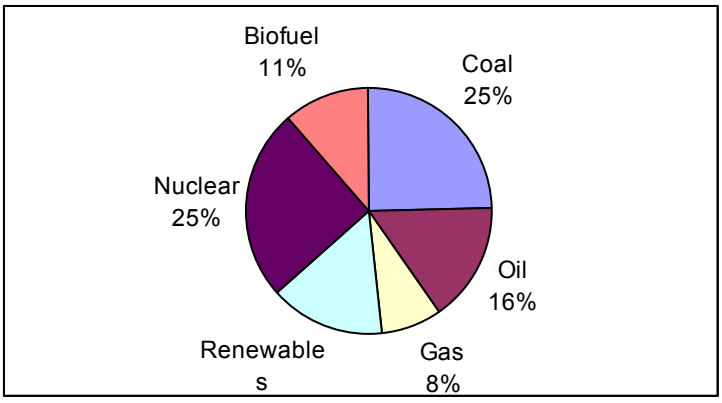
### *Supply side*

Table 2. Electricity sources

| Source | Electricity use (Mtoe) | % of grid supply | % of total electricity supply |
|---|---|---|---|
| CF | 3.4 | 6% | 4% |
| CCGT | 3.4 | 6% | 4% |
| NU (Grid) | 19.6 | 37% | 21% |
| NU (H2) | 5.8 | - | 6% |
| RENEW (Grid) | 12.2 | 23% | 13% |
| RENEW (h2) | 12.8 | - | 14% |
| CCS | 14.7 | 28% | 16% |
| BIO | - | 0% | 0% |
| C-CHP | 2.1 | - | 2% |
| G-CHP | 4.1 | - | 4% |
| B-CHP | 3.0 | - | 3% |
| ON-REN | 12.7 | - | 14% |
| **TOTAL** | **93.9** | | |

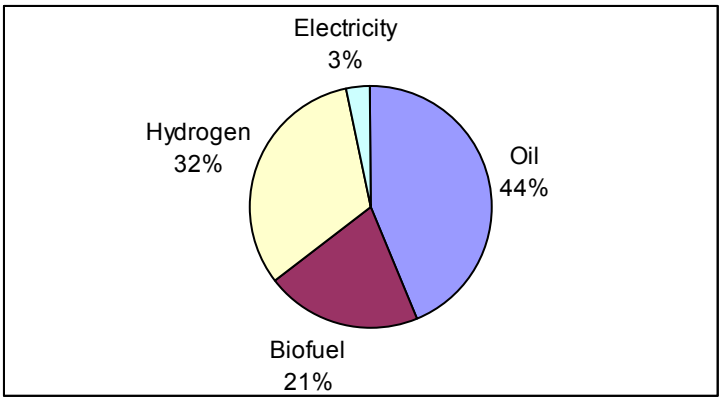
There is a diverse electricity grid supplying a quarter of energy needs. The major contributions come from renewables, nuclear and coal with carbon capture and storage with some gas and conventional coal plant. There is no combustion of biofuels for the grid. On–site renewables supply electricity and space and water heating directly to end users, particularly in the chemical industry and the commercial sectors which have experienced the highest growth.

Figure 1. Primary energy demand




CHP has penetrated the market across all sectors, with gas the most important fuel, followed by biofuels and then coal. The high proportion of gas implies a role for gas fired micro-CHP systems, with coal fuelling larger district and neighbour plants supplying a variety of end users.

Figure 2. Transport fuel mix




Hydrogen supplies a fifth of total energy, with a strong penetration as a transport fuel rather than stationary applications; biofuels are also prevalent across all transport modes. The technology has developed to allow hydrogen within the aviation sector, leading to hydrogen powered planes for long international flights where drag and fuel weight issues are less critical. Biofuels are also important in aviation, though kerosene is still the major fuel. Half of marine transport is hydrogen powered. Across road transport vehicles, biofuels and hydrogen are replacing oil as the sector becomes increasingly low carbon, with a corresponding supply and distribution infrastructure in place. Liquid biofuels will have to be imported to meet demand.

