Version 1.4a July 2011

Future Climate UK 2050 Energy Plan - The challenge continues

Version Control

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Version 1.1	16 May 2011	General review with T Fox, Transport rewritten Sources list modified
Version 1.2	7 June 2011	Energy Production section rewritten after review with MK,BB
Version 1.3	10 June 2011	General review by RA, MK, BB and transport by P. Oldham
Version 1.4a	28 July 2011	Final Review and inputs.

Contents

1 Executive Summary

1 This report presents the ongoing work of the IMechE in support of the International Future Climate Project. Previous work was presented in our report: “UK 2050 Energy Plan” published in September 2009.

2 The primary basis for this project continues to be the objective of keeping the maximum global average temperature rise to within the guideline of $2^{o}C$. As a developed country, the UK has shown international leadership in enacting legal obligations to reduce total GHG emissions by 80% of 1990 values by 2050. The UK also has an obligation under the EU Renewable Energy Directive to achieve a target of 15% of energy from renewables by 2020. The overall renewables target for Europe is 20% by 2020.

3 The analysis work of DECC, led by Prof. David MacKay and the development of the DECC pathways software has shown clearly that to maintain a modern developed society in the UK it is necessary to build an energy supply system based on a combination of wind energy (the only renewable currently available at scale in the UK), nuclear power and gas/coal combinations abated by CCS. The major issue is that the current version of the DECC pathways model does not include pathway cost comparisons such as cost per tonne of CO_2 abated as used by other models.

4 In total, other sources of energy such as biomass, solar, wave and tidal power, hydro, geothermal, waste heat recovery and energy from waste materials have an important role to play in providing a resilient energy system. Some of these may develop into major energy sources in the future.

5 As in our previous report we believe that doubling the existing electricity supply is at the limit of practical achievement of the current UK approach to infrastructure projects. This means that the demand side of the energy equation must reduce to balance with supply. This can be achieved through a combination of three activities listed in ease of implementation, behaviour change being the most difficult to achieve:

a) Efficiency improvements throughout the system

b) Time shifting of electrical demand.

c) Basic reduction in demand by energy conservation through modal shift and lifestyle change.

6 Our investigations suggest that the target reductions in emissions will not be achieved through energy efficiency measures and existing technologies alone but that new innovative technologies will be needed in all sectors of the energy supply and demand landscape.

Some of these innovations may already be recognised as important - such as marine energy - but based on past experience it is likely that other so far unrecognised technologies will need to be brought into play before 2050.

7 The cost of implementing the new infrastructure needed in the UK to deliver a new, balanced and low carbon energy economy is significant and estimated at around £500 billion between now and 2020.

To obtain best cost for the new infrastructure it is important that technologies and their supporting industries reach critical mass. In evaluating the relative costs of the alternative infrastructure pathways it is critical that the benefits such as job creation are also taken into account.

8 We believe that the creation of so called Green Jobs will be a major motivator in driving forward the low carbon energy supply. The UK needs some 1million additional manufacturing jobs over the period to balance the economy. To reach this level of new job creation will require a conscious development of UK based supply chains so that the supply chain job multiplier comes into play.

9 It is recognized however that there should not be an overemphasis on reducing greenhouse gases as resource management in the broadest sense, population growth and the adequate provision of food and water are no less pressing global challenges for engineering in the coming decades.

2 Acknowledgements

In preparing this report we have been assisted by a large number of members of the Institution of Mechanical Engineers. We have also received much external advice and assistance from people outside the IMechE for which we are extremely grateful. We hope that this collaboration will continue to grow.

Brian Cox Lead Author

July 2011

3 Introduction

The Institution of Mechanical Engineers joined the Future Climate project in 2009 and is the only UK representative in this important and growing action to find Engineering Solutions to the global energy and climate change challenges. Previous work was presented in our report “UK 2050 Energy Plan – Making our Commitment a Reality” published in 2009.

Over the past few years the nature of the several challenges facing us all have been clarified and generally accepted.

A rise in global average temperatures of $2^{o}C$ is now widely accepted as the limit beyond which changes to global weather patterns, sea levels and other environmental factors may become dangerous. To avoid exceeding this limit it is also accepted that global GHG emissions need to halve by 2050. Given the developing nature of many parts of the world, the already developed countries need to shoulder a large part of this reduction and for the UK this is taken as a commitment to an 80% reduction in emissions by 2050. This was made legally binding by the Climate Change Act 2008.

The Committee on Climate Change was set up to provide independent advice to Government on meeting the requirements of the Climate Change Act and is responsible for proposing Carbon Budgets on a rolling four year cycle and monitoring progress.

The Fourth Carbon Budget proposal was published in December 2010 and covers the period 2023 to 2027. The UK Government presented a Policy Statement to Parliament in May 2011 seeking Parliament's agreement to accepting the Committee on Climate Change's recommendation on setting the level of the fourth carbon budget at 1950 million tonnes of carbon dioxide equivalent ($MtCO_2e$).

(Source: Implementing the Climate Change Act 2008: Policy Statement May 2011)

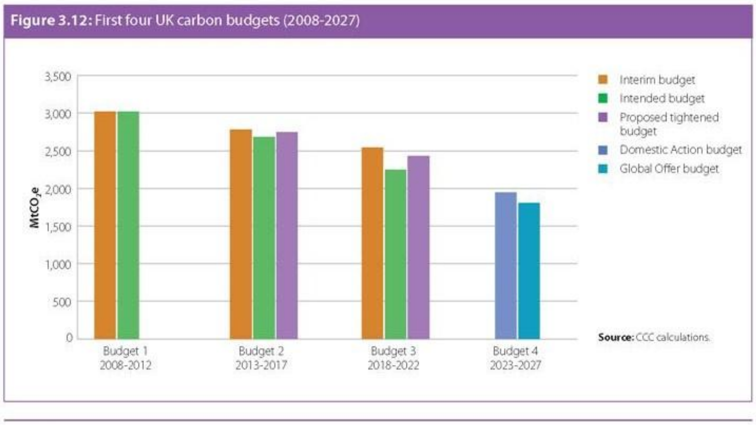


Figure 3.12: First four UK carbon budgets (2008-2027)

Source: CCC 4th Budget report Dec 2010

The concept of peak oil, peak gas and practical limits to the availability of other key materials has also become widely understood. However as demand continues and prices rise, other substitute materials and processes tend to appear as alternatives. These alternatives may be uneconomic in the short term and can need assistance to achieve significant market penetration and the resulting economies of scale. Selecting which of the new technologies to support is a significant challenge.

At the same time the world population continues to grow with a good part of the developing world still living well below average developed country standards of living. As the developing world strives to improve its standard of living this will inevitably further increase the demand for global energy supply and put further pressure on the need for clean energy and the better use of scarce resources.

The simultaneous impact of these challenges requires urgent and innovative engineering solutions as well as modal and behavioural changes in society in order that we can develop a positive future trajectory and not regress to a lowest common denominator situation.

In this report we present the ongoing work of the IMechE and its members in support of the Future Climate project. Future Climate now involves Engineers from more than sixteen countries worldwide and is continually growing providing a valuable international context to the work.

The structure of the report – a Process Led Approach

Most reports and comment in this large and important field have divided the topic into manageable segments such as the Built Environment, Transport, Industry, Agriculture and Power Generation. We feel that in the next stage of emission and energy use reduction it is necessary to look across segments and take a more holistic process led approach while at the same time keeping recognisable process headings.

Therefore we look at:

Neighbourhood Energy – the built environment together with distributed energy.

Transport systems – to emphasise the need for more integrated transport systems, and the need to design future transport around the needs of the low carbon economy and future living styles.

Agriculture, Food Production and Land Use
- taken together as a supply chain these emit between 20% to 30% of UK GHG emissions.

Industrial Processes

Energy production and distribution and developing the CO_2 Utilisation Industry –as energy production becomes synonymous with chemical processing, developing downstream value generation becomes significant.

Together with an overarching topic:

Green Jobs and building the Low carbon Economy – what are Green jobs? How can we achieve a multiplier effect and how can the massive investment needed essentially to catch up be achieved? Where will it come from?

The need for new Innovative Technologies

Our investigations suggest that the target reductions in emissions will not be achieved through energy efficiency measures and existing technologies alone but that new innovative technologies will be needed in all areas of the energy supply and demand landscape.

Some of these innovations may already be recognised as important - such as marine energy - but based on past experience it is likely that other so far unrecognised technologies will need to be brought into play before 2050.

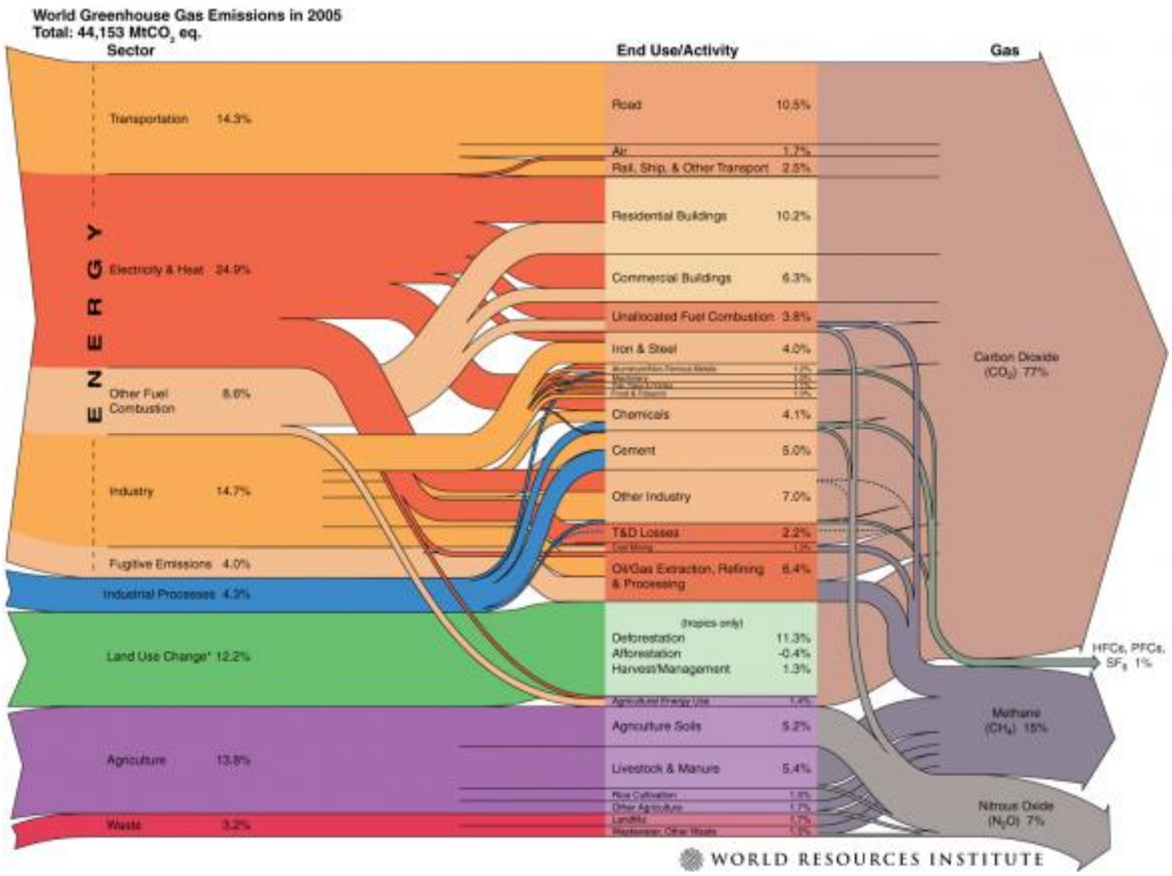
We have highlighted innovations known to us in the body of the report to emphasize their importance in the later stages of the pathway to 2050.

The UK in comparison with the World Situation

The World Resources Institute map of World GHG Emissions shows that the UK, despite having a smaller proportionate Agricultural and Land Use sector, otherwise has similar GHG emission reduction challenges to the rest of the world.

Solutions found for the UK's challenges are therefore likely to be applicable at scale for other countries and equally solutions found elsewhere may well be what we need in the UK.

International collaboration in the field of GHG emission and energy use reduction is a vital part of meeting the challenges ahead.



(Source: World Resources Institute)

4 Neighbourhood Energy – the built environment together with distributed energy.

It is now generally recognised that across the UK the built environment is one of the three big energy users along with Transport Systems and Industrial Processes, and therefore one of the largest GHG emitters.

According to most analyses, energy demand from the built environment sector equates to some 47% of the total UK energy supply and of that some 27% of the UK total is attributable to domestic dwellings. The balance being a mixture of commercial, industrial and historic buildings

The UK Climate Change legislation requires an 80% reduction in GHG emissions by 2050.

Achieving an 80% reduction in actual energy use in the built environment sector is beyond reasonable expectations due in part to the nature of the UK building stock. Therefore even if the UK achieves its separate target of decarbonising the electricity supply through 20-30% renewable energy generation and further Nuclear Power plant (Green Electricity), it is still necessary to consider ways of achieving reductions in NET energy demand from the built environment sector - that is, the energy demanded from the National Grid less any locally produced or used green source of energy not already counted in the national energy balance equation – because the total energy demand (currently equivalent to some 340 GW of electrical generation capacity) is around twice the likely future Green Electricity supply available from the National Grid.

For this reason it is better to consider Neighbourhood Energy as a single topic – the built environment together with its local energy supply made up of individual building supplies and local community/distributed supplies.

We have used DECC Pathway Alpha/A (effort spread across all sectors) as the reference for trajectory comparison as it is similar to the pathway proposed in the IMechE UK 2050 Energy Plan (2009 version) (Source:DECC 2050 Pathways)

The Energy Hierachy

In its Energy Policy Statement 09/03, the Institution of Mechanical Engineers developed the following Energy Hierarchy which provides a good basis for discussion and action:

Action Priority 1: Energy Conservation. Changing wasteful behaviour to reduce demand

Action Priority 2: Energy Efficiency. Using Technology to reduce demand and eliminate waste

Action Priority 3: Exploitation of renewable, sustainable resources

Action Priority 4: Exploitation of non-sustainable resources using low-carbon technologies

Action Priority 5: Exploitation of conventional resources using new technologies.

In practice to achieve the UK's 2050 goal, concurrent work on all five priorities is needed. Priority 5: the better use of conventional fossil fuels, will continue to be needed both by poorer underdeveloped countries in the long term and by developed countries in the midterm as suitable mitigation and replacement technologies are developed. Coal remains the largest fuel for the production of electricity across the world.

Energy Conservation

Changing occupant behaviour with regard to energy use in buildings is an important factor, as energy efficiency projects have shown that variations in user behaviour can easily outweigh the results of any energy efficiency work. Typical current figures of average UK domestic household energy use of 20,000 kWh/year must be balanced against a variation of plus/minus some 50%.

It is known that when householders are motivated by campaigns such as British Gas Green Streets, or commercial occupants by Corporate energy reduction projects, significant energy reductions can be obtained. However in general these will not be sustained in the long run. This pattern of behaviour has long been known in the industrial world from, for example, Elton Mayo's experiments at the Hawthorne, Chicago factory of GE in the 1920s.

We therefore consider that the energy efficiency gains which could result from behaviour changes need in general to be automated. For example more sophisticated thermal management systems in domestic houses, occupant sensitive lighting controls in commercial buildings.

None the less, local motivational groups such as "Transition Towns" and "Sustainable Villages" can play a major role in public awareness and can trickle through to affect personal behaviour both at home and at work.

INNOVATION

The Wattbox energy controller learns the house occupants behaviour.

Energy Efficiency

In our previous report we referred to the Passivhaus standard of total power consumption of 13.7 watts/m^2 and the comparative current domestic average of about 30 watts/m^2. Given an average UK 2 storey house with a plan floor area of eg 70 m2 and therefore 140 m2 living space this equates back to the 20,000 kWh/yr annual consumption figure at 4000 hrs/yr. However many UK houses are much smaller.

The English Housing Survey Headline report 2009–10 gives data on the Housing stock at 22.3 million dwellings and details of the Stock Profile.

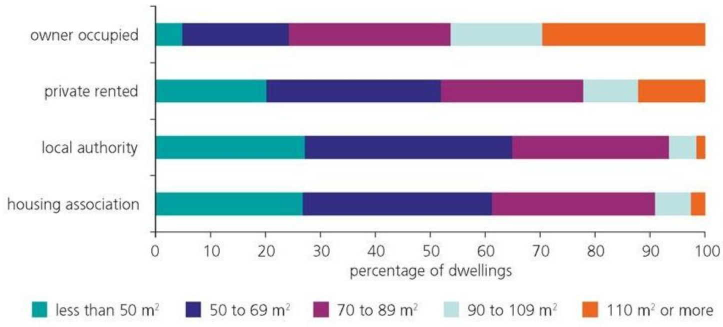
Table 13: Stock Profile, 2009

all dwellings							
	private sector			social sector			
	owner occupied	private rented	**all private sector**	local authority	housing association	**all social sector**	**all dwellings in group**
							thousands of dwellings
floor area							
less than 50 m2	740	724	**1,464**	493	529	**1,022**	**2,487**
50 to 69 m2	2,889	1,139	**4,028**	683	679	**1,362**	**5,390**
70 to 89 m2	4,406	930	**5,335**	517	585	**1,102**	**6,438**
90 to 109 m2	2,506	359	**2,864**	91	129	**220**	**3,084**
110 m2 or more	4,422	436	**4,859**	28	50	**78**	**4,937**
type of area							
city centre	306	345	**650**	57	84	**141**	**792**
other urban centre	2,166	1,028	**3,194**	544	403	**947**	**4,141**
suburban residential	9,286	1,725	**11,011**	1,095	1,215	**2,309**	**13,320**
rural residential	2,015	237	**2,252**	87	214	**301**	**2,553**
village centre	660	116	**777**	23	47	**70**	**846**
rural	530	136	**667**	6	10	**16**	**683**
(Source: English Housing Survey, dwelling sample)							

The average (mean) total usable floor area of dwellings in 2009 was 91m2. Dwellings in the owner occupied stock were most likely to be larger than 110m2, 30% compared to 12% of the privately rented stock and 2% of social sector homes, Figure 11. In contrast 65% of local authority homes and 61% of housing association homes were smaller than 70m2 compared with 52% and 24% of the private rented and owner occupied sector respectively.