Hydrogen is produced in equal proportions from electrolysis from nuclear energy and renewables and coal gasification. Nuclear and coal gasification supplies will require a more centralised production, distribution and storage system for the hydrogen produced, whereas renewable production may be more dispersed, with on-site renewables offering the potential for on-site electrolysis at nodes across the road network.

# 200 b

**UK picture**

Scenario 200b is one of two medium-high growth scenarios where energy demand is a third higher than today. This scenario differs from the 200a scenario in that it experiences a high level of economic growth and an industrial renaissance driven by new industries.

This high growth world shows large improvements in energy intensity which may potentially be the result of a high level of innovation, although widespread behavioural change is also likely. Such change may also be the result of legislation, economic instruments or advanced control technology, rather than widespread strong environmental values. Technology is potentially an important driver in a society where an interventionist government imposes a more environmentally sustainable lifestyle on its citizens in order to meet strong international regulations.

An alternative view is for strong environmental values within society to have driven a push towards new technologies. Nuclear power is widespread, but problems with waste have been solved and public perceptions are no longer a barrier to a build new programme. A mix of small and large scale technologies may have resulted from a strong desire for local supply, driven by new communities forming round new industrial clusters. Although the population is potentially more wealthy, people's preferences arise around non energy intensive activities. In this case there may be a less interventionist style of government.

Table 1. Economy and energy demand summary

| Module | Consumption (Mtoe) | % of consumption | Carbon (MtC) | % of carbon | % of GDP |
|---|---|---|---|---|---|
| Household | 11.1 | 5.6% | 1.8 | 2.7% | |
| Industry (Intensive) | 18.7 | 9.4% | 4.3 | 6.7% | 5.5% |
| Industry (other) | 36.7 | 18.4% | 7.7 | 11.9% | 20.8% |
| Public Administration | 3.0 | 1.5% | 0.2 | 0.4% | 9.9% |
| Commercial | 6.8 | 3.4% | 0.5 | 0.8% | 53.5% |
| Aviation domestic | 0.6 | 0.3% | 0.3 | 0.4% | |
| Aviation international | 81.7 | 41.0% | 32.9 | 50.5% | |
| Rail | 4.2 | 2.1% | 1.6 | 2.5% | |
| Road Freight | 4.2 | 2.1% | 2.0 | 3.1% | |
| Road Passenger (Private) | 4.8 | 2.4% | - | 0.0% | |
| Road Passenger (Public) | 2.2 | 1.1% | - | 0.0% | |
| Water Domestic | 0.8 | 0.4% | 0.4 | 0.6% | |
| Water International | 21.6 | 10.9% | 8.0 | 12.3% | |
| **Total Transport** | **120.2** | **60.4%** | **45.2** | **69.4%** | |
| Agriculture | 0.4 | 0.2% | **0.1** | 0.1% | 0.4% |
| Construction | 2.1 | 1.1% | 0.3 | 0.5% | 9.9% |
| **Total consumption** | **199.0** | 100.0% | **60.2** | **-** | **3.07%** |
| Energy industry use | 16.3 | 5.5% | 4.9 | 8% | |
| **Total primary demand** | **294.3** | **-** | **65.1** | **-** | **£4,305** |

### *Shape of the economy*

The structure of the economy has seen substantial change from current conditions. The UK has been undergoing an industrial renaissance with strong growth in both energy intensive and non energy intensive industries. The growth in the non energy intensive industry sectors could be driven by new technologies such as biotech or nanotech. Growth in other industrial sectors may be driven by declining manufacturing opportunities overseas.

### *General Demand Characteristics*

Total energy consumption has increased by a third of current levels, with an increase in the consumption of gas and electricity; the increase is more marked in the case of electricity. Rates of reduction in energy intensity across the whole economy are considerably greater than current trends.

**Services and Industry**

Energy intensity is reducing across service and industry sectors at higher rates than current trends; such high rates are likely to require changes in capital stock with more efficient plant as well as operational and behavioural changes. With widespread growth in new and traditional industries, these new plants may be inherently more efficient, potentially through intensification or synergistic co-location of plants.

**Households**

A high growth rate sees household numbers top 40 million, with a total energy consumption which is 80% lower than today. With such a large increase in household numbers, new housing stock is likely to be inherently more efficient in terms of energy use, yet the very high improvements in energy intensity also require change in the behaviour of householders themselves. This is particularly relevant in the light of the high levels of economic growth.

**Transport**

This is a highly mobile society, with five times as many passenger kilometres travelled than at present. There has been a modal shift from private road transport to public transport which both expand at a rate faster than the level of economic growth. Whilst domestic aviation has been curbed, there is large growth in international aviation with sixteen times as many kilometres travelled in international aviation as the present day. There are large increases in the number of passenger km travelled per unit of fuel input, with efficiency of mobility far greater than today.

For the transport of freight, rail and water freight are gaining in importance compared with road freight. The energy intensity reduces across all modes requiring improving operational procedures and more efficient technology.

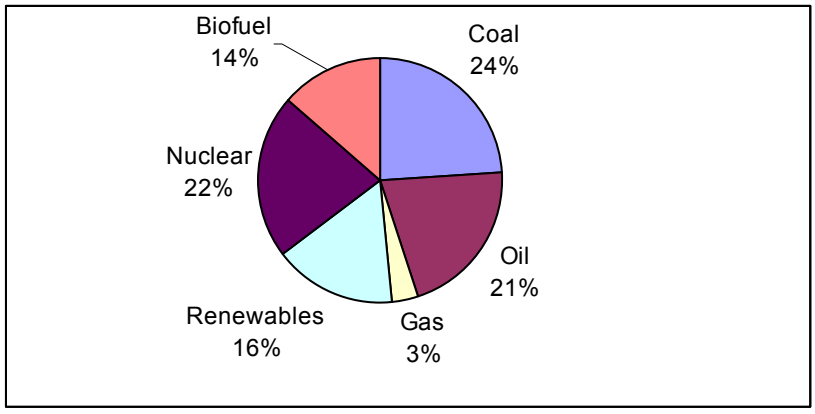
### *Supply side*

Table 2. Electricity supply

| Source | Electricity use (Mtoe) | % of grid supply | % of total electricity supply |
|---|---|---|---|
| CF | - | 0% | 0% |
| CCGT | - | 0% | 0% |
| NU (Grid) | 10.4 | 33% | 15% |
| NU (H2) | 6.3 | - | 9% |
| RENEW (Grid) | 15.6 | 50% | 22% |
| RENEW (h2) | 9.3 | - | 13% |
| CCS | 5.2 | 17% | 7% |
| BIO | - | 0% | 0% |
| C-CHP | 4.7 | - | 7% |
| G-CHP | 4.1 | - | 6% |
| B-CHP | 6.2 | - | 9% |
| ON-REN | 8.1 | - | 12% |
| **TOTAL** | **70.0** | | |

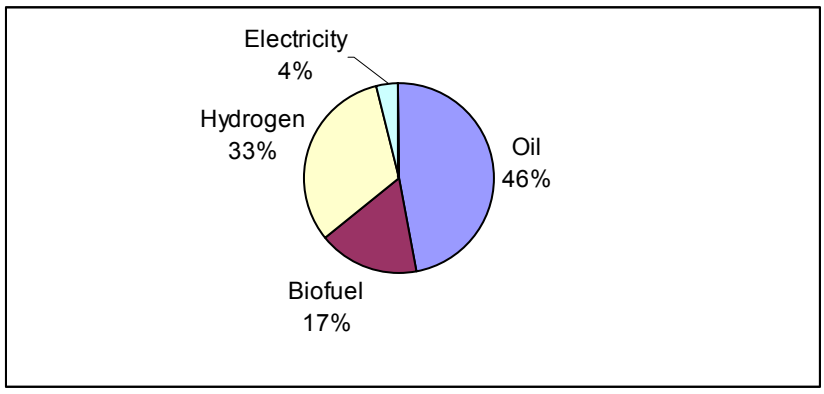
Renewable energy supplies 50% of electricity to the grid, with electrolysis from renewables for hydrogen production as well as on-site renewables for heat and power. On-site renewables use is concentrated within the high growth industrial sectors. Nuclear energy contributes 30% to the grid, with the remainder from coal with carbon capture and storage. There is no combustion of biofuels and gas use in combined cycle gas turbines has been phased out in favour of more efficient CHP technology. Overall, there is a highly diverse supply system with a mix of small and large scale technologies.