Further investigation of the heating intensity in UK dwellings would be useful.

Figure 11: Usable floor area by tenure, 2009



Base: all dwellings
Source: English Housing Survey, dwelling sample

<u>We suggest that the Passivhaus standard remains the simplest reference that occupants can easily understand as against the various technical building standards.</u>

Energy efficiency measures for more modern buildings such as roof and cavity wall insulation and high efficiency glazing, are well understood and promoted through various Government programmes (CRC, CERT, CESP, the Green Deal etc) but work on harder to treat buildings with solid walls and other problems is still at an early stage. Building standards for new build are pushing construction methods in the Passivhaus direction but given the large proportion of older housing stock and the low replacement rate of buildings in the UK, refurbishment is the key area where successful energy efficiency work has to be achieved.

Since the last report we have seen the completion of a number of both domestic and commercial refurbishment projects. In particular the TSB Retrofit for the Future project, as well as many individual projects. These have shown that retrofitting to Passivhaus standards is possible but at significant cost and difficult unless the properties involved are vacant.

We suggest that innovative technical solutions are needed that are more appropriate to occupied buildings such as:

INNOVATION

- Application of BMS systems widely used in commercial buildings to the domestic market allowing for example room zoning with wireless radiator valve actuators, weather compensation and 7 day complex timing facilities. Most UK houses have simple on/off controllers.
- Simple, easy to fit draught control such as Chimney Balloons .
- The use of Aerogel based insulation products for the internal insulation of solid walls, together with appropriate moisture control measures and a greater understanding of the role of cold bridges in heat loss and condensation formation.
- Renewal of lighting systems in commercial buildings can lead to good energy use reduction.

- For buildings with suitable electrical loads, power conditioners can give of the order of 10% energy use reductions.

A way is needed to bring the cost of such innovative products down during the early adoption period so that mass market sales and consequent price reduction through volume manufacture is possible.

More thought needs to be given to the new product lifecycle of high tech products relating to the built environment. Typically we may now see new products within a 5 year horizon. Cost and payback calculations for energy efficiency schemes need to reflect this high tech lifecycle rather than the 25 year building lifetime commonly quoted.

It is likely that with considerable effort by all, energy usage by the UK building stock can be reduced by some 25-30% from current levels.

Buildings, Communities and Neighbourhoods

Domestic buildings can be considered in terms of individual dwellings, multi occupant buildings or groups of buildings forming neighbourhoods, streets or villages.

Commercial, Industrial and historic buildings similarly cover a wide spectrum from individual small premises to large integrated mall/office complexes.

It is convenient to consider the whole built environment as consisting of three types of building groups:

1. Type A: Individual small and medium sized buildings –which can be either commercial or domestic.

2. Type B: Groups of buildings which have a common energy related purpose but multiple ownership eg villages, streets, parishes, voluntary communities, cohousing.

3. Type C: Integrated building complexes which may have mixed use but have single overall ownership. eg modern shopping mall/office complexes, large industrial sites, campus type groups of buildings, business unit estates, retail parks.

Exploitation of renewable, sustainable resources

In order to help to meet the 80% emission reduction goal it is necessary to find suitable local sources of energy.

The UK National scale development of the major sources of renewable energy –Onshore and Offshore Wind, Hydro, Biomass and Marine will be covered in the Energy Production Section of the report. As will Nuclear which is low carbon but not renewable

The viable sources of local renewable energy in the UK are:

<u>Solar Energy</u> in the form of solar water heaters and PV electricity generation.
<u>Heat pumps</u> to extract solar energy from the air, water or ground.
<u>Wind.</u> In most cases needs to be at least a community sized project to be viable.
<u>Hydro</u>. A good source of 24hr/day energy in suitable locations, although suitable watercourses are not widely available throughout the UK and the effects of climate change may alter yields.

Biomass – using natural wood or plant based fuels. Using waste to generate heat and electricity is not normally regarded as a renewable and is discussed separately.

Geothermal – drilling down to the hotter geological strata to obtain heat.

At a local level waste heat recovery and energy from waste are also sources of energy.

Solar Energy

Solar water heaters are perhaps one of the best investments for a UK householder because they reduce heating costs which are in most cases the biggest utility bill.

Solar PV has become increasingly popular due to the large Feed In Tarriff available for small systems.

Heat Pumps

A recent report by the Energy Saving Trust investigated 83 heat pump installations across the UK in Type A buildings. This report showed mixed experience and the importance of correct installation and operation. This emphasises the need for increased skill levels and more professional national suppliers.
(Source:EST)

The application of heat pumps to Type C Complexes is well established. No 1 New Change, Land Securities new complex next to St Paul's Cathedral has MEP design by Hoare Lee who give the following description of the energy system.

> *One New Change complies with Part L 2006 and will realise the Mayor's target of generating 10 per cent of its energy needs from renewable sources. A pioneering energy system combining open loop bore holes (which extract and discharge water from the underground aquifer) with 219 closed loop energy piles, will maximise the renewable energy contribution*

The New Change complex has 220,000 ft2 of retail/leisure space and 340,000ft2 of office space.

Larger commercial buildings of this type normally require energy for cooling more than heating and so should also be regarded as potential heat sources for local area heat distribution networks (see below)

Wind

It is now accepted that small propeller type wind turbines on urban buildings do not function effectively.

INNOVATION

A recent ly introduced solution is the Ridgeblade. This innovative design sits in the ridge of a pitch roof and has lawnmower like blades which catch the increased velocity of the air as it flows over the roof.

Some industrial sites have sufficient space and clear airflow to run turbines. Otherwise larger wind turbines are best sited in open spaces away from buildings allowing a minimum distance of 10x the height of the nearest building or other obstruction. The top of a gently sloping hill is very suitable.

This is a problem for city based Type C complexes because current onsite generation rules mean that wind turbines sited in another location cannot easily be used to help meet renewable energy objectives.

Although individual Type A dwellings cannot normally install effective turbines there are now a growing number of community (Type B) and industrial (Type C) owned wind turbine projects installed or underway. Typical domestic single occupant electricity use is average about 4,500kWh/yr. So a 1000 house community will need 4.5 GWh/yr.

Medium sized turbines are suitable for local energy generation: for example

- Gamlingay, Cambridge Community Turbine project plans a 330 kW turbine sited on land adjoining the village. Based on a 33m rotor, this should generate about 2.8MWh/yr

- Westmill Wind farm near Swindon is community owned and has 5x 1.3MW turbines.

As with PV, current FITs would make it preferable to sell electricity to the Grid but in future this may change.

Hydro

Small scale water power has been in use for many centuries with increasingly efficient types of turbine developed to suit different water flows and heads.

Recently reverse Archimedes screw type turbines have been installed successfully in a number of locations.

Biomass

Efficient biomass boilers are now available at all size ranges together with supplies of wood pellets.

The Energy Saving Trust website advises that for Type A buildings, stand alone (wood burning) stoves cost around £5,800 inc installation and auto fed boilers around £11,500 inc installation.

Balcas, a large wood pellet supplier suggests that a 4 ton or 6m3 pellet store is needed. Pellets to CEN/TS 14961 have a calorific value of 4.8 kWh/kg so for the 20,000 kWh/yr house this adds up.

The high cost compared to a gas boiler and similar fuel costs mean this is not a financially attractive investment for buildings on the gas grid. The RHI may change this situation.

There is an issue with the sustainability of biomass sources. To achieve zero net contributions to GHG emissions, CO_2 absorption by the growing replacement biomass crop needs to balance the emission of CO_2 during combustion. For wood this is difficult to achieve without very large forests and small populations of wood burning stoves.

Using waste wood products for fuel is a waste to energy action.

Geothermal

Due to the costs of deep drilling Geothermal would normally require significant National funding. Current Geothermal projects are discussed in more detail in section 8.

Waste Heat Recovery

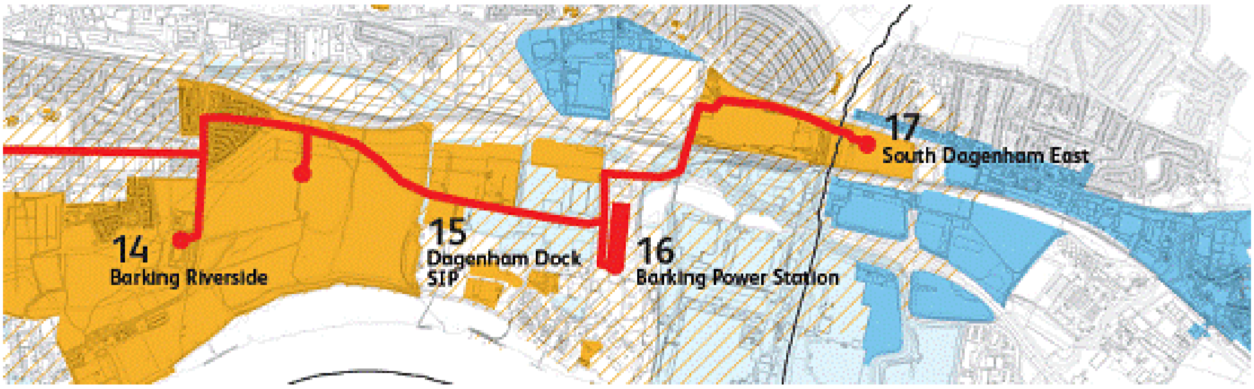
The recovery of waste heat is primarily an efficiency measure, however as the source and sink for the heat exchange may be in different building environments it can be regarded as another local source of heat.

Within Type A buildings waste heat recovery can include the following:

HRV (Heat recovery ventilation) or MVHR (Mechanical ventilation Heat Recovery) extracts heat from the hot moist air from Kitchen, Bathroom etc and warms the incoming air to a controlled condition.

Boiler exhaust heat recovery is available on some modern boiler designs (condensing boiler or separate heat recovery unit) and can significantly increase efficiency.

The major sources of waste heat are from power plant, industrial sites and large office complexes (Type C) . Past planning philosophy has been to separate domestic and industrial areas but this may turn out to be wrong from an energy efficiency point of view.



- London's Thames Gateway Heat Network project is one of the largest attempts to use waste heat recovery in the UK.

  The LTGHN Project will construct, operate and exit a heat transmission network connecting sources of low cost, low carbon heat to homes and properties throughout the London Thames Gateway. The Network will help to decarbonise the London Thames Gateway by supplying affordable low carbon heat from sources including Barking Power Station and Tate & Lyle sugar refinery. The Network will also allow other sources of heat including new advanced conversion from waste technologies, industrial waste heat and other low cost, low carbon heat sources to be distributed. The equivalent of over 120,000 homes and properties could have their heat requirements met by the network, which would save upwards of 67,000 tonnes of CO2 per year.
  (Source: LDA Briefing note)

Waste to Energy and Waste Heat Recovery

Energy can also be sourced locally from Waste to Energy plant, and from harnessing waste heat from various industrial and commercial operations. It is also sensible to use waste heat recovery in individual buildings once they are well insulated. These are not generally sustainable energy sources
Anaerobic Digestion may be practical in some rural areas or as a shared facility across communities. This is also using waste and therefore not totally sustainable.

The Household waste composition analysis report prepared for Merseyside Waste Disposal Authority in 2006 gives a typical breakdown of waste types

Table 5: Estimated composition of residual domestic waste of Merseyside 2005–06 (by category)

Category	kg/hh/wk	%
Paper	2.45	16.70
Card	1.02	6.96
Plastic	1.95	13.29
Textiles	0.69	4.68
Glass	1.11	7.59
Wood (not garden waste)	0.08	0.53
Disposable nappies	0.59	4.00
Metals	0.62	4.21
Electrical items	0.19	1.28
Hazardous items (non WEEE items)	0.13	0.90
Garden waste	0.51	3.48
Kitchen waste	3.98	27.10
Miscellaneous Items	1.03	7.05
Fines	0.33	2.23
TOTAL	14.69	100.00

Figure 2: Estimated composition of residual domestic waste of Merseyside 2005–06 (%)

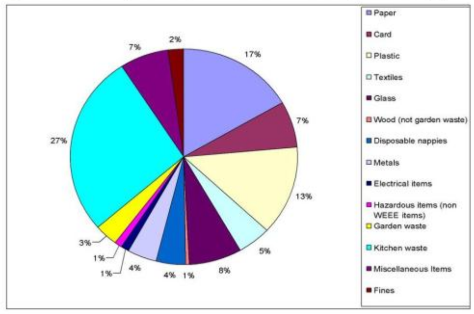
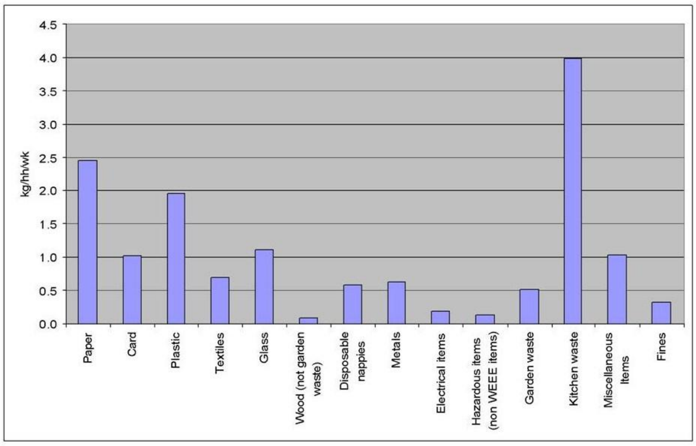


Figure 1: Estimated composition of residual domestic waste of Merseyside 2005–06 (kg/hh/wk)



(Source Merseyside: Waste Disposal Authority)

These analyses show that kitchen waste, paper and plastic are the largest volume of domestic waste equal to about 200 kg/household/yr. A 1000 household community would produce about 4 tons/week.

A pilot AD plant near Cambridge processes 17 ton/day so this indicates that Type B communities and Type C Complexes can only look to AD as an energy generation method if they can share with other partners. Typical large scale AD operates at 30,000 tons/yr generating 1.3 MW of electricity.

Waste is not a renewable and ultimately should be reduced to an absolute minimum. However as long as our society produces the levels of waste it does, waste should be considered as a locally available fuel. The UK has lagged badly behind other countries in utilising waste for energy generation.

Waste can be a fuel for either heat or electricity generation or for a combined plant (CHP). Electricity from Waste plants can typically process between 20,000 and 600,000 tonnes of waste per year, from which they can generate between 1 and 40 MW of electricity (REA data).

The term Waste covers a wide variety of materials with different combustion or digestion properties.

There are equally different technologies to suit these fuel types which can be roughly divided into Thermal Processes including eg: Gasification, Pyrolysis, Plasma gasification etc and Bio type processes including Anaerobic digestion (AD), fermentation and MBT

Some examples:

- Anglian Water and Waste -to -Energy Ltd Brer Project to pilot sewage sludge gasification. The pilot plant will generate a suitable feed gas for a gas engine which then generates electrical power. A large proportion of Anglian's sludge is disposed to farmland but this is becoming an unreliable disposal route. Waste to Energy Ltd Gasifiers range from 10 kW to 1 MW.

- Peterborough Renewable Energy Ltd plan a 66MW electrical and 234 MW heat Energy-from-Waste plant consuming nearly 500,000 ton of waste/year. An Energy Industrial Park is to be constructed around the power plant to make use of the combined output

Can a Neighbourhood become Energy Independent ?

In an ideal situation, Type B neighbourhoods – those Groups of buildings which have a common energy related purpose but multiple ownership eg villages, streets, parishes, voluntary communities, cohousing and so on- would generate enough energy within their own neighbourhood to be energy independent. Is this possible?

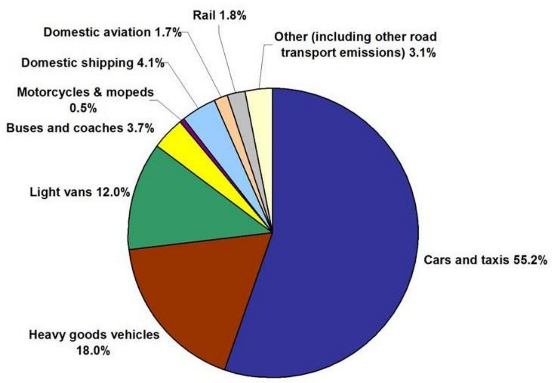
Clearly this depends on the size of a neighbourhood. Typical villages may have around 1000 homes and town parishes or Wards 3000 or more. At 20,000 kWh/yr per home this equates to an order of 60 to 100MWh/yr per community.

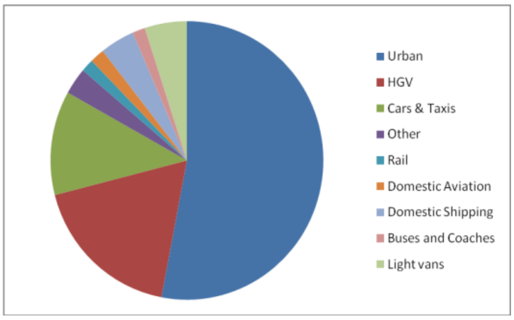
This level of energy supply can be provided in country areas by wind turbines but with the added problem of energy storage. Within larger towns and cities, centralised heat and electricity generation using biofuels and waste, and some form of district heating and electricity distribution are the more suitable solution. In both cases changes to individual perceptions of energy supply are needed.