Figure 1. Primary energy demand




CHP schemes are widespread across the whole economy fuelled by gas, coal and biofuels. The diversity of fuel types implies a mix of large and small scale schemes.

Figure 2. Transport fuel mix




Hydrogen meets nearly a quarter of energy needs, with both stationary and motive applications. Half of the hydrogen is produced by electrolysis from renewable energy. Such a system has the potential to be either dispersed, fuelling a network of transport filling stations for example, or more centralised, generating hydrogen from large renewables such as offshore wind farms. All private, and a proportion of public, road transport is hydrogen fuelled and it is used for marine and international travel. That said oil remains the most widely used transport fuel, with some biofuels, for road freight and aviation.

# 330a

## UK picture

330 a is one of two high energy demand scenarios, distinguished from scenario 330b by a renaissance in industrial sectors as well as a strong commercial sector.

Given the large growth across the productive sectors, a lack of significant decreases in energy intensity potentially points to a government weak in the face of a powerful industrial and commercial sector. The declining importance of the public sector reinforces this, as more services are privatised, augmenting the commercial sector.

The scale of nuclear energy, and the penetration of nuclear CHP points to either a widescale acceptance of the technology, or a public unable to object. This future for the UK is corporatist world where big business and government makes decisions behind closed-doors.

Alternatively, we have a high tech manufacturing world where communities are nestled around their nuclear power plant and industrial zone. Such zones are government planned, with $CO_2$ commitments met through low carbon generation without a broader drive towards sustainability, as a consequence of the relative costs of low carbon and fossil based fuels.

Table 1. Scenario economic and energy demand summary

| Module | Consumption (Mtoe) | % of consumption | Carbon (MtC) | % of carbon | % of GDP |
|---|---|---|---|---|---|
| Household | 52.6 | 15.9% | 1.9 | 3.0% | |
| Industry (Intensive) | 39.6 | 12.0% | - | 0.0% | 2.8% |
| Industry (other) | 47.7 | 14.5% | 1.3 | 2.0% | 13.9% |
| Public Administration | 4.3 | 1.3% | 0.1 | 0.2% | 4.5% |
| Commercial | 41.3 | 12.5% | 1.9 | 2.8% | 71.4% |
| Aviation domestic | 2.6 | 0.8% | 1.3 | 2.0% | |
| Aviation international | 76.3 | 23.1% | 40.1 | 61.2% | |
| Rail | 2.7 | 0.8% | - | 0.0% | |
| Road Freight | 14.2 | 4.3% | 0.8 | 1.2% | |
| Road Passenger (Private) | 20.9 | 6.3% | 2.3 | 3.6% | |
| Road Passenger (Public) | 1.2 | 0.4% | 0.2 | 0.2% | |
| Water Domestic | 1.6 | 0.5% | - | 0.0% | |
| Water International | 22.2 | 6.7% | 11.6 | 17.7% | |
| **Total Transport** | **141.7** | **43.0%** | **56.3** | **85.9%** | |
| Agriculture | 1.8 | 0.5% | **0.4** | 0.6% | 0.7% |
| Construction | 0.8 | 0.2% | 0.2 | 0.2% | 6.6% |
| **Total consumption** | **329.7** | 100.0% | **62.1** | **-** | **3.94%** |
| Energy industry use | 18.2 | 4.2% | 3.4 | 5% | |
| **Total primary demand** | **436.9** | **-** | **65.5** | **-** | **£6,456** |

### *Shape of the economy*

The country experiences very high levels of economic growth, resulting in an economy six times larger than today. As well as a strong commercial sector, there has been an industrial revival, with strong growth within energy intensive industry, particularly metals and chemicals, and non energy intensive industry. Such a revival could be led by the development of new industrial processes or the changing economics of importing manufactured goods, due to high fuel prices or increased labour costs in most parts of the world by 2050.

### *General Demand characteristics*

Energy demand is nearly twice as large as today, despite meeting the 60% reduction in carbon emissions. Demand increases for both electricity and other energy, with a shift towards the use of electricity for meeting heating needs, such as for space, process or water heating needs. The electricity grid is carbon free. Decreases in energy intensity across productive sectors of the economy continue at current trends, by contrast energy intensity in the domestic and transport sectors show a significant decrease up to 2050.

**Service and industry**

Decreases in energy intensity continue at current trends with the result that large growth across the wealth creating sectors leads to an energy demand over twice the level it is today. Energy intensive industry has been decarbonised, through the widespread use of carbon free, reliable grid electricity and CHP.

The public sector has declined and has a low growth rate which contrasts to the rest of the economy.

**Household**

There has been a net increase in household numbers in the UK to approximately twenty eight million. There has been large penetration of nuclear CHP; such a technology is likely to be on either on a large scale, or with new neighbourhood size nuclear plants. Either way, many new homes, and new residential districts are likely to have been built and large energy intensity reductions result from improvements in building regulations, form and services.

**Passenger transport**

Demand for passenger transport grows across all sectors with a five fold increase in passenger kilometres travelled. There is a slowdown in growth of private road transport with growth in all public modes of passenger transport including domestic aviation. Similarly, there is continued growth in international aviation, albeit more slowly than current trends. The largest decreases in energy intensity are seen in the road transport sector with more efficient fuel use results in similar levels of energy consumption to today despite a two fold increase in distance travelled. The picture is different within the aviation sector where increases in energy intensity see energy consumption ten times greater than in 2002.

Road freight continues to increase, though the rail network and inland waterways have expanded to transport the output from a highly productive economy, with shipping for exports of goods.

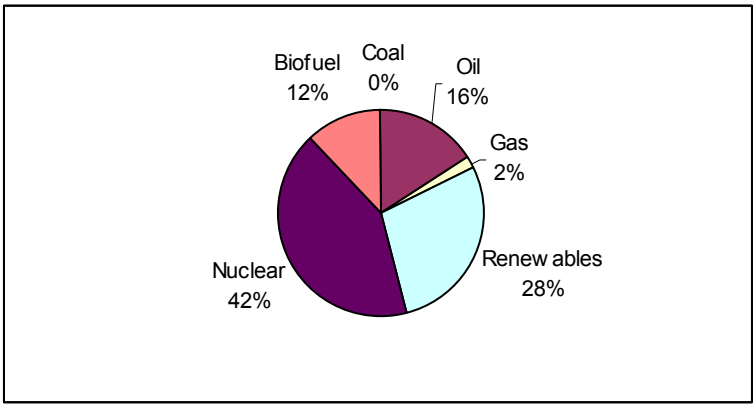
### *Supply side picture*

Table 2. Electricity

| Source | Electricity use (Mtoe) | % of grid supply | % of total electricity supply |
|---|---|---|---|
| CF | - | 0% | 0% |
| CCGT | - | 0% | 0% |
| NU (Grid) | 40.1 | 40% | 26% |
| NU (H2) | 10.2 | - | 7% |
| RENEW (Grid) | 60.1 | 60% | 39% |
| RENEW (h2) | 33.9 | - | 22% |
| CCS | - | 0% | 0% |
| BIO | - | 0% | 0% |
| C-CHP | - | - | 0% |
| G-CHP | 3.8 | - | 2% |
| B-CHP | 7.9 | - | 5% |
| N-CHP | 15.7 | - | 10% |
| ON-REN | 11.3 | - | 7% |
| **TOTAL** | **182.9** | | |