In other parts of Europe, these "neighbourhood" energy solutions are common. They are starting to spread across the UK and will perhaps in time make the biggest contribution to achieving the new Low Carbon economy and life style.

In a previous IMechE report, the issues facing distributed energy systems were discussed in detail.
(Source: IMechE, Distributed Energy Systems)

5 Transport Systems





Total UK Transport Sector modal split by GHG emissions (Source: http://www.dft.gov.uk/pgr/statistics/)

Estimated Urban (all vehicles) vs Long distance travel mode by GHG emissions.

The UK transport system is responsible for more than 20% of the UK greenhouse gas (GHG) emissions and is made up of a combination of different transport modes. In total, urban transport (short distance) makes up somewhat over half of the total.

Priorities for the Transport Sector

The following hierarchy of priorities for the transport sector has been proposed. This follows the same logic as the more familiar energy and waste hierarchies and in the same way needs to be considered as a concurrent action plan.

The Transport Hierarchy

More Sustainable		
Priority 1	**Reduced Demand**	To **reduce demand** for transport while delivering the same access to services, activities, goods.
Priority 2	**Modal Shift**	To enable use of **more sustainable modes** of transport, and to facilitate **inter-modal** connections.
Priority 3	**Efficiency**	To increase the **efficiency** of transport.
Less Sustainable		

(Source: A Proposal for a Transport Hierarchy. Daniel Kenning)

A similar hierarchy was proposed by the Sustainable Development Commision
(Source: Fairness in a Car Dependant Society Feb 2011)

When cost efficiencies are also considered, vehicle efficiency improvement comes out as the most effective action although long term reduced demand would be likely to have the greatest GHG reduction effect.
In the following part of the report the urban and long distance parts of the transport system are considered separately from the point of view of GHG emission and energy use reduction.

Urban Transport

Reduced Demand

Some cities in Europe have reorganised themselves around a new approach to transport and over the next four decades planning for UK towns and cities should likewise ensure that changes made are consistent with re-localising services; enabling access to education, health, retail, leisure, employment involving less travel. So this reduction in demand may largely be achieved by improving facilities for local working by mixed building developments (offices and clean light industry within walking/cycling distance of residential areas) and improved urban transport systems. . A key to success is the integration of transport and land use policy and better use of brownfield and other sites to provide transport hubs. The overall pattern of urban travel is complex when out of town shopping and leisure are taken into account.

Reducing actual personal mileage demand substantially is complex, and depends on measures taken to improve access to service more locally. The evidence from the Social Trends survey records suggests that it is the total time spent driving which is the limit, at around 3 hours per day. The 3 hour limit also appears to hold for multiple car ownership where mileage per vehicle declines but total mileage for all family cars remains the same. This is interesting in the context of early Nissan Leaf owners, many of whom are reported to have purchased their EV as a second car but make conscious decisions on which vehicle to use according to the journey type.

We believe that whilst the efforts of Sustrans and others have resulted in significant additions to the cycle/pedestrian network, the planning and layout of cycle and foot ways in urban areas leaves much to be desired. We do not consider white lines marked down the sides of busy roads to constitute a safe cycleway. Cycleways need to be physically separated from powered vehicle traffic.

The Netherlands and China are examples of countries which understand and integrate physically separate cycleways into their town planning.

In suburban areas cycling or walking to Park and Ride sites is a useful way to combine some mode change with better use of public transport.

Home working has been proposed as a way to reduce energy use through reductions in travel, however it is not clear where the balance lies between this and the increased use of energy at home.

Modal Shift

For urban areas modal shift mainly implies transferring daily journeys (or parts of daily journeys) from private vehicles to public transport or to walking and cycling. We believe that there is huge popular demand for public transport but that in many places there are very inadequate services and that there are also comparative cost barriers to modal shift. If travel by personal car is cheaper at face value than by public transport then there is little incentive to change. The change to electric, hybrid or high efficiency ICE vehicles may make this situation even more widespread. Cost normally relates to ticket price but should also take account of for example travel time and other user related factors such as parking.

Although a number of UK urban mass transit projects have run into contractual problems, this is most likely to be a result of poor tendering practice rather than fundamental bad thinking. It is important that as for other infrastructure projects the UK builds up a pool of experienced contractors and a realistic cost database as more urban systems are likely to be required in the future. Good practice examples need to be more widely disseminated, such as Curitiba in Brasil.

Personal Vehicle Evolution

In the UK, Toyota Prius hybrid cars are a common sight. Electric cars are less common now but the introduction of the Nissan Leaf and other electric vehicles in the coming year or two will result in these also being seen more often. In the USA hydrogen fuelled cars have been tried.

IC engine cars probably have a lower emission limit of between 90 to 80 g CO_2/km, so that alternatives will be needed as the main vehicle fleet by 2050 to reach the overall UK emission reduction goal.

It is difficult to predict exactly how this transition will take place due to the range of technology and human factors involved.

(Source: J King. The King Review Parts 1 & 2)
(Source IMechE: Low Carbon Vehicles)

Electric and Hybrid Vehicles

Electric and hybrid vehicles fall somewhere between a modal shift – in that they require a change of behaviour- and efficiency improvement.

The majority of major manufacturers are now in the process of preparing for the manufacture of at least one model of electric or hybrid car as well as high efficiency ICE vehicles.

Nine electric vehicles have been declared eligible for a UK 25% purchase grant of up to a maximum of £5,000. They are (data where available):

<u>All Electric</u>			
Mitsubishi iMiEV	21KWh battery	7hrs charge time	100 miles range
Mercedes-Benz smart fortwo ED			
Peugeot iON	17KWh battery	6hrs charge time	80 miles range
Citroen Czero	16KWh battery	7hrs charge time	
Nissan Leaf	24KWh battery		100 miles range
Tata Vista EV			
<u>Hybrids</u>			
Toyota Prius Plug-in		1.5hrs charge time	12.5 miles electric range
Vauxhall Ampera		4hrs charging time	40 miles electric range
Chevrolet Volt.	16KWh Battery	3hrs charging time	37 miles electric range

Grants have also been awarded for plug-in recharge points in a number of regions. However it is expected that most owners will prefer to recharge at home or at work. There is little information about work located charging but this will need to come if any fleet vehicles change to electric. Some manufacturers indicate that high speed charging can be done in 15 minutes from 3-phase supplied charging points so this may be the key requirement for public charging stations although there are real questions about the practicalities of high speed charging of private vehicles.

The question now is how fast the take up of electric vehicles will be. There may be a rush of early adopters to take advantage of the 25%/£5000 grant once the whole product range is launched although so far this has not happened. It is much less clear how long it will take the mass market to evolve especially given the increasing efficiency of IC engine vehicles.

The WWF has proposed a middle pathway leading to 1.7 million electric and hybrid vehicles by 2020 and 6.4 million by 2030 as the minimum market penetration needed but this assumes some degree of demand reduction.
(Source: WWF Electric Avenues 2011)

Annual new car sales are around 2 million, with a car population of 28.5 million out of a total vehicle population of 34.3 million. The implication of say 25 million Electric and Hybrid vehicles by 2050 is that they have overcome all range, temperature and cost issues to become the desired incumbent vehicle by the early 2020s. The whole vehicle parc must then turnover which currently takes about another 20 years. Historically the diesel change actually took 25 years for the diesel engine to offer similar utility and comfort to a gasoline engine.

If optimistically, some 25 million vehicles were to be electrified by 2050 (80%) and use night time home/factory recharging, then this could add of the order of 30 GW of extra grid demand spread over the day and the night depending on the vehicle type/recharging mix.

When the volume of electric and hybrid vehicles becomes that significant will there have to be major changes to National Grid thinking? Opinion seems to be that provided smart metering provides suitable tariff incentives to avoid early evening plug in and charging, then night time charging will be within the grid capacity, but workplace charging could add a different load challenge.
(Source RAC Foundation)
(Source: IMechE : Electric Vehicle Recharging Infrastructure.)

Vehicle Light-weighting

One of the areas of excitement within the automotive industry is looking at the light-weighting of vehicles. Over the last decade vehicles have got heavier due to the addition of added safety features. However, with the use of higher specific strength materials, including aluminium and composites, vehicle body weights can be reduced by between 25% and 40%. Combining this with smaller vehicles, optimised aerodynamics, improved lubricants and low rolling resistance tyres will help tremendously, however, there is only so much that can be done within the constraints of the number of seats, comfort and safety. Second cars could be targeted to offer less accommodation while maintaining key customer needs and reduced emissions.

(Source: IMechE Low Carbon Vehicles)

Biofuels and Synthetic Fuels

Brasil has led the world in the use of sugarcane based ethanol biofuels for vehicles. Today virtually all cars in Brasil have flexible fuel capability and can run on a blend of 25% ethanol and 75% gasoline known as E25. However only a few countries have the land area available to support this level of biofuel productio per head.

In the UK the Renewable Transport Fuels Obligation requires a target of 3.5% biofuel content for 2010/11.

There is a trade off between growing crops for biofuel production, the CO_2e emissions during cultivation compared to savings as a fuel, and the comparative benefit of growing crops for food. It is interesting to note that Brasilian sugarcane has a particularly low Carbon intensity at 24 GCO_2e/MJ.
(Source: DfT Carbon and Sustainability Reporting Within the Renewable Transport Fuel Obligation)

The CCC suggests that the UK could achieve 8% biofuels content by 2020. However current opinion seems to be moving in the direction of reserving this scarce resource for HGV and aviation where there are currently no other good solutions for emission reduction. In this case biofuels includes both crop based and synthetic fuels.
(Source CCC 4th Budget)

Efficiency

In the urban transport environment there will continue to be a need for power units for heavy and specialist vehicles such as waste disposal lorries, emergency vehicles like fire engines, and some passenger vehicles serving mixed urban/ suburban routes without full electrification.

For these vehicles some form of hybrid vehicle is most likely to be the most suitable but the efficiency of the main (non-electric) power unit will be critical. Where internal combustion (IC) engines are retained they will need to be multifuel capable. There will be niche markets for fuel cell and gas powered vehicles including hydrogen.

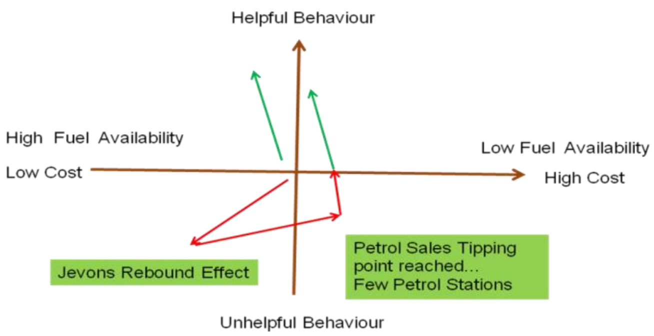
Engine Efficiency

Current work on increasing the efficiency of IC engines will continue to be important.

In our 2009 report we said that significant improvements in IC and hybrid engine design should allow emission levels to reach 130 g/km by 2015 and 70g/km by 2030 with a possible overall 2050 target of 30g/km including all forms of propulsion. SMMT's 10th annual CO2 report stated that for 2010, emissions of new cars fell to an average of 144.2g/km CO2 (equivalent to 50mpg). Cars in the sub-130g/km CO2 category represented almost 40% of the market in 2010. Nearly 40,000 vehicles were exempt from Vehicle Excise Duty (VED) with emissions under 100g/km (equivalent to about 70mpg) so we believe these targets are likely to be achieved. (Source:SMMT)

Human and Marketing Factors

It has been assumed in most of the reports published that the transition from the current dominant IC engined vehicle population to a mainly electric/hybrid population will be smooth but that will not necessarily be the case.



(Source: Cox Future Climate 2009)

Several factors that may interfere with the transition including:

- the Rebound effect

- driver variability
- the Tipping point for petrol sales
- future oil prices
-

The rebound effect is generally credited to the 19th C economist W Stanley Jevons writing about the then perceived impending "peak coal" problem. This principle is that as an activity becomes more efficient and therefore has reduced running costs, more activity results. This means that as the mpg of IC engines is increased (leading to less emissions/km) people actually drive more because the cost/km is less. The result is that only a proportion of the expected savings from efficiency measures are actually realised.
(Source: W.Stanley Jevons. The Coal Question)

The Royal Automobile Club's RAC Brighton to London Future Car Challenge gave some very interesting results both on energy efficiency and carbon reduction.

On a Well-to-wheel CO_2e emissions basis hybrids currently outperform electrics because of the high GHG contribution from grid electricity. Electric cars used the least amount of energy.

In all categories there was a large spread of results indicating the difference in driving technique.

Another effect is a marketing problem. As petrol and diesel consumption declines due to the take up of electric and hybrid vehicles, more efficient IC engines and reduced demand due to modal change, petrol/diesel fuel distribution will tend to change with fewer larger petrol stations.

It is also not clear how oil prices will react to a significant reduction in demand

Long Distance Transport

Reduce demand

Over the next four decades we must focus our efforts on looking at the supply chains for all goods (and services), while still providing the goods and services that people need . A large part of the long distance road freight business involves trucking goods from the major ports situated on the south and east coasts of England to London and towns and cities in the Midlands and North.

Although road freight presents the most difficult part of the transport market to decarbonise, there is evidence that road freight volume in the UK has decoupled from GDP.
(Source: McKinnon)
Understanding the root causes of this decoupling may help our understanding of how to achieve further reductions.

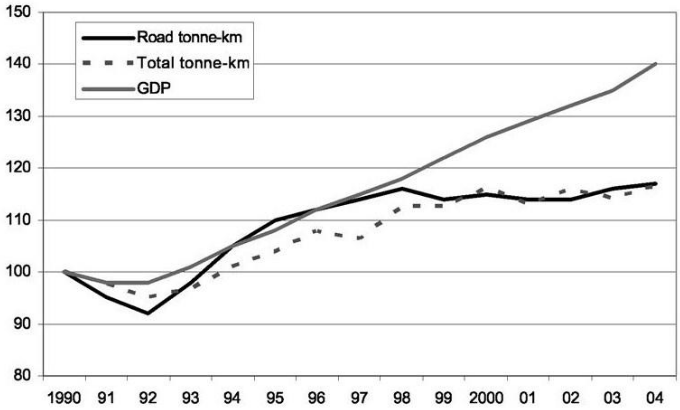


Figure 1. UK gross domestic product, tonne-km and road tonne-km trends (index 1990 = 100), 1990–2004. *Source*: Department for Transport (2005a and 2005c)

McKinnon examined twelve possible causes of the decoupling as shown in Table 7.

60 *A. C. McKinnon*

Table 7. Estimated impact of the possible causes of decoupling

Possible cause of decoupling	Relative contribution (percentage or qualitative estimate)
1. Change in the systems of statistical accounting	very little
2. Dematerialization	little
3. Change in the composition of gross domestic product	significant
4. Decline in road's share of the freight market	22%
5. Increased penetration of UK haulage market by foreign operators	33%
6. Displacement of freight from trucks to vans	little
7. Reduction in the average number of links in the supply chain	little
8. Diminishing rate of spatial concentration	very significant
9. Improvement in the efficiency of vehicle routing	little
10. Domestic supply chains becoming fully extended	significant
11. Erosion of industrial activity to other countries	very significant
12. Increase in the real cost of road freight transport	12%

It would be very useful to investigate some of these factors further. For example if the bulk of foreign operators' loads are from outside the UK these could be a prime target for transfer to rail freight. Some form of transport carbon indicator might help this to happen.

A further avenue of demand reduction is to explore the possibility of reducing empty running – trucks returning empty. Larger logistics companies are able to arrange efficient backloads but it is still reported that there are some 25% of empty trucks on the road.

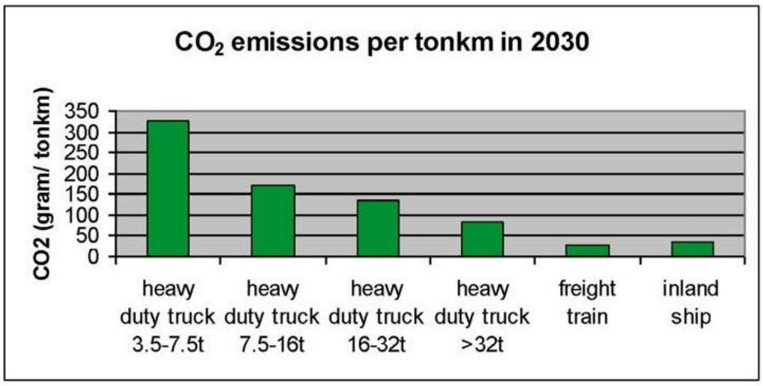
Modal Shift – Rail and Coastal Shipping

As every tonne of freight carried by rail produces significantly less carbon dioxide emissions than that carried by the average truck, the best way to reduce emissions from long distance freight movements is by the the transfer of freight from HGV to rail. Coastal shipping is also a relatively low emission transport mode and the development of additional ports around the UK coast which can handle international freight should be part of an integrated freight transport plan.

EU Transport GHG: Routes to 2050?
Contract ENV.C.3/SER/2008/0053

Modal split and decoupling options
AEA/ED45405/Paper 5

Figure 13 Average CO_2 emissions for various freight transport modes according to TREMOVE



(Source EU)

note: 3.5 -7.5t trucks would normally be called Medium in the UK.

The challenge is that the current UK rail network is overloaded, tries to balance the competing demands of passenger and freight movements and in places is unable to handle modern containers due to gauge problems. Some progress has been made in that rail freight has grown by almost 50% in the last ten years with a current market share of over 10% of surface transport.

The need is to reduce road freight by some 50% by 2050. This can best be achieved if there is an economic advantage to freight/logistics companies to do so.