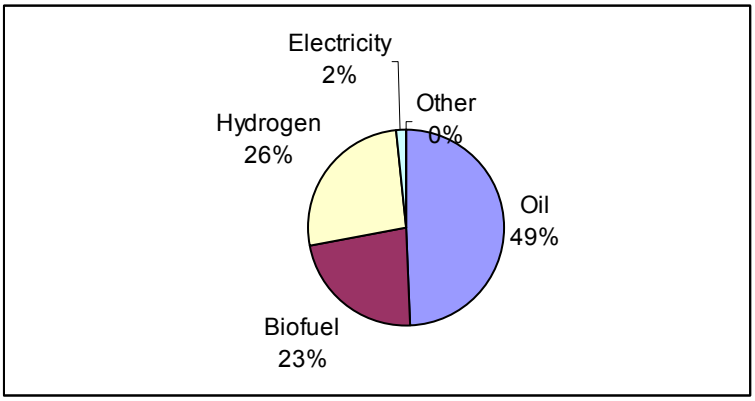
Coal is no longer part of the generating mix; a large grid is supplied by a combination of renewable energy and nuclear power. Gas use is solely within efficient CHP schemes. Nuclear power is widespread, with large scale penetration of nuclear CHP as well as nuclear production of hydrogen.

Figure 1. Primary demand




Hydrogen technology has developed for stationary and motive applications, though not within the aviation sector. Electrolysis from renewable energy and nuclear energy, with the potential for the thermal decomposition of water to use heat from nuclear CHP systems during warmer months, are the two hydrogen production routes.

Figure 2. Transport fuel mix




Biofuel use is widespread, in CHP applications, but primarily used for transport and aviation in particular. The levels of liquid biofuels required by the transport sector will necessitate substantial imports from overseas.

# 330b

**UK picture**

330 b is one of two high energy demand scenarios distinguished from scenario 330a by its economy. 330 b is driven by exceptionally high growth in the commercial sector alongside low growth in industry, and has a major reliance on coal generation with carbon capture and storage to supply the national electricity grid.

Potentially, governments have been weak, or not motivated, in curbing consumer behaviour with respect to energy consumption though strong in implementing large infrastructure projects, such as hydrogen, nuclear generation and carbon capture and storage, through long term national energy planning for example. There has been a supply-side push approach to cope with increasing demand. A large developed supply infrastructure may have been implemented by government, or by a coalition of major firms driven by economic incentives and technological innovations

An alternative viewpoint is that in a high growth economy, economic instruments such as taxes have been tried but have proved to be ineffective in reducing demand. Consequently, high international and national $CO_2$ emission targets have only been achieved through a large scale low carbon supply rather than via demand reduction. In a high service economy the strength of the commercial sector may have focused investments and innovation towards improving energy efficiency within office and service environments and away from large scale industry. Alternatively industrial sectors which are perceived as struggling, and as having a relatively lower impact on emissions, may be less of a focus for regulation and economic instruments.

Table 1. Scenario economic and energy demand summary

| Module | Consumption (Mtoe) | % of consumption | Carbon (MtC) | % of carbon | % of GDP |
|---|---|---|---|---|---|
| Household | 50.1 | 15.2% | - | 0.0% | |
| Industry (Intensive) | 14.8 | 4.5% | - | 0.0% | 1.1% |
| Industry (other) | 18.8 | 5.7% | - | 0.0% | 4.9% |
| Public Administration | 4.2 | 1.3% | - | 0.0% | 6.5% |
| Commercial | 28.1 | 8.5% | - | 0.0% | 81.2% |
| Aviation domestic | 1.3 | 0.4% | 1.0 | 1.6% | |
| Aviation international | 147.8 | 44.7% | 50.6 | 78.3% | |
| Rail | 1.1 | 0.3% | - | 0.0% | |
| Road Freight | 11.1 | 3.4% | - | 0.0% | |
| Road Passenger (Private) | 26.6 | 8.0% | - | 0.0% | |
| Road Passenger (Public) | 1.2 | 0.4% | - | 0.0% | |
| Water Domestic | 1.6 | 0.5% | 0.7 | 1.1% | |
| Water International | 21.6 | 6.5% | 6.8 | 10.6% | |
| **Total Transport** | **212.4** | **64.3%** | **59.1** | **91.7%** | |
| Agriculture | 0.7 | 0.2% | **-** | 0.0% | 0.2% |
| Construction | 1.3 | 0.4% | 0.2 | 0.4% | 6.0% |
| **Total consumption** | **330.5** | 100.0% | **59.4** | **-** | **4.16%** |
| Energy industry use | 28.6 | 5.3% | 5.1 | 8% | |
| **Total primary demand** | **538.8** | **-** | **64.5** | **-** | **£7,135** |

### *Shape of the economy*

Overall, there is high economic growth that is driven by the commercial sector, which makes the largest contribution to GDP.

### *General Demand characteristics*

Total energy consumption across the economy is twice as high as today, with proportions of electricity compared with other energy roughly the same as at present. The decarbonised grid, a strong hydrogen economy, on-site renewables and the sole use of biofuels as fuel for CHP schemes means that stationary energy demand is delivered from carbon free sources, with all 'allowable' carbon emissions 'saved' for transport.

**Services and industry**

Decreases in energy intensity across productive sectors continue at a similar rate to current trends, with the exception of energy intensive industries where current high rates drop off substantially.

**Households**

Growth in the number of households sees an additional two and a half million new homes. Energy consumption in the household sector has increased since 2050, though decreased energy intensity means that the amount of energy consumed within the home on energy services, such as heating, per unit of consumer expenditure has reduced faster than current trends. Improvements in the efficiency with which energy is used within the home are likely to have occurred, as well as behavioural changes and consumption practices.

**Transport**

This is a highly mobile society with a nine fold increase in the number of passenger kilometres travelled. That said, across all modes, with the exception of international aviation, the mobility intensity of economic activity is decreasing. International aviation has grown at a slightly lower rate than currently, leading to a large aviation sector, consuming 70% of all 'allowable' carbon emissions, despite widespread use of hydrogen fuel. The energy efficiency of mobility is increasing across all modes of passenger transport. Such improvements could be achieved through more efficient engines, changes in operational and travel practices.

More freight is carried by road than in 2002, although the two fold increase in freight tonne kilometres is lower than is suggested by the rate of economic growth in a break from past trends. Given the size of the service and commercial sector, it is likely that the economy is becoming more weightless. Large increases in marine freight transport, both domestic and international are required in order to move good into and around the country. Energy intensities are decreasing across all modes.

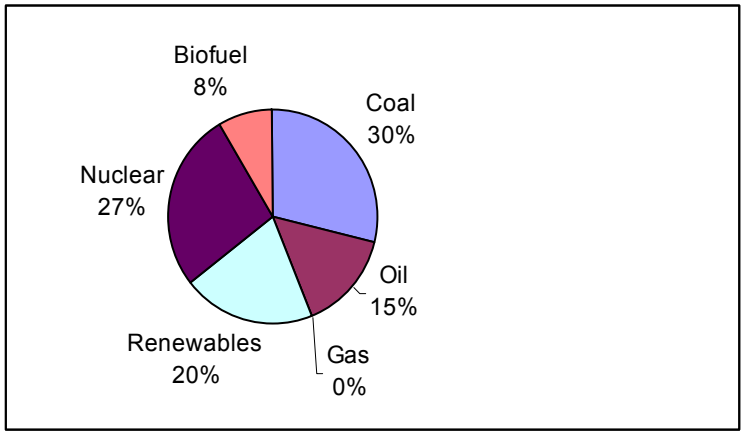
### *Supply side picture*

Table 2. Electricity

| Source | Electricity use (Mtoe) | % of grid supply | % of total electricity supply |
|---|---|---|---|
| CF | - | 0% | 0% |
| CCGT | - | 0% | 0% |
| NU (Grid) | 15.4 | 33% | 11% |
| NU (H2) | 17.8 | - | 13% |
| RENEW (Grid) | 15.4 | 33% | 11% |
| RENEW (h2) | 39.4 | - | 29% |
| CCS | 15.4 | 33% | 11% |
| BIO | - | 0% | 0% |
| C-CHP | - | - | 0% |
| G-CHP | - | - | 0% |
| B-CHP | 3.4 | - | 2% |
| ON-REN | 30.9 | - | 22% |
| **TOTAL** | **137.6** | | |