There would seem to be three ways to increase the capacity of the rail network

a) Build new passenger lines probably as proposed by Greengauge 21
b) Build new dedicated freight rail routes
c) Debottle neck existing lines.

The Greengauge 21 proposal provides for a basic modern passenger network of West and East coast north-south routes, east-west routes connecting London to Bristol, and Glasgow to Edinburgh plus a further east-west connection from Sheffield to Manchester. We suggest this network would be better called the High Performance Rail network as it needs to be built to the highest standards of passenger service of which journey time is only one aspect, but station facilities and interchange to other transport modes are also very important. We envisage through trains to European Standards from Edinburgh and Glasgow to Paris and beyond by 2040.

As the High Performance passenger network is built this will free up capacity for freight on the existing lines. Following the Strategic Freight Network plan, the lines should have already been upgraded by the time they become available. In some places new freight lines may be a good investment to bypass pinchpoints.

What is the Strategic Freight Network?

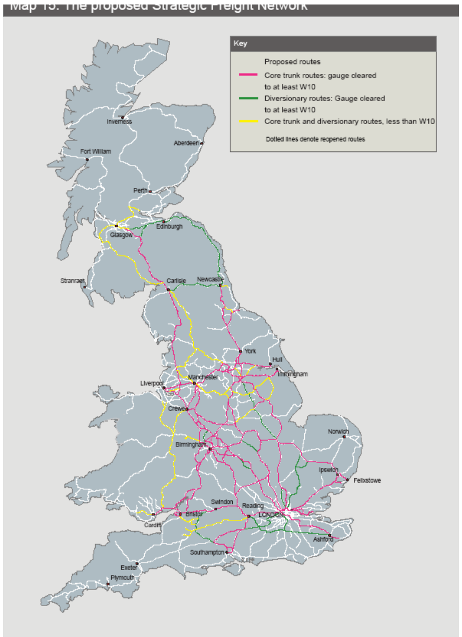
- The Strategic Freight Network is a core network of trunk freight routes, capable of accommodating more and longer freight trains, with a selective ability to handle wagons with higher axle loads and greater loading gauge, integrated with and complementing the UK's existing mixed traffic network.

- The practical effect of this network would be to: To upgrade freight routes and optimise the pattern of freight trunk routeing to remove pinch points and minimise passenger/freight conflicts and to implement ways of operating the railway network that keep freight trains moving.

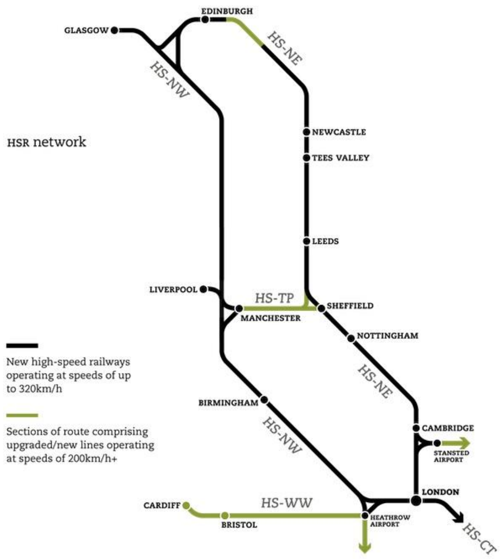
- To enhance freight routes to create more space for freight and enable the operation of longer, higher and wider trains including the ability to operate mainland European freight wagons on selected UK routes

The Strategic Freight Network: The Longer Term Vision
(Source: DfT, Network Rail and the Rail Freight Group)

- *The ten principles in the SFN longer-term vision are*
    - ***Longer and heavier freight trains**: operate 750m long trains as standard and ensure rail freight terminals can accommodate longer trains.*
    - *Allow heavier trains (with the resulting increased capacity) on selected routes.*
    - *Keep on rolling: **achieve non-stop running of freight trains** rather the constant, inefficient stop-start that happens at present*
    - *24/7: **rail freight needs to operate 24 hours a day, 7 days a week – just like road freight**. Ensure that the rail network is able to do this*
    - ***Loading gauge enhancement:** not just for deep-sea containers but also for refrigerated containers and European swap bodies*
    - ***European Freight Link**: build on the use of High Speed 1 by mainland European high capacity wagons by enhancing the network to enable them to reach the Midlands, potentially via the electrified Midland Main Line*
    - *New Freight Capacity: **increased capacity on key arterial routes** or those that avoid major conurbations*
    - ***Electrification of freight routes**: especially small infill schemes linking existing electrified routes and lines with heavy long-distance freight usage*
    - *Strategic Rail Freight Interchanges and Terminals: **encourage the development of additional interchanges and terminals** supported by planning processes that recognise the national interest*
    - ***Protect freight capacity**: by introducing a scheme that retains existing, released and newly created paths for long term freight use*
    - *Freight routeing studies: to **identify and then create the optimal rail freight routes** between London/South East and the Midlands & North of England.*



Proposed Strategic Freight Routes



Greengauge 21's Fast Forward proposed Passenger Routes
(Source: Greengauge 21)

We think that building the Strategic Rail network by debottlenecking the existing rail network will be an extremely expensive and time consuming project not least because of the difficulty of keeping the trains moving whilst work goes on.

Dedicated new freight lines between the major ports and key urban areas could be the most cost effective way of achieving substantial modal shift in a controllable time frame.

example: A new rail freight line direct from Felixstowe to Birmingham. In the existing plan this is being done in sections including:

- a new 1km section of track north of Ipswich goods yard, linking the East Suffolk and Great Eastern lines .
- two 775m sections of track east of Ely station to enable better regulation of trains through the junctions at Ely.

Futurenet

The Futurenet project is examining possible future resilient transport networks for the UK.

(Source: http://www.arcc-futurenet.org/)

Efficiency

For the HGV fleet significant improvements in fuel efficiency are being expected from a combination of:

- Improved driving techniques

- Lower resistance tyre systems
- Reduced wind resistance through better aerodynamic design
- Improved power unit and drive train efficiency

The LowCVP Technology Challenge has also highlighted a number of new innovations aimed at improving HGV efficiency and reduced emissions. The 2010 winners were:

- Flybrid Systems — Flywheel Hybrids
- The Flybus Consortium — Bus Kinetic Energy Recovery System
- The Hardstaff Group — Dual Fuel system for HGV
- MIRA — Vehicle Aerodynamics
- Zeta Automotive — Econospeed Dynamic Throttle Control
- RDS Europe Ltd — Hydraulic Hybrid system
- SOMI Trailers Ltd — Advanced trailer loading to reduce journeys.

Some or all of these HGV efficiency improvements should result in some 25 to 30% reduction in per tonne-km emissions.

Vans

Vans and light trucks (LCV: vehicles under 3.5 tons) have been the fastest growing but previously unregulated part of the freight market and a significant contributor to GHG emissions and other pollution. The EU in September 2010 confirmed the short term target for vehicles of under 3.5 Tons of 175 g CO2/km by 2017 and a longer term target of 140 g/km by 2040. These are higher permissible levels than is desirable but do start the process of bringer LCVs into the emission controlled environment.
(Source: EU emission regulations)

Comparison with DECC Pathways

The DECC Pathways Calculator provides a convenient way of identifying the factors involved in achieving an 80% reduction in UK GHG emissions by 2050. We have chosen the Alpha/A Pathway (which achieves 80% emission reduction by 2050) for comparison as it is the nearest to the pathway in the IMechE 2009 version UK Energy Plan. http://2050-calculator-tool.decc.gov.uk/pathways/a/primary_energy_chart

The transport related part of the pathways calculator is as follows:

DECC Pathway Alpha/A

Individual transport behaviour	1 Mileage grows but slows	2 Cars & Vans 80% of passenger mileage	3 Cars & Vans 74% of passenger mileage	4 Significant low carbon modes of travel
Electrification of individual transport	1 Conventional Cars & Vans 80%	2 65% of Cars plug-in, EV etc	3 80% of Cars plug-in, EV etc	4 100% of Cars plug-in, EV etc
Domestic freight	1 Road Haulage 73%	2 Road Haulage % falls slowly	3 Road Haulage % falls and greater efficiency	4 Road modal share 50%

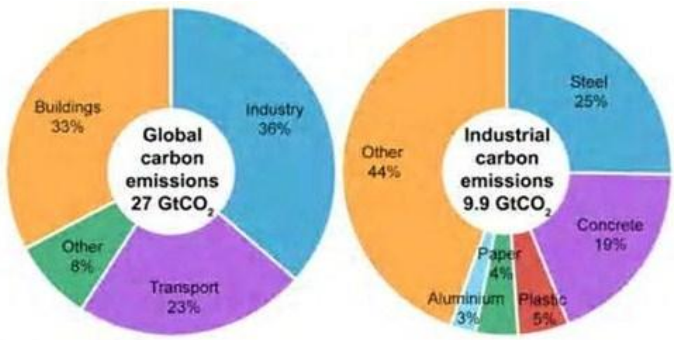
Yellow highlight is the DECC Alpha/A choice and represents the situation achieved in 2050 if the Alpha pathway is followed. Green highlights indicate where we suggest the pathway that should be followed.

Transport Conclusions

To achieve the overall UK requirement of an 80% reduction in GHG emissions by 2050 the following are needed:

- Reduction in energy demand from both urban and long distance domestic, business and freight transport .
- Increased rate of modal transfer of urban travel to electric and mass transport systems .
- Increased rate of modal transfer of Freight transport to rail by building new passenger lines and upgrading freight lines to European standards.
- Accelerated efficiency gains for LCVs and HGVs through a combination of actions as indicated above

6 Industrial Processes



Global emissions of carbon dioxide (a) by major sector and (b) within industry

(Source: IEA, Allwood and Cullen 2009)

Industrial Processes are one of the “big three” emitters of GHGs both globally and in the UK.

Reducing Industrial Process emissions is fairly complex and is best looked at from a supply chain point of view.

UK Industry Related Regulations

In the UK industry is subject to three key emission and energy use reduction regulations:

- EU ETS EU Emissions Trading System
- CCA Climate Change Agreements
- CRC Carbon Reduction Committment

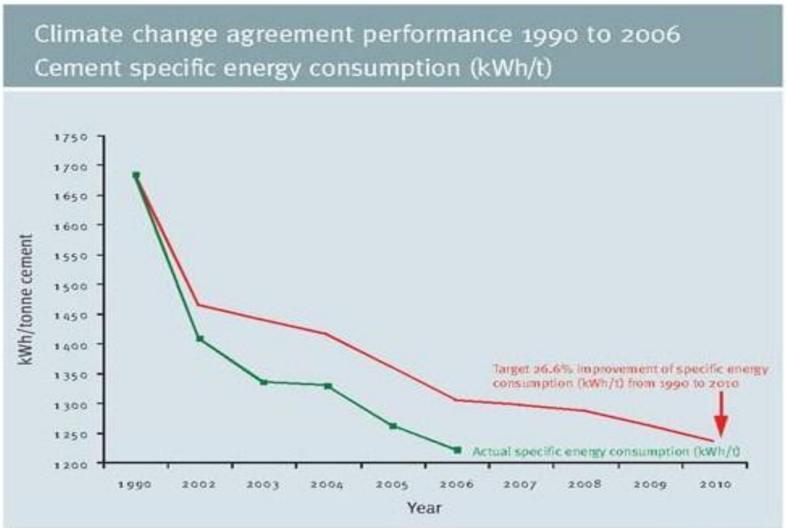
Electricity market response etc

The European Union Emissions Trading Scheme EU ETS is a so called cap-and-trade scheme which covers large industrial sites which have combustion sources with a rated thermal input of 20MW or more and large energy intensive industrial units such as refineries and offshore, iron and steel, cement and lime, paper, food and drink, glass, ceramics, engineering and the manufacture of vehicles. Combined, these account for around 48% of UK industrial CO2 emissions.

The EU ETS was started in 2005 and continues to develop in response to many criticisms of way it operates.

Climate Change Agreements are UK regulations which allow agreeing parties to reduce Climate Change levies. They have mainly been negotiated on an industrial sector basis.

Example: British Cement Association CCA.



Energy targets achieved

(Source:British Cement Association)

The CRC Energy Efficiency Scheme is a mandatory climate change and energy saving scheme which started in April 2010.

Qualification for the scheme is based on half-hourly metered electricity usage. An organisation will qualify if during the 2008 calendar year it:

- had at least one half-hourly electricity meter (HHM) settled on the half-hourly market across the whole organisation.
- had a total half-hourly electricity consumption over 6,000 megawatt-hours (MWh) once electricity used for transport and domestic accommodation has been excluded.
- All organisations that meet the first criterion but consume less than 6,000MWh of half-hourly electricity will not qualify but have to register.

– The scheme will only include emissions not covered by Climate Change Agreements (CCAs) or the EU Emissions Trading System (EU ETS)

The CRC scheme was originally planned as cap-and-trade scheme but the trading part of the scheme has currently been dropped.

UK Industry is also encouraged to reduce emissions through three incentive schemes:

- ROCs Renewable Obligation Certificates
- FITs Feed In Tarriffs
- RHI Renewable Heat Incentives

Renewable Obligation Certificates (ROCs).

Generators of all sizes can claim ROCs for every megawatt hour (MWh) of renewable electricity they generate. Different renewable generating technologies receive different numbers of ROCs/MWh

- The Renewable Obligation places an obligation on licensed electricity suppliers in the United Kingdom to source an increasing proportion of electricity from renewable sources. In 2010/11 it is 11.1% This figure was initially set at 3% for the period 2002/03 and under current political commitments will rise to 15.4% by the period 2015/16 and then it runs until 2037. Since its introduction the RO has more than tripled the level of eligible renewable electricity generation (from 1.8% of total UK supply to 5.4% in 2008).

DECC have announced that Arup will carry out a review of renewable technology costs in support of the 2013 Banding Review

Feed in Tariffs have been in use in other European countries for some time and were introduced into the UK in February 2010.

A range of electricity generating renewable energy systems can receive Tariff support. The scheme has been particularly successful for PV installations to the extent that the support for large PV farms has been significantly reduced. Current FIT tariffs give an approximate 10 year payback on domestic PV installations.

It is intended that FIT support will reduce as technologies develop and achieve volume pricing.

Renewable heat Incentive

The Renewable Heat Incentive which operates in a similar manner to FITs was introduced inApril 2011 except for individual domestic installations which will be included in 2012.

Heat generated from renewable energy sources currently only meets 1 percent of the UK's total heat demand. To reach the 2020 renewable energy target, around 12 percent of the UK's heat needs to be generated from renewable sources.

UK Industrial Structure

Figure C2: Percentage share of UK manufacturing output (2007)[94]

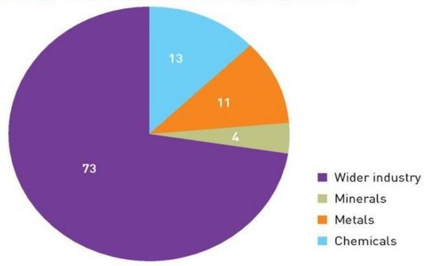
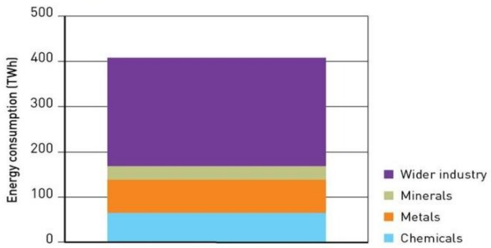


Figure C3: Energy consumption by UK industrial sector (2007)[95]



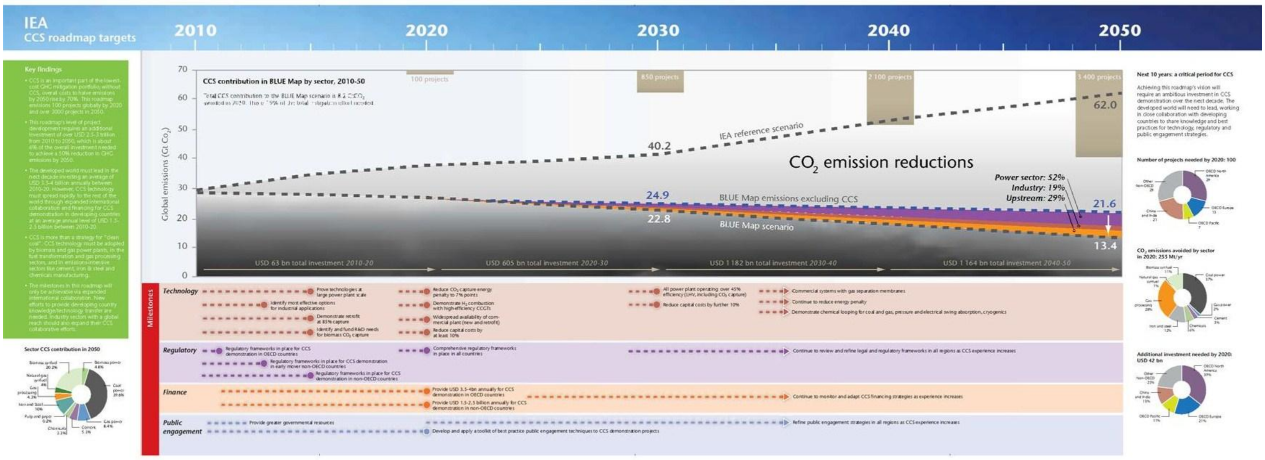
(Source:DECC Pathways Analysis)

In the UK, general manufacturing industry is responsible for some 73% of industrial GHG emissions and energy use (DECC pathways).

The big polluting industries: Chemicals (13%), Metals (11%) and Minerals (4%) make up the balance. The steel and cement industries have sectorial emission reduction and energy reduction plans.