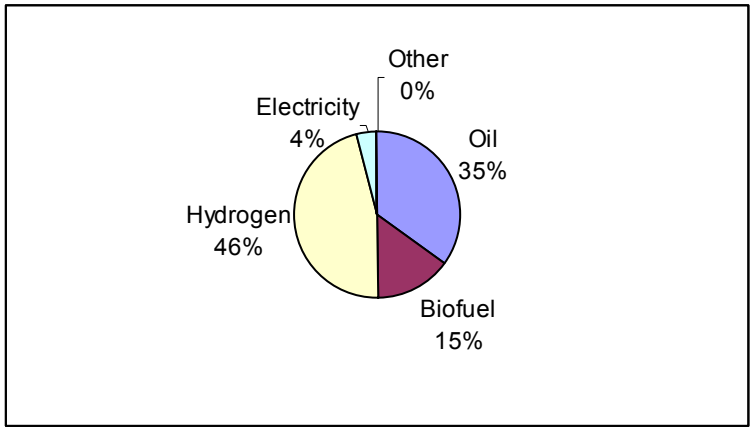
Electricity for the grid comes from renewable energy, nuclear power and coal generation with carbon capture and storage. Gas is no longer part of the energy mix and biofuels are not combusted solely for electricity, but only within CHP supply schemes. On-site renewables supply 40% of household energy and are important across all sectors of the economy.

Figure 1. Primary energy demand




The large primary energy demand, increased by the size of the hydrogen economy and the large penetration of renewables, leads to a sizable, and probably highly conspicuous, energy generation and supply infrastructure. There is an extensive and fully developed hydrogen economy which supplies one third of energy needs across stationary and motive applications. Such a system, with centralised production of hydrogen from nuclear energy and coal gasification, as well as distributed production from renewable energy, necessitates a large network and supply, storage and distribution infrastructure, with the development of a supply grid, replacing that which is currently used for the supply of natural gas. Large scale investment will have been required both for the development of the supply infrastructure as well as installing end use plant in buildings.

Figure 2. Transport fuel mix




The small CHP penetration is limited to biofuels, though another major use for biofuels is within transport where their use has been prioritised for international aviation. The high demand for liquid biofuels requires a substantial level of imports, potentially by pipeline. Storage technology allows electricity to be used to power land-based transport.

# Assumptions

***Demand***

- Aggregated GVA of limited sectors provides adequate proxy for GDP
- International marine emissions-see separate methodology sheet , 50:50 assumption of UK & others responsibility
- International aviation emissions: 50:50 assumption of UK & others responsibility
- Aviation freight: not explicitly included as there is an absence of decent data. Can be assumed to be carried free in passenger aircraft with no additional fuel penalty.
- Industry intensive: *metals, minerals and chemical* sectors are a blend of subcategories from DUKES and ONS – necessary as GVA data is from one source and energy consumption from the other.

**Supply**

- All power stations are current state of the art with high efficiencies
- Coal Fired IGCC or equivalent: **50%** efficient
- Gas CCGT or equivalent: **60%**
- Nuclear stations: **45%**
- Coal IGCC/CCS: *conversion 50%, 10% loss in capture and 5% loss in pumping and storage – net efficiency:* **35%.**
- Grid losses : **6%** total *(transmission and distribution)*
- Energy industry use: **7%** *of total non renewable consumption + biomass + transformation and losses. The 7% figure is based on the historical relationship (1995-2002) between energy industry use and total primary supply excluding non-biomass renewables. The period chosen is one in which the energy imports and exports were approximately balanced.*
- CHP : based on 50:50 ratio of electricity to heat (currently, between 30:70 and 40:60)
- CHP Coal : **75%** efficient
- CHP Gas: **85%**
- CHP Biomass : **70%**
- Hydrogen large electrolysis :**81%**
- Hydrogen Coal with CCS: *coal gasification conversion efficiency of 60%, with 5% penalty for collecting, compressing and storing the carbon dioxide, hence, net:***55%** efficiency

**Note:**

*Electrolysis efficiency figure is based on The Hydrogen Energy Economy: its long term role in greenhouse gas reduction - Tyndall Centre Project No. ITI 26 Final Report. Table 4-12. Page 43.*
*CCS details from private communication with Simon Shackley - 08/10/04 and private communication with Geoff Dutton - 08/10/04.*
*Efficiency data for coal gasification (60%) taken from The Hydrogen Energy Economy: its long term role in greenhouse gas reduction - Tyndall Centre Project No. ITI 26 Final Report. Table 4-12. Page 43.*