Minerals – the Cement Industry

The World Business Council for sustainable Development together with the IEA have developed the WBCSD_IEA Cement Technology Roadmap issued in 2009. This covers emission reductions up to 2050. The use of CCS in the cement process is a significant part of this plan.



(Source:WBSCD_IED)

The introduction of new cement industries based on different raw materials also offers another way forward.

Innovation

Novacem has developed a new class of cement based on magnesium oxide (MgO) and hydrated magnesium carbonates which will offer performance and cost parity with ordinary Portland cement, but with a carbon negative footprint.

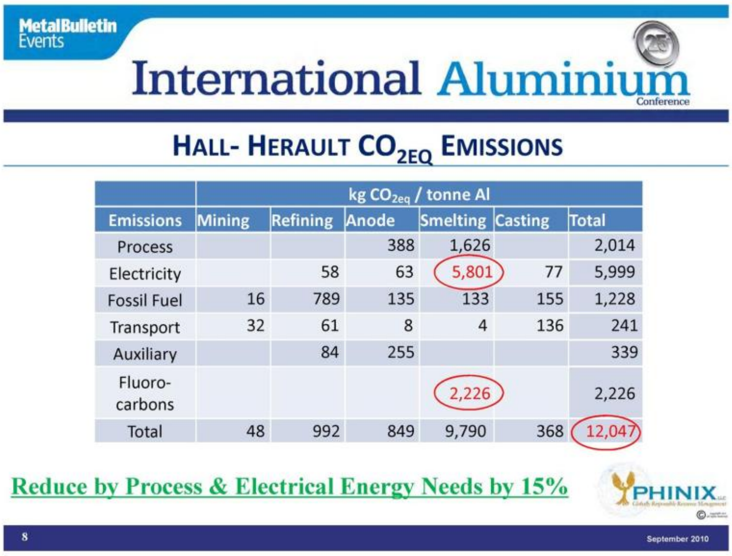
The production process to make 1 tonne of Novacem cement absorbs up to 100 kg more CO_2 than it emits, making it a carbon negative product.

Metals

Steel - The ULCOS Project

ULCOS stands for Ultra–Low Carbon dioxide(CO_2) Steelmaking. It is a consortium of 48 European companies and organisations from 15 European countries that have launched a cooperative research & development initiative to enable drastic reduction in Carbon dioxide(CO_2) emissions from steel production. The consortium consists of all major EU steel companies, of energy and engineering partners, research institutes and universities and is supported by the European commission. The aim of the ULCOS programme is to reduce the Carbon dioxide(CO_2) emissions of today's best routes by at least 50 percent. The UK partner in the ULCOS project is Metalysis Ltd.

Aluminium



	kg CO_{2eq} / tonne Al					
Emissions	Mining	Refining	Anode	Smelting	Casting	Total
Process			388	1,626		2,014
Electricity		58	63	5,801	77	5,999
Fossil Fuel	16	789	135	133	155	1,228
Transport	32	61	8	4	136	241
Auxiliary		84	255			339
Fluoro-carbons				2,226		2,226
Total	48	992	849	9,790	368	12,047

The Aluminium Industry has suffered in the past from operational problems known as Anode Effects. These lead to process emissions of PFCs (Perfluorocarbons) which are strongly active GHG emissions. CO2 is also emitted from the carbon anode used in the electrolytic process.

Aluminium industry actions have significantly reduced the frequency of Anode Effects. The residual emissions would be further reduced by the adoption of neutral anodes.

One of the largest sources of emissions from aluminium production are now from the main energy source. For this reason Aluminium plant are often sited next to large Hydroelectric stations or nuclear plant. Major aluminium producers are making substantial efforts to reduce the process energy use.

Aluminium mining from landfill sites has been suggested as a way of reducing both new ore mining and energy use and emissions. Recycled metals require significantly less energy to process than new ore.

Aluminium makes a positive contribution to energy efficiency through its use in lightweighting vehicles.

Metal Recycling

UNEP International Panel for Sustainable Resource Management have published their first report "Metal Stocks in Society" as part of their project to understand the level of metals available for recovery and recycling.

Recycling of metals offers a major potential way to reduce energy consumption and hence GHG emissions from metal processing. The UNEP work shows that metal stock and recycling data is not extensive and that current recycling levels are generally low.
(Source: UNEP)

Process Emissions

Some industrial sectors produce direct emissions from chemical reactions involved in their activities. These are more difficult to reduce. Substantial reductions in process emissions will require new techniques, such as:

- electrolysis within the steel industry;

– use of inert anodes within aluminium production;

– new catalysts within chemical processing.

Wider Industry

As the bulk of the UK industrial emissions come from wider industry which includes a disparate range of processes and technologies it is helpful to use some general techniques to analyse and provide solutions to emission and energy use reduction.

Some useful tools that are available include:

Traditional Energy Audits covering for example: Heating, Lighting, Pumps, Motors, etc

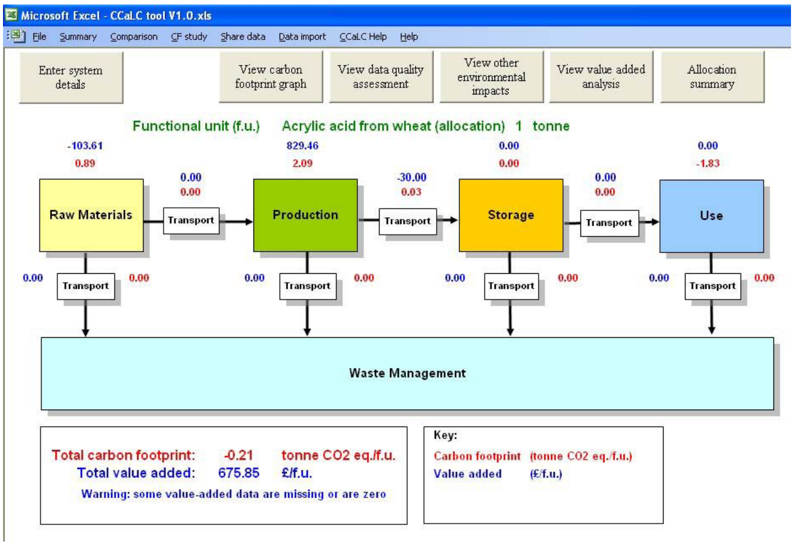
Heat Balance Analysis

Supply Chain Footprint Analysis.

Supply Chain Carbon Footprint Analysis

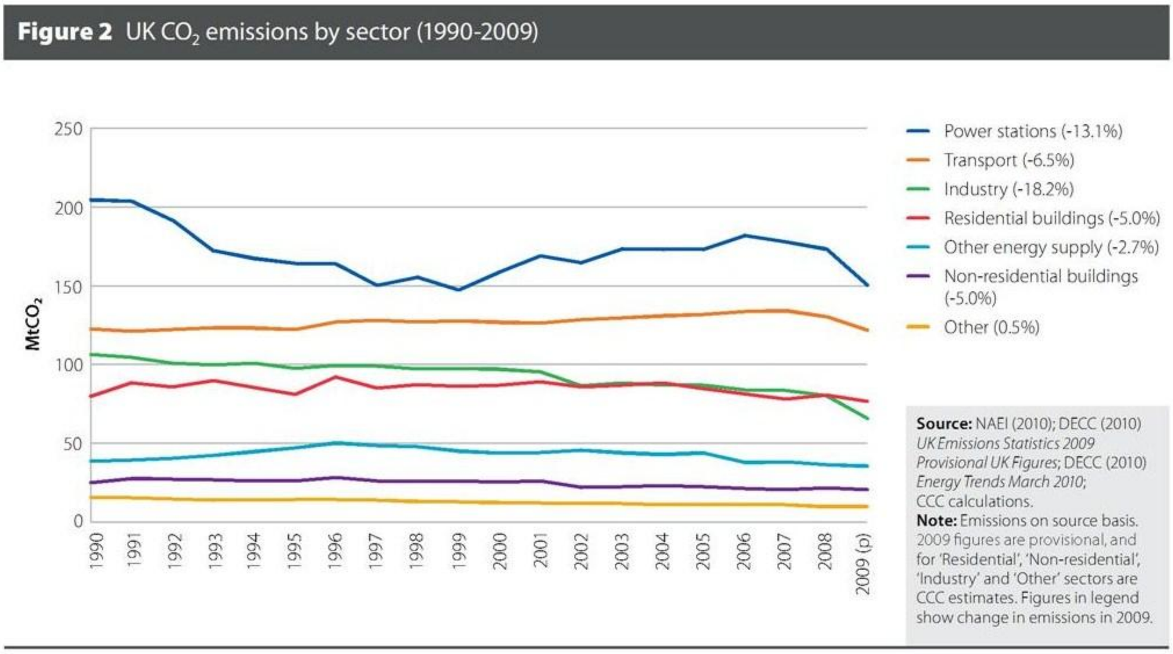
This technique is extremely helpful for businesses as it not only quantifies the energy use through the supply chain but also highlights parts of the process where there are opportunities for efficiency improvements. Comparing the supply chain analysis of alternative supply solutions can also throw up unexpected results.

The CCaLC Supply chain analysis software was developed by a research group based at the University of Manchester and funded by Carbon Trust, EPSRC and NERC.



(Source:CCaLC)

Overall Industrial Processes have achieved better reductions in emissions and energy use than most other sectors as recorded by the Commission on Climate Change..



(Source: Committee on Climate Change 2010).

7 Agriculture, Food Production and Land Use

In the overall UK energy use and emissions breakdown the Agriculture sector only uses some 1% of the UK energy supply. For this reason the sector has perhaps received less attention in UK energy planning than it deserves. In fact as we recorded in our 2009 report, the Agriculture sector is responsible for nearly 7% of UK emissions.

The Agriculture sector has several important aspects:

55% of Agricultures emissions are of Nitrous Oxides which are much more powerful GHGs than CO2. A further 40% of Agricultural emissions are of Methane also a powerful GHG. The balance of 5% is CO2.
(Source: Zero Carbon Britain, CAT)

> Methane is primarily related to grazing livestock; Nitrous Oxides are largely related to the use of fertilisers on grazing pastures.

Agricultural land is a limited resource which is also sought for the production of bio-energy crops.

Agriculture is an integral part of the Food production process. The food supply chain is estimated to produce between 20 to 30% of the UK's total emissions and therefore represents a key target for GHG emission reduction.

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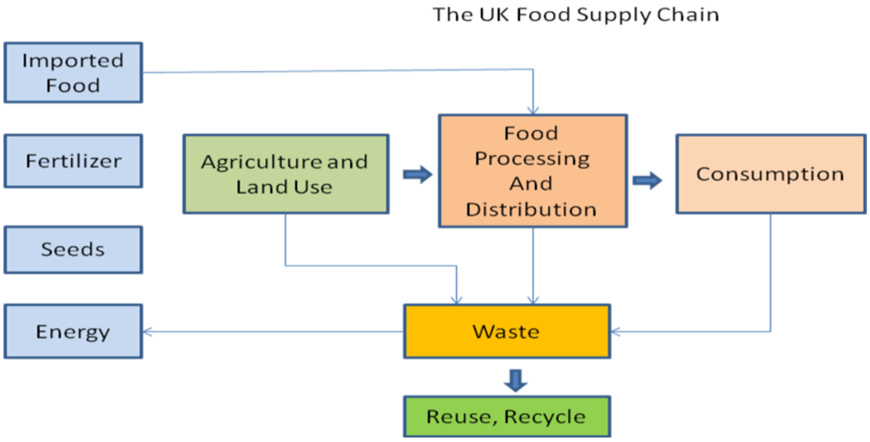
(Source: World Wildlife Fund)

Land use in general can also deliver negative emissions through the careful husbandry of woodlands, plants and soil.

Taken together the Agricultural sector is therefore subject to a range of conflicting but important objectives.



The World Wildlife Fund have suggested that reductions in emissions and energy use from the food supply chain can be separated into:

1. Decarbonisation of energy used by a) mobile (eg Tractors and other machinery) and b) static machinery
2. Reductions of direct emissions from processes and from agricultural use.
3. Reductions of emissions by improving energy efficiencies throughout the supply chain.
4. Changes in basic demand by changing consumption
5. Reduction of and the efficient use of waste.

Mobile Energy Use

The current dominant energy source for agricultural machinery is diesel. As with road transport we can expect significant improvements in fuel economy over the next few years. Stop-start and flywheel/hydraulic energy storage systems would seem well suited to agricultural use.

New Holland launched the NH3 hydrogen powered tractor in 2009.

New Holland NH3 Tractor

New Holland’s concept is that farmers generate their own hydrogen on the farm from crop and other waste leading to an energy independent farm industry.

Static Energy Generation

There is good support in the farming industry for using renewables and waste to generate electricity and gas on the farm. AD, Wind and Solar PV are the top choices. Farms have traditionally used biomass boilers for heating and wind power for both pumping and back up electrical supply so this is a natural process. AD is well suited to generate renewable gas from farms, food processing and waste but gas processing is required to bring the biogas to pipeline standards. This has made gas engine electricity generation more popular.

Of the supporting processes, **fertilizer production** is a significant emission generator.

According to the International Fertiliser Association:

Fertiliser production consumes approximately 1.2% of the world's energy and is responsible for approximately 1.2% of the total emission of the greenhouse gases in the world, consisting of 0.3% of pure CO_2, 0.3% as N_2O and 0.6% as flue gas CO_2.

Theoretically, global energy consumption by the fertiliser industry can be reduced by almost 40% and the greenhouse gas emissions by almost 60% through implementing new technology. This is positive in view of a ongoing replacement of old technology over the next decades. The specific energy consumption in the West European fertiliser industry is approximately 15% lower than the global average. In West Europe, the fertiliser industry consumes 0.9% of the total energy consumption and emits 1.8% of the CO_2/N_2O emissions. Lower energy consumption is mainly due to higher energy cost and higher emissions are due to different product ranges (more AN versus urea).

The main energy requirement for production of fertilisers is linked to the nitrogen component; 94% for N, 3% for P_2O_5 and 3% for the K_2O component on a global basis. Production of the most common phosphate fertilisers

(DAP/MAP and SSP/TSP) with modern technology releases excess energy due to the huge surplus energy formation in modern sulphuric acid processes.
(Source: International Fertiliser Association)

There are two other factors which will affect the use of fertilisers in future. There is an approaching international shortage of phosphate minerals. To some extent this can be mitigated by the recycling of animal waste to the land in the form of manure. Phosphates lost to the food chain can also be harvested as Struvite at sewage treatment works.
(Source: Soil Association)

Perhaps the most positive step is the likely reductions in fertiliser demand through the development of new plant varieties suited to low fertiliser application, significant reductions in grazing pasture fertilisation and the development of organic fertilisers.

Food transport like all freight transport needs to change mode to rail, and ship where possible. Overall distribution cost in emission terms can be further reduced by the use of locally produced food and an adaptation of demand to seasonal availability of food varieties.

Totnes Market Gardens

Totnes had three commercial market gardens within the town itself: Heaths, Gills and Phillips/Victoria Nursery. The largest, at least initially, was Heath's, started in 1920 by George Heath senior, and then run by his son, also called George, until its closure in 1981. Much of the south-facing area of the town had been dedicated to food production back through history, and the gardens serve as a powerful reminder of the potential of urban market gardening.

own greengrocer shops. Whilst there has been a resurgence of interest in allotments and grow your own vegetable production at the personal level, to meet the requirements of the whole population there is a need to create a modern version of these mid-sized local food supply chains and reduce the dependence on imported food.
(Source: Transition Towns)

8 Energy Production, Storage and Distribution and developing the CO2 Utilisation Industry

The Power Sector was in 2008 the biggest single generator of GHG emissions, with power stations the largest within the sector.

Besides its basic duty to "Keep the lights on", the sector must also balance several demanding constraints:

Emission reduction to comply with UK law.

Increased use of renewable energy sources to comply with EU law
End of life of old plant.
Security of energy supply
Distribution issues within the changing energy environment.

As discussed before, it is generally accepted that the bulk of the energy generation up to 2050 must come from three main sources – wind, nuclear, and coal/gas with CCS abatement. The other energy sources being important in total but none likely to be able within the timescale to act as a major energy source for the UK.

In our 2009 report we suggested that by 2050, Wind Energy generation would be the largest single type at 40 GW delivered electricity output capacity, followed by Nuclear at 25 GW, Coal/Gas at 16GW, Biomass at 12 GW, Marine at 11GW and Solar PV at 6GW. We accept that over time the actual final balance of these main contributors may change particularly if any new innovations come to fruition.

However even with such challenging targets the total delivered electricity supply would only be near twice the current grid supply level.

Review of Energy Supplies

This review looks to document progress since our 2009 report.

Review of Energy Supplies (redraft)

Previous reports and IMechE Energy Policy Statements including 11/01 and 11/02 have used the DUKES (Digest of UK Energy Statistics) data as their basis for comment on the UK generating capacity. The DUKES data is the correct historical source but suffers from being two years old. For example the latest current DUKES report is for 2009.
(Source: Dukes, IMechE Energy Policy Statements 11/01 UK Energy Security, 11/02 UK Electricity Generation)

In order to obtain a more recent view of the developing generation situation we therefore use the 2010/2011 data from table 5.4 of the National Grid Seven Year Statement 2011 as the basis for discussion.

The National Grid Seven Year Statement 2011 has the following notes:

It should be noted that the generation background, on which this document is based, ***is not National Grid's forecast*** *of the most likely developments over the next seven years.*
The generation background is a factual list of existing and proposed generation projects that have a signed connection agreement. Consequently, care must be taken when interpreting the results as there is a degree of uncertainty associated with the number of generation projects opening or closing.

'*SYS Background' (SYS)*
This background includes the existing generation and that proposed new generation for which an appropriate Bilateral Agreement is in place. The fact that a generation project may be classified as 'contracted' does not mean that the particular project is bound to proceed to completion. Nevertheless, the existence of the appropriate signed Bilateral Agreement does provide a useful initial indicator to the likelihood of this occurring.

Table 5.4 - Capacity by Plant Type (SYS)								
Plant Type	**2010/11**	**2011/12**	**2012/13**	**2013/14**	**2014/15**	**2015/16**	**2016/17**	**2017/18**
Biomass	45	97	97	851	1730	1730	1730	1730
CCGT	29022	32172	32922	34717	39738	41258	45258	45258
CHP	2240	2240	2240	2240	2240	2240	2240	2240
Hydro	1113	1113	1113	1113	1113	1113	1113	1113
IGCC with CCS	0	0	0	800	800	800	800	800
Large Unit Coal	4342	4342	4342	4342	4342	4342	2284	2284
Large Unit Coal + AGT	21440	21440	21440	21440	21440	21440	17517	17517
Medium Unit Coal	1102	1102	1102	1102	1102	1102	0	0
Medium Unit Coal + AGT	1131	1131	1131	1131	1131	1131	0	0
Nuclear AGR	8246	8246	8246	8246	8246	8246	8246	8246
Nuclear EPR	0	0	0	0	0	0	0	3340
Nuclear Magnox	1390	960	0	0	0	0	0	0
Nuclear PWR	1207	1207	1207	1207	1207	1207	1207	1207
OCGT	578	578	578	578	578	578	478	478
Oil + AGT	3636	3636	3636	3636	3636	3636	0	0
Pumped Storage	2744	2744	2744	2744	2744	2744	2744	2744
Small Unit Coal	783	783	783	783	783	783	783	783
Tidal	0	0	0	10	10	10	10	110
Wind Offshore	1198	2406	3057	4395	6734	10313	13457	18087
Wind Onshore	2281	3033	4166	4850	6945	7234	7461	7849
Woodchip	0	0	0	350	350	350	350	350
Total Capacity (MW)	**82498**	**87230**	**88804**	**94535**	**104869**	**110257**	**105678**	**114136**

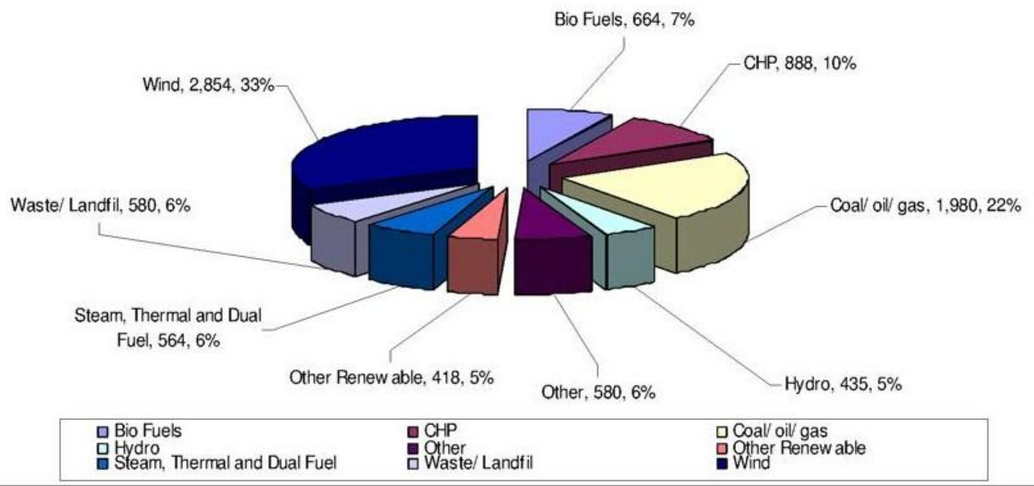
(Source:National Grid Seven Year Statement 2011)

This table shows the significant increase in the proportional of gas and wind based generation over the period particularly beyond 2016 when the EU Large Combustion Plant Directive comes into force and before new Nuclear plant come on stream after 2018.

Not shown is the power available from the international interconnects from France and to Holland (Britned).

The table shows the sources of generation which are used to supply electricity to meet Peak Demand and also does not include what National Grid refer to as "embedded and renewable generation".

Figure 4.1 - Main Types of Embedded Generation (MW)



(Source:National Grid Seven Year Statement 2011)

NG Figure 4.1 shows the analysis of the main types of embedded Generation over 5MW based on NG Appendix F3.

Smaller local generation such as domestic PV can be sensibly regarded as negative demand. DC to AC inverters on distributed generation are set to switch off when Grid problems are detected. This may change in the future if local microgrids are installed in any volume. Distributed Energy Systems and Energy from Waste are discussed in previous IMechE reports.

(Source: IMechE Distributed Energy Systems, Energy from Waste)

The future reliance on Gas and the proportionally low generation capacity of renewable is shown in DECC Energy Projections. CL and CH refer to Central High and Low projection models.

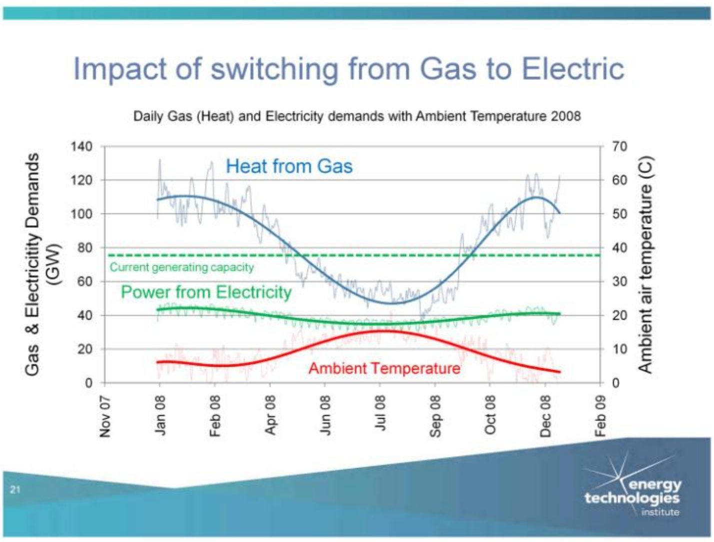
Table D.1 Electricity Generation by Fuel Type, TWh

CL	1990	1995	2000	2005	2010	2015	2020
coal	204	145	105	54	38	31	26
oil	15	9	1	0	0	0	0
gas	0	57	134	196	236	278	307
nuclear	59	81	80	86	66	40	27
renewables	5	6	11	22	43	43	43
imports	14	18	15	12	7	6	5
Total	**297**	**315**	**345**	**370**	**390**	**399**	**408**
CH	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
coal	204	145	104	96	83	74	49
oil	15	9	1	0	0	0	0
gas	0	57	132	142	173	216	264
nuclear	59	81	80	86	66	40	27
renewables	5	6	11	22	41	41	41
imports	14	18	16	13	8	7	6
Total	**297**	**315**	**343**	**360**	**371**	**378**	**387**

(Source: http://www.decc.gov.uk/assets/decc/statistics/projections/file11257.pdf)

The above generation capacities should be compared with typical patterns of demand calling for from 40 to 60+ GW in the winter period.

If Heating and Transport energy demand is substantially electrified clearly a considerable increase in grid capacity will be required, although much transport demand (electric vehicle charging) could be at night given suitable meter/tariff systems.

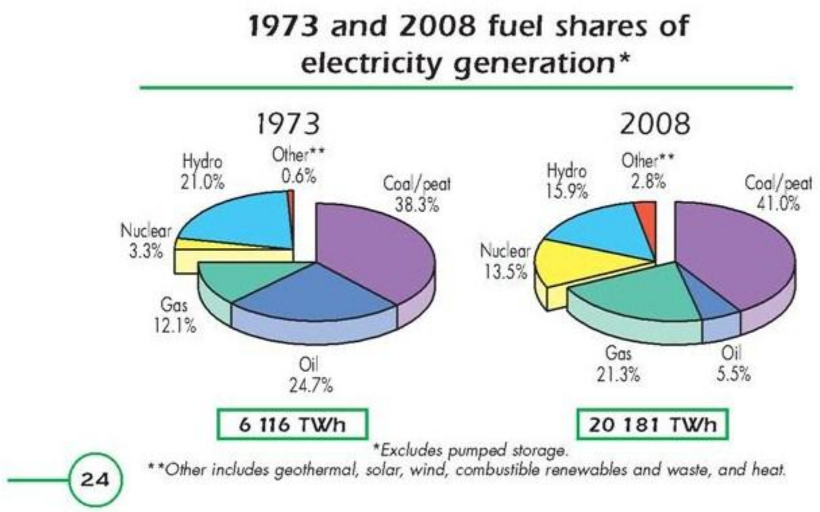


(Source:ETI)

Heat demand is highly seasonal and currently largely gas powered. A major changeover to electric powered heating would probably be beyond the likely future capacity of the Grid. The use of heat pumps has been proposed as a way of mitigating this demand through their typical 3:1 energy multiplier effect but we see this as remaining only a section of the market partly due to the high cost of electricity.

Coal and Gas Power Stations and CCS

Globally, coal remains the largest individual source of electric power generation and marginally increased its share from 1973 to 2008. Gas has increased significantly over the same period and oil has reduced. Due to low cost and ease of extraction, gas and coal will remain the major sources of energy in future decades for many parts of the world.



(Source: IEA World Energy Statistics)

To meet the emission reduction target all Coal and Gas plant will need some form of Carbon Capture and Storage (CCS). There are major CCS projects in progress around the world. Details are reported in for example the CaptureReady CCS Biweekly Newsletter

There is a pre-existing need to also remove Nox and Sox from any fumes released to atmosphere. Until now Pulverised Fuel (PF) boilers have been almost solely used for coal fired plant. CCS, like Flue gas desulphurisation and LoNox could be applied to them relatively easily at a cost and energy penalty. Integrated Gasification Combined Cycle (IGCC) gas turbine plants are being used now with the benefit of being able to produce hydrogen for burning in engines or used in fuel cells. The PF route, that is likely to predominate for many years, can be made more suitable for CCS by burning the coal in an oxygen-rich atmosphere - Oxyfuel combustion. PF firing also has the ability to co-fire biomass as at Drax B power station where around 10% by MW output is currently being produced in this way. Up to 20% biomass co-firing may be possible in the future if sufficient biomass is available. This has the further advantage of reducing CO_2 emissions..

Currently Gas power plants are the lowest capital cost and quickest to build. Although increasing reliance on imported gas is a concern, none the less, gas is likely to remain the UK's primary energy source for the next two decades. It is estimated there may be as much as 30GW of additional CCGT installed in the UK between now and 2030.

This reliance on imported gas may be mitigated somewhat by the introduction of renewable gas into the Gas Grid.

(Source: National Grid. The potential for renewable gas in the UK)

The UK CCS competition programme kicked off in March 2010 with the award of FEED (Front End Engineering and Design) studies to E.On and Scottish Power.

£1billion has been confirmed (in October 2010 and in the budget 2011) for capital expenditure on the first demonstration plant and the government has committed to supporting three further projects, with the competition opened to gas as well as coal.

Separately the Energy Technology Institute has started a project for CCS technology which can be retrofitted to CCGT plant.

The EU NER300 Project will fund at least eight CCS projects and 34 renewable energy projects.

Monday, May 16, 2011 CaptureReady.com – CCS Information Hub <newsletter@captureready.com>

7 Member States have applied for a total of 13 CCS projects under the first call for proposals under the so-called NER300 funding mechanism. In addition, Member States have submitted 65 renewable energy project applications.

Majority of UK projects

Out of the thirteen CCS applications, seven are from the UK:

- Alstom Limited Consortium: oxyfuel new supercritical coal-fired power station on Drax site in North Yorkshire.

- C.GEN: new integrated gasification combined cycle (IGCC) power station (pre-combustion with CCS on the coal-feed) in Killingholme, Yorkshire.

- Peel Energy CCS Ltd: post-combustion amine capture on new supercritical coal-fired power station at Hunterston in Ayrshire, Scotland.

- Don Valley Power Project (formerly known as the Hatfield Project): new IGCC power station in Stainforth, Yorkshire. The project has already received €180 million from the EEPR.

- A consortium led by Progressive Energy Ltd; pre-combustion coal gasification project in Teesside, North East England.

- Scottish Power Generation Limited: post-combustion amine capture retrofitted to an existing subcritical coal-fired power station at Longannet, Scotland.

- SSE Generation Limited: post-combustion capture retrofitted to an existing CCGT power station at Peterhead, Scotland.

Six other countries have submitted applications for a single CCS project:

- Air Liquide is the applicant from The Netherlands. The Rotterdam-based hydrogen project, involves the capture and storage of CO_2 that is released in the production process of hydrogen from hydrocarbons. Air Liquide is currently investigating, together with Maersk Oil, the possibility of permanently storing the captured CO_2 in mature Danish oil fields, in combination with Enhanced Oil Recovery.

- In Italy, the post-combustion CCS project in Porto Tolle aims at capturing and storing parts of the CO_2 from a new 660MW coal-fired unit. It has already been awarded €100 million from the EEPR.

- The French candidate is the industrial project developed by ArcelorMittal at its Florange steelworks in northern France.

- In Germany, the Jänshwalde project, which also runs for the competition, has already received €180 million from the EEPR for an oxyfuel coal-based project.

- As for Poland, the Belchatow power plant consists in a 250MW capture plant at a new coal-fired unit, using an amines-based capture

technology. It has already been awarded €180 million from the EEPR.

Developing the CO2 Utilisation Industry

Fitting CCS to fossil fuel power plant adds significantly to the overall electricity generation cost. As the world wide installation base of CCS plants increases the unit cost will fall, as with any industrial process, through continuous improvement and process innovation.

A second way of reducing the cost is to develop the CO2 Utilisation market and add value to the emission reduction process.

EOR (Enhanced Oil Recovery) is a well proven technology which may be very applicable to the UK North Sea oil fields. It has been estimated that CO2 production from the eastern part of the UK could power North Sea EOR for 10 to 15 years. This would generate further oil supplies during the period when the low carbon economy is still in an early stage of development, finance a major part of the carbon capture infrastructure and generate increased tax revenues.
(Source: J Gluyas, Durham University Energy Institute)

The Global CCS Institute and Parsons Brinckerhoff have listed seven other potential industrial uses for CO2:

- Mineralisation (including carbonate mineralisation / concrete curing / bauxite residue processing);
- CO2 as a feedstock in urea yield boosting;
- Enhanced geothermal systems (using CO2 as a working fluid);
- CO2 as a feedstock in polymer processing;
- Algae production
- Liquid fuels (including renewable methanol / formic acid); and
- CO2 for use in enhanced coal bed methane (ECBM) recovery.

There is concern that some of these technologies still result in CO_2 release to the atmosphere again within a relatively short time period.

Clearly if any of these technologies reach maturity, they will give CO2 an enhanced market value which will impinge on the overall cost of generating electricity from fossil fuels.

For most of these technologies commercial operation looks likely to be in the timescale 2015 to 2020

Note: The light blue circle represents the technology at demonstration scale, while the dark blue circle represents commercial operation of the technology based on claims from the respective proponents. Consequently, the predictions appear optimistic. The arrow extending from the dark blue circle indicates a more pragmatic timeframe to commercialisation.

(Source: Parsons Brinkerhoff)

Innovation

In February 2011 Bayer announced that it had brought a pilot plant on stream for the production of high quality plastics from CO2. Bayer's Dream Production project produces a polyurethane like end product. Bayer is working on the project with the energy company RWE which supplies the CO_2 used in the process. This process is made possible by the development of a new catalyst.

(Source: Bayer)

Renewable Gas

In its 2009 report, National Grid estimated that renewable gas generated from Anearobic Digestion and other waste processes could supply up to 48% of the UK residential gas heating demand. Given the existing gas distribution network in the UK this is a very attractive way to reduce overall emissions from the system. AD alone is thought to have a potential to supply 20% of domestic heating requirements.
(Source: National Grid)

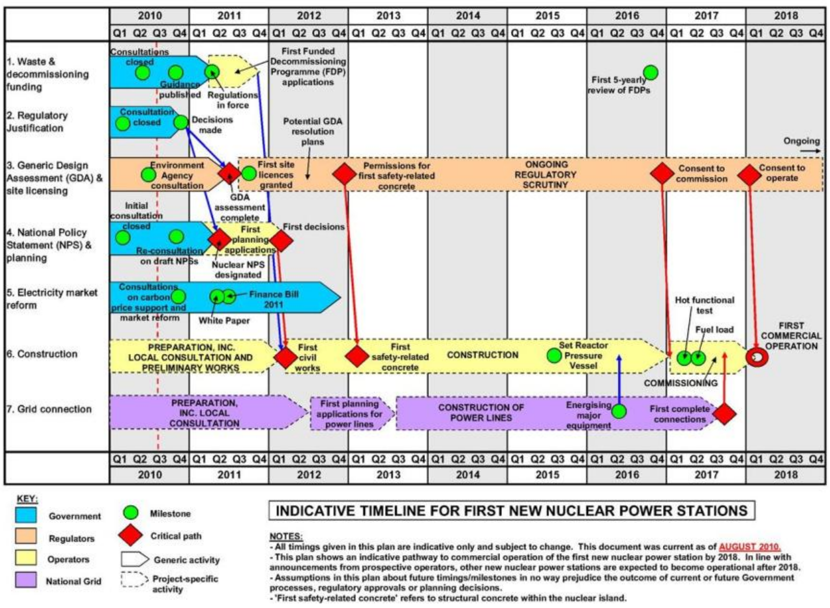
The UK demand for gas is at present about 97 billion cubic metres with a residential demand of 35 billion cubic metres. Renewable Gas injected into the Gas Grid has to be treated to meet UK pipeline standards. The result is almost pure methane called Biomethane. AD plant are attractive to farmers but the necessary processing means that use of gas engines to produce electricity has been a better investment although much less efficient. The new RHI includes Biomethane injection into the National Grid and will help to encourage more industrial plant producing gas as an output.

- On the 5th October 2010 biogas was injected into the UK gas grid for the first time by a joint venture between Thames Water, British Gas and Scotia Gas Networks. Sewage from over 30,000 Oxfordshire homes is sent to Didcot sewage treatment works, where it is treated in an anaerobic digestor to produce biogas, which is then cleaned to provide gas for approximately 200 homes. The landmark project at Didcot - marks an important milestone in the UK's efforts to decarbonise the gas grid and move towards a low-carbon economy. It is hoped this will be the first of many similar projects.

Nuclear

The last UK Magnox reactors are planned to close by the end of 2012. (Oldbury in mid-2011 and Wyfla in 2012). AGR reactors planned closures are supposed to start in 2016 (Hinkley Point B and Hunterston B) but may be delayed.

New starts now will only come on stream from 2018 at the earliest leaving a nuclear energy supply gap.



(Source: DECC Nuclear)

Ten sites for new plant were approved in November 2009, but this has since been reduced to eight sites.

The new plant will be built by three new build consortia; EDF Energy, Horizon Nuclear Power, and Iberdrola, Scottish and Southern Energy and GDF Suez. EDF will use the EPR design from Areva. The other consortia have yet to decide which reactor to deploy. There are currently two reactor technology designs going through the licensing process in the UK – the EPR from Areva and the AP1000 from Westinghouse (NIA)

The Health and Safety Executive report good progress on the Generic Design Assessment process with final conclusions originally expected to be published in June 2011 but delayed due to events in Japan..
(Source:HSE December 2010)

The Nuclear Safety issues raised by the Japanese Tsumane catastrophe have been reviewed by the Office of Nuclear Regulation, which has issued an Interim Report in May 2011.
Some of the important conclusions of the report were;

Conclusion 1: In considering the direct causes of the Fukushima accident we see no reason for curtailing the operation of nuclear power plants or other nuclear facilities in the UK. Once further work *is completed any proposed improvements will be considered and implemented on a case by case basis, in line with our normal regulatory approach.*

Conclusion 4: To date, the consideration of the known circumstances of the Fukushima accident has not revealed any gaps in scope or depth of the Safety Assessment Principles for nuclear facilities in the UK.

Conclusion 7: There is no need to change the present siting strategies for new nuclear power stations in the UK.

(Source: HM Chief Inspector's Interim Fukushima Report)

Based on the conclusions of this report we hope that there will be no resultant delays to the nuclear build programme.

<u>Thorium Reactors</u>

Thorium is an alternative source of nuclear power and been proposed as a cleaner and more easily manufactured fuel for power systems. Small reactors have been built in the past. India, Russia and France currently have Thorium reactor programmes.

Renewable Energy Sources

The UK Renewable Energy Strategy has been drawn up by the Government to meet the EU commitment to achieve 15% of Renewable Energy by 2020.

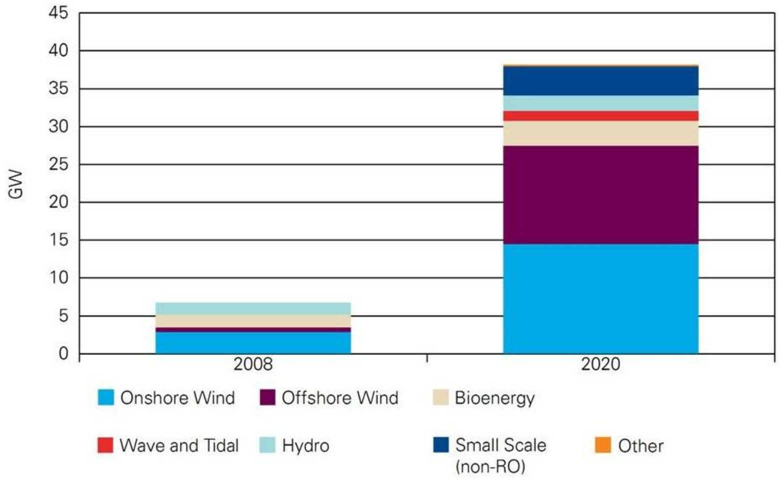
This totally equates to 240 TWh and an installed capacity of some 37.5 GW by 2020.

The strategy sees the proportion of renewable energy split as follows:

30% of the renewable energy generated contributes to electricity generation
12% of the renewable energy generated contributes to heat
10% of the renewable energy generated contributes to transport fuels.

The breakdown of the installed capacity is projected as shown;

Chart 2.4:
Renewable electricity technologies – comparison between 2008 and projected to 2020



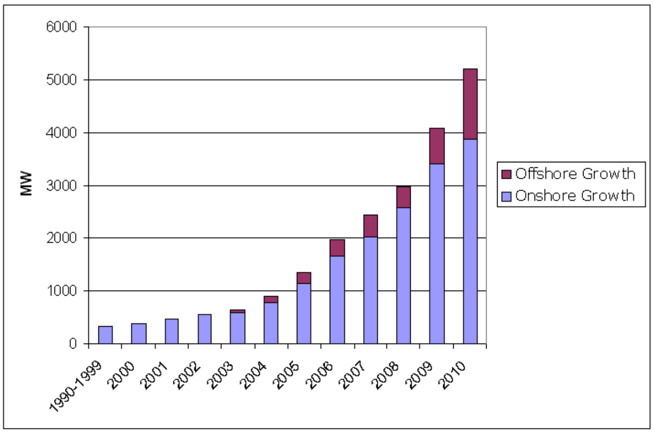
Source: Energy Trends (June 2009) and DECC analysis based on Redpoint/Trilemma (2009) and Element/Pöyry (2009)

Note: Small-scale electricity not separately identified in 2008

(Source: DECC The Renewable Energy Strategy)

Wind

At the start of 2011 the UK had totally 5.2 GW (nameplate) of wind power installed and some 9 GW planned and consented. An additional 33GW of offshore wind has been judged permissible. As can be seen from the National Grid Seven Year Statement actual generating capacity may be somewhat different.



(Source: Wikipedia)

The growth rate of both onshore and offshore wind has been exceptional taking the UK to first place in offshore wind installations. However the long term targets for both Off-shore and On-shore installations require a further significant increase in installation rate. The funding for these investments are being considered as part of the Electricity market Review to be published as a White paper in July 2011.

On-shore the UK is behind Germany which has already installed some 24 GW of onshore wind.

Solar PV

Noticeably absent from the DECC Renewables Strategy is Solar Energy. Solar water heating is considered as a small scale energy source and as such works well at reasonable cost, but Solar PV could be a good contributor to the UK's national generation portfolio.

Solar PV is now a 16 GW Global market with cost approaching electricity market grid parity. In Europe Germany dominates the installed base with some 16 GW already installed.

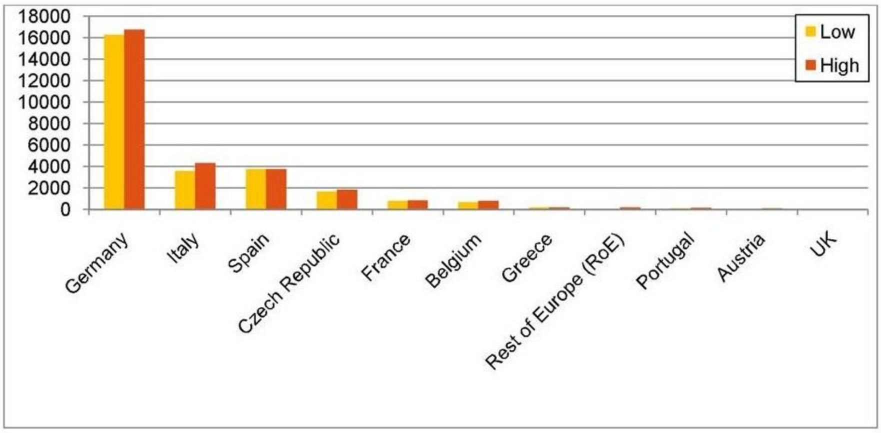
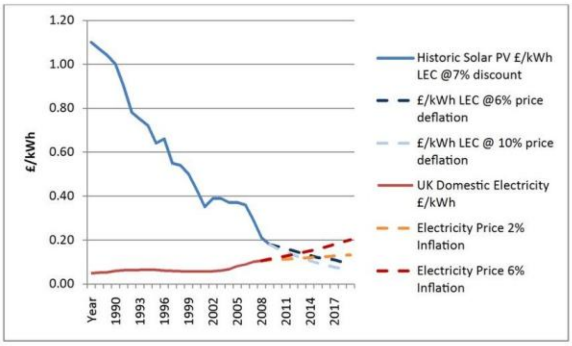


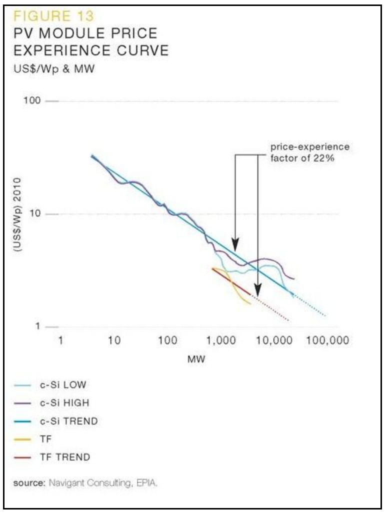
Figure 4: Estimated cumulative PV capacity in Europe in 2010 (in MW)

(Source: EPIA)

The recent review of FIT rates for PV Solar farms in the UK has significantly reduced the attractiveness of solar farm investment.



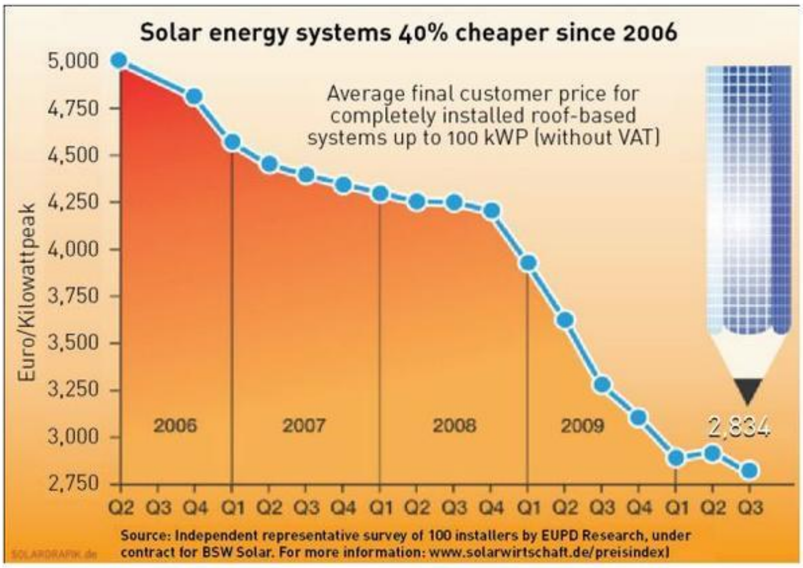
(Source: Renewable Energy Association)



(Source: EPIA)

Solar PV has shown a steady cost reduction both in the manufacturing and supply chain cost elements.

Retail prices in the German Market have shown consistent reductions and are now significantly below UK market prices.



(Source: BSW Solar)

There are also new innovations in the PV market such as:

INNOVATION

- The Enecsys solar PV micro-inverter eliminates the single most common point of failure in conventional solar PV systems – the string inverter. The Enecsys micro-inverter is the only product of its kind that matches the operating life of solar modules.

- Eight19 Limited, a new solar energy company will develop and manufacture high performance, lower cost plastic solar cells for high-growth volume markets.

Enecsys micro inverter

Eight 19 plastic solar cell

So far UK policy has been to regard Solar PV as a small scale energy source mainly for installation on individual sites. This is perhaps missing an alternative national scale renewable resource.

Hydroelectric

Total UK hydroelectric power capacity is estimated as 1650 MW equal to some 1.8% of all current installed capacity. All the larger stations are in Scotland. The largest are Cruachan Dam, 400 MW and Foyers , 300 MW both with pumped storage. There are also large pumped storage plants in Wales at Dinorwig (1728 MW) and Ffestiniog (360 MW) for peak load supply.

The largest English unit is at Kielder Water, 12 MW.

Totally hydro power supplies some 1.3% of the UK total.

Although there is little scope for additional large systems in the UK, small scale hydro has potential in some areas with the use of Archimedes screw type generators increasing.

Biomass and Energy from Waste

DECC Alpha pathway calls for 224 TWh/yr of Biomass. This is equivalent to 11.2 million x 20,000 kWh/yr installations or roughly half the Type A buildings with Biomass heating. This seems unlikely to be achieved. There is also a question of biomass supply on this scale without importing wood products from unsustainable sources.

As there is also some question about the GHG release cycle time for wood based Biomass, it is more likely that Biomass will be mainly used for gas and liquid fuels where there is no alternative.

Using Biomass waste however fits well into the Energy Hierarchy as a recycling action.

There are two main streams – incineration of solid wastes and Anaerobic Digestion (AD) for biological wastes.

see Section 4 Neighbourhood Energy

- Severn Trent Water have started work on an industrial scale AD plant of 2MWe capacity. Like many water companies they have used AD systems for many years but normally to produce electric power and heat for internal use. Many other plants are now in the planning phase but the total national energy capacity from AD is not yet clear.

Waste Heat at scale

In 2006, the UK's heat demand was estimated at 735 TWh, a study suggests around 4% of total heat demand could be met through thermal power station heat recovery (excludes CCGT). The main drawback is the traditional siting of power stations away from urban areas.

Geothermal

Geothermal sources of heat are tapped by drilling deep underground. Southampton's system has long been the only UK system in commercial operation. Southampton Geothermal Heating Company generates 16 GWh/yr of heat from an aquifer.

However a number of new projects are under way in Cornwall which has suitable rock formations. Tests have been carried out at Rosemanowes Quarry since 1976.
DECC Pathway Alpha calls for 7 Twh/yr of Geothermal. As Geothermal once installed should have a high utilisation at say 7000 running hours/yr, this is equivalent to about 1 GW of installed capacity.
Current Geothermal Projects are:

DECC, awards from the Deep Geothermal Fund made In December 2009 to:

- EGS Energy for a scheme at the Eden Project
- Geothermal Engineering Ltd for the Redruth power plant.
  (Redruth is planned to supply 10MW of electricity and 55MW of heat).
- Newcastle University for the Eastgate project

Further awards were made In the December 2010 to:

- Newcastle/Durham Universities for Eastgate
- Cofely for refitting the Southampton Plant.

The Decc awards are all to "hot rock" projects. It has also been suggested that Geothermal could be tapped in the North Sea where the earth's crust drilling depth is relatively thin and there are existing drilling platforms.

Eon have proposed a 150 MW Biomass Power plant at Portbury Docks nr Bristol. This will be their third large Biomass fuelled plant.

Marine Energy

The UK has ample potential energy available from the sea, however extracting that energy is extremely challenging.

Various forms of marine energy generation are at the testing stage with the Pentland Firth being a major trials area. It is possible that the Pentland Firth's Tidal Race may represent up to 25% of the EU marine energy and eventually be capable of generating 10 GW of electricity.

- The Crown Estate has licensed a tidal energy syndicate consisting of International Power (45%), Morgan Stanley (45%) and Atlantis Resources (10%) to develop a huge tidal energy project in the Pentland Firth. The early plan is to put together a scheme that will involve 400 submerged turbines capable of generating 400MW of electricity

- October 2010. Rolls-Royce has produced first power from its 500kw tidal turbine at the European Marine Centre in Orkney.The system, build by Bristol's Tidal generation Limited, generated peak output of around 150kw and clocked up its first megawatt –hour during a "gentle run-in" over the 10 days following installation on 21 September.

  The work will inform a follow-up project called Reliable Data Acquisition Platform for Tidal, or Redapt, funded by the Energy Technologies Institute. A spokesman for ETI said the first phase of the three and a half year programme will see 1MW Rolls-Royce / TGL tidal turbine installed and operating at EMEC in early 2012

In addition to turbines, wave energy converters (WEC) such as the Pelamis Sea Snake, and Aquamarine Oyster are under development.

A WEC with a different form of power take off, such as a linear generator, would be able to operate in the North Sea. Although the North Sea has a much lower wave energy density than the Atlantic, (10-20 kw/m), maximum wave heights are lower and survivability is a lot easier. The analysis also assumes a linear set up with a low conversion efficiency. As long as the WEC does not operate as a breakwater, the energy in the waves is not lost and the wave farm can be considered as a two dimensional array.

It will make commercial sense to integrate wave farms with offshore wind farms, especially when considering point absorber WECs. This form of marine generation could conservatively generate 100TWh/year.

Energy Storage

Because the available renewable energy sources such as wind, solar and in future marine are all intermittent, energy storage becomes critical in the future energy sytem.

The most effective and economical way to store energy is pumped storage as used with Scottish hydroelectric plant. Worldwide there is some 130 GW of pumped storage.

Other large scale storage systems already developed are:

Flywheels – up to 1 GB but very expensive

Williams Hybrid Power are developing large flywheel systems using MLC (Magnetically Loaded Composite) rotors based on FI experience and Nuclear industry technology.

Underground Compressed Air – up to 400 MW but not efficient.

Sodium Sulphur Batteries – less than 100 MW and very expensive but used in Japan and elsewhere.

It is estimated that if the UK has 30 GW of wind installed it will need 5 GW of storage.

INNOVATION

Isentropic is developing a new kind of heat engine/heat pump that will store energy in typically 2 MW units. If these were produced and sold to industrial companies, then an installed base of 2500 units would make a significant contribution.

Highview Power Storage have developed a Cryo Energy Storage process to grid connected pilot demonstration stage. This uses the phase transfer of gases to store and regenerate electric power.

Distribution, Distributed Energy, Smart Grids and Meters and off grid resilience.

In the next few decades grid supply is likely to be under pressure due to extra demands of growing electric transport requirements, together with the shutdown of centralised fossil fuel power stations (particularly old coal plant); all this is causing concerns over possible energy shortfalls.

In parallel energy supply sources will change radically in line with the requirements of the 'the low carbon economy' and with considerable growth in the range of renewable energy (as well as nuclear and CCS). In particular it is planned that a significant contribution will come from small scale local plants to replace and add to main grid suppliers and with much expected expansion of domestic scale providers.

The existing national electricity system was primarily designed to supply all users from large centralised power stations via high voltage main grids down to 'one way flow' low voltage local distribution networks. Much more resilience will have to be integrated into this system to cover the introduction of a range of new localised 'distributed energy' suppliers, who may feed back to, as well as receive from, the main grid system. There are some small scale users now (e.g. emergency services) who currently have capability to use their own resources or switch to mains supply, but it is not normal for these users to also feed back to the 'mains'.

Currently the main body of power stations (coal, gas, nuclear, CCGT etc) represent the core grid providers. A number of wind farms have been integrated into this system using sub-stations.

To supplement this:--

i) There are already over 7000 MW of industrial or institutional plant, mainly CHP, which provide their own in house services, but are also provide 'back up' to the grid. These serve such industries as chemicals, engineering and metals, food, water, agriculture etc and also facilities such as university and college institutions. This sector is expected to expand significantly.

ii) The creation of new 'Distributed Energy Systems' sometimes referred to as 'micro-grids' are being considered and planned. This involves a town or community, perhaps local industry and community working together, creating a supply network based on local electricity producers. This may be a combination of small wind, solar roofs and parks, possibly local hydro, perhaps a local farm based AD plant and inevitably a fall back gas or biogas generator. The benefits of local production are the more cost effective use of local resources, avoidance of line losses, and local control on supply issues.

Such a network may be reliant on grid support initially but with the eventual aim to be self sufficient and be a grid supplier as well. This concept is already being developed in some other countries, Scandinavia and USA for example. However, build up of this technology will require new considerations from planning and financing aspects.

iii) New house estate and mini towns building complexes should be designed for maximum self reliance, both in minimising energy needs, but also in basing supply on locally produced electricity with a significant renewables content.

iv) Domestic residences are and will be encouraged to produce part of their needs from renewables such as high efficiency micro-chp including fuel cells, roof solar, small wind, heat pumps and biomass resources. Encouragement is already provided by the FIT and RHI grant payments which are phased over long periods to ensure attractive compensation.

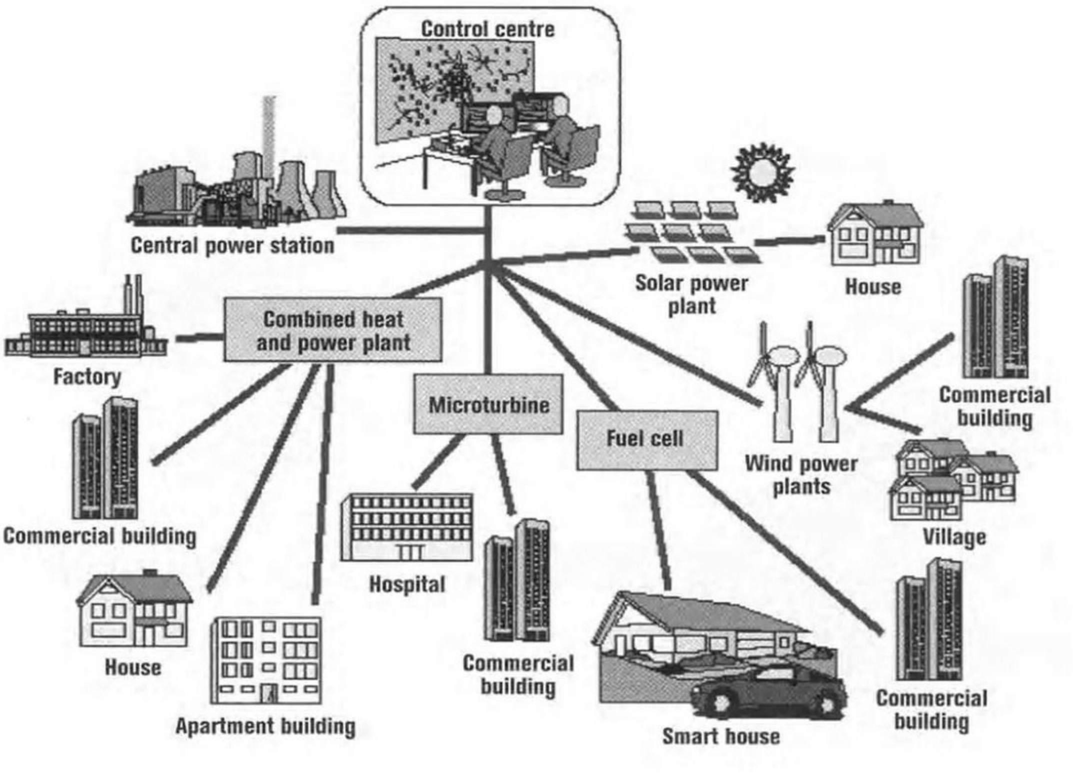
It is not clear what total input to national electricity supply these various inputs will make. Basically the prime purpose is to reduce demand on the grid but due to the in-balances of supply and demand in most residences and establishments there is likely to be a significant electricity input also to the grid in the decades ahead. Currently domestic demand is just under a third of total demand and it is feasible to assume a significant proportion could be replaced or offset in a decade.

The other challenge is the extent that local grid changes need to provide 'smart' and more tolerant systems. Many of these are quite small networks which feed only a few megawatts. Controls have to be integrated to ensure supply remains at defined voltage and frequency limits with the varying local inputs and mains balancing. Safety issues are important to ensure homes cannot feed into a network which is shut down for repairs. Stability control is essential. It is hoped that as experience grows modification to each local network will become more straight forward.

The other issue is one of 'smart metering'. Some current meters being installed have limited functions of providing better information to home owners and also allowing providers to monitor use on line for billing purposes. In fact in the future, these meters will have wider functions, such as to record both inward and outward current flows, and perhaps optimise/schedule in home use, and monitor fault or safety issues. The smart grid concept is not fully functional without suitable smart meters. The cost of these has recently been assessed by Government at £300 each approx., which means for say 10M houses (UK total residences is about 26M) there would be a cost of say 3£bn.

There is a need to have smart meters which allow consumers to manage their energy in conjunction with smart appliances. Multi-tarriff meters may be a solution. Tests have already been carried out in the UK with smart refrigerators. However current smart meter designs seem to be concentrating on Utility Company aspects rather than consumer benefits.

Overall the DES /Smart grid route will provide a significant contribution to the energy scene and justifies much effort using all the ingredients above, but it is unlikely the cost per KW to install will be more economic than other new energy routes.



Distributed Energy Systems Example

(Source: ABB Alternative Energy Systems 2000)

There has been considerable work and attention paid to the development of the Smart Grid and the roll out of smart meters across the UK. However little attention seems to have been paid to the requirement for a resilient system to take us through these difficult transitions.

The ability to switch from on grid to off grid is common in rural and remote areas, and standard for military and medical facilities. As more domestic homes and different types of neighbourhoods install local energy generation the demand for off grid switching is likely to grow.

The development of micro-grids is likely to grow.

- EPSRC UK Microgrids by the University of Manchester, and University of Cardiff in Collaboration with Turbo Power Systems Ltd, E.on Engineering UK Ltd, National Grid, and Scottish Power

  Small Distributed Generators (DG) based on low-carbon generation (such as solar cells, combined-heat-and-power) are not well-behaved i.e. they generate electricity but do not act to support network cooperation especially during network disturbances.
  This project investigated the 'MicroGrid' where DG is combined with electrical energy storage and intelligent load control to make a small area of the network.

- The University of California at San Diego has its own power generation, monitoring and security and classifies itself as a microgrid.
  It runs two 13.5 MW gas turbines, one 3 MW steam turbine and a 1.2 MW solar-cell installation that together supply nearly 80% of the campus' annual power. For HVAC, it uses a 40,000 ton/hour, 3.8 million-gallon capacity thermal energy storage tank, plus three chillers driven by steam turbines and five driven by power.
  The campus is linked to the main supply by a single 69 kV substation, which defines the microgrid as everything behind the substation

  UCSD is building added energy storage and plans to purchase 2.8 MW molten-carbonate fuel cell that uses methane piped onto campus from a local wastewater-treatment plant

The Way Forward – Cost Effective options

The IMechE Policy Statement 11/02 looks at the relative cost of developing the alternative sources of electricity generation in order to arrive at the most cost effective combination of technologies. Future versions of the DECC Pathways calculator are planned to include costings of the Pathways. Mott MacDonald's Cost Update report is very helpful in this respect.
(Source: Mott MacDonald. UK Electricity Generation Costs Update)

In summary, the most cost effective alternative would appear to be as follows:

Lower Cost	Hydro, Co-firing Biomass, Nuclear, Onshore wind.
Medium Cost	Biomass, CCGT Gas with CCS, PCoal & IGCC Clean Coal with CCS
Higher Cost	Offshore Wind, Solar PV

In selecting future projects for support through ROCs or other incentives, consideration also has to be given to potential new industry creation and other local factors but the UK should still aim to achieve value for money where possible.

In considering these options, Hydro has very low growth possibilities and Biomass for electricity production looks most likely in the form of local energy from waste plants at relatively small scale. CCS has still to be proven at scale in power generation environments. Gas has energy security issues and large onshore wind farms are finding it increasingly difficult to obtain planning consent. This does not leave a lot of choice of energy pathways.

<u>The importance of giving sufficient backing to the development of new energy generation processes at commercial scale is therefore underlined.</u>

9 Green Jobs and the Economics of Building the New Low Carbon Infrastructure

For a new technology to be viable it has to achieve critical mass. In fact several different critical masses. For example:

> Production critical mass means that the fixed overhead cost can be economically spread over the product volume and result in a market price which fits the target market.
>
> Installation critical mass means that enough units are installed to give statistically meaningful data on performance, market acceptance and other feedback needed for continuous improvement.
>
> Support critical mass means there is a sufficient body of skills and support infrastructure to ensure the long term viability of the product in the market.

Those companies that have extensive experience of global manufacture have long realized that to be fully successful in a market it is necessary to localize to some extent the product range. Balancing the global ie standardized and localized parts of a product is one of the challenges of modern manufacturing. In many cases that means that for long term success, at least a part of the production process must be local to the market the products serve.

These issues apply equally to the products needed by the Low Carbon economy. From Wind Turbines to PV panels to new power plant.

Building the new Low Carbon economy means not just building small numbers of prototypes of new technologies, or importing products designed for use in other parts of the world. It means installing at scale, and building the critical mass of local skills and the local manufacturing processes needed to create the right product for the UK and achieving critical mass.

Green Jobs

As the economy decarbonises many jobs will become "greener", sometimes referred to as "Pale Green". However, we define "green jobs" as <u>new</u> job creation resulting from the introduction of new low carbon technologies.

So far the key area for green jobs in the UK has been the Wind energy sector (including Wind farm support) and the production of parts for both on and offshore wind and the electric vehicle industry. The electric vehicle industry has generated new jobs for battery production and to a certain extent vehicle production although some of this may be employees transferred from existing production lines. Examples of new job creation in these areas are:

- Siemens to build £80m wind turbine factory in the UK – Hull selected; around 700 UK jobs to be created
- Mitsubishi Power Systems Europe (MPSE) is investing £100m in offshore wind turbine research in Britain and will create up to 200 jobs by 2014.
- GE to build £99m UK wind turbine plant creating 1,900 jobs
- Nissan Electric car battery factory in Sunderland

However it is clear that larger numbers of Green Jobs would come from the supply chains feeding these key factories if these are located within the same regions. The Supply Chain Job Multiplier is a powerful mechanism for driving new job creation.

Estimates of the size of the green jobs market are uncertain. In 2006, about 400,000 such roles existed in the UK, comprising all those employed in producing environmental goods and services.
(Source: ENDS Report 395, pp 9-10)
In Australasia the green jobs market is estimated to be anywhere between 50,000 and 300,000+.

It is possible to make some specific estimates of potential green skills demand growth. So, for example, as Electric Vehicles integrate into the market many employees will need to "convert" their skill set; this could considerably increase demand for level 3+ qualifications - as Continuing Professional Development and to enable new, mature, entrants. Initially this will be in manufacturing but increasingly in maintenance (i.e. the retail sector). The UK now has an apprenticeship scheme dedicated to electric vehicles. The introduction of EVs to the mass market indicates that there will be a rapid increase in the demand for EV related apprenticeships to as much as 7,500 to 10,000 (at levels 2 and 3 combined) for Hybrid EV and full EV vehicles, across manufacturing and the retail motor industry.

However, quantifying potential growth in green jobs across engineering is highly speculative at best. In the UK, despite the perceived failure of the UN climate summit in Copenhagen much of the impetus will stem from the evolving low-carbon agenda; in particular the detail of the Low-Carbon Transition Plan, the Low-Carbon Industrial Strategy and the Carbon Reduction Commitment.

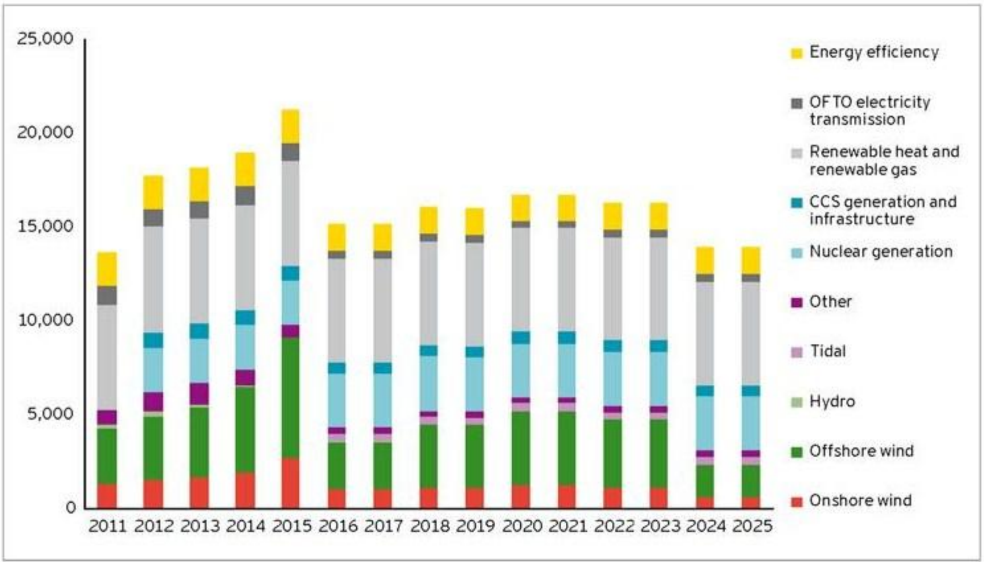
Several barriers to growth in green jobs exist and unless they are navigated the UK will be left behind in the green jobs race– and therefore in developing its low carbon economy.
(Source: ENDS Report 409, p 11)
Skills shortages, an inadequate policy framework and a lack of political and financial will are all likely to hold the UK back. Skills shortages may well be the toughest barriers to green jobs growth in the UK. A number of bodies have already warned of the looming skills gap. *Engineering our future*, a report by National Grid concluded that skills shortages could slow the transition to a low-carbon economy. The IPPR, in its report, *The future's green: jobs and the UK low carbon transition* also warned that without action on skilling the workforce to make them 'climate ready', the UK would be ill-equipped to compete in the low-carbon economy.
(Source: ENDS Report 418, p 4, National Grid: Engineering Our Future, IPPR: The Future's Green).

How much will all this cost and where will the money come from?

Summary table – Likely minimum level of infrastructure investment required in Britain by 2020

Sector	Requirement	Cost (£ billion)
Energy	Replacement requirement	42
Energy	Investment in the networks	65
Energy	Renewables	136
Energy	Energy efficiency	21
Transport	Rail networks and high speed lines	69
Transport	London transport	32
Transport	Roads	9
Transport	Air transport	10
Communications	Nationwide roll-out of Fibre to the Cabinet/Very High Speed DSL (FTTC/VDSL)	5
Water	Water and sewerage networks	37
Water	Flood and coastal defences	8
TOTAL		**434**

(Source: Dieter Helm, James Wardlaw and Ben Caldecott. Policy Exchange)



(Source: Ernst & Young)

At the start of current discussions about climate change and its effects and required actions, the Stern Report proposed that the cost would be of the order of 1% of GDP. In their first report the Committee on Climate Change confirmed that:

"the cost of meeting(the carbon) budgets is less than 1% of GDP in 2020. This cost is due to the impact of higher energy prices, net of any increases in income due to energy efficiency improvements."

The Policy Exchange estimates the likely minimum cost at around £500 billion by 2020. E&Y suggest a rate of about £15 billion per year which spreads the investment over a longer period.

The need for cost data in the DECC Pathways model has been highlighted as a necessary next development of the model.

Funding the change to the Low carbon Economy is perhaps the biggest challenge facing the UK.

The proposal is that the Green Investment bank will provide the necessary capital. So far the details of how this will operate are still under discussion (April 2011)

10 Conclusions

The challenges facing the UK in achieving a low carbon economy remain severe. This situation is likely to persist until the transition phase when both supply and demand side of the energy picture transition to new status.

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