Country Report United Kingdom
IEA Bioenergy Task 42

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Country introduction

Under the EU Renewable Energy Directive the UK must meet 15% of its energy use (on a net energy basis) through renewable energy by 2020. Given a projected UK primary energy consumption of 6071 PJ (145 MTOE) in 2020, renewables will need to contribute 911 PJ. In the road transport sector, 10% by road transport fuel must be from renewables by 2020 requiring around 184 PJ of liquid biofuel. Biomass sources will be an important contributor towards meeting both bioenergy and liquid biofuel goals.

The UK has made significant progress towards reaching these challenging targets in the past year. The UK Government's positive and encouraging stance on anaerobic digestion as a mechanism for waste treatment and producing renewable energy has resulted in a significant increase in both the number and capacity of anaerobic digestion plants using farm and food wastes. Indeed, at the beginning of 2010 there were 37 such plants with a total capacity of 21 MWe and a further 41 have been announced that will have a total capacity of 63 MWe. Europe's largest wheat biorefinery, operated by Ensus, began production in 2010 and has increased UK bioethanol production capacity to 0.96 PJ (237 ktoe), all of which has come on stream since 2007. The UK has also become a leading player in the thermochemical conversion of waste derived biomass to biofuels with the announcement that Ineos Bio will develop a waste to ethanol plant on Teesside from 2012 with expansion planned for 2014.

The UK is investing heavily in its research base in biorefining with several multi-million pound projects in progress, a large number of these building upon the UK's academic and industrial excellence in plant and microbial sciences. This has been accompanied by significant investment in scale up facilities such as the industrial fermentation facilities at the National Industrial Biotechnology Facility, to bridge the gap between academic research and industrial implementation.

Energy production and consumption based on biomass

Current energy production and consumption

In 2008, the primary energy supply[1] was 9831 PJ and total domestic energy production was 7411 PJ. Total final consumption[2], which includes non-energy use of fuels, was 6858 PJ. Both total primary energy supply and total final consumption have been reducing in the UK. Total primary energy supply has reduced since 2005, decreasing 5.4%, from 10362 PJ to 9831 PJ, while final energy consumption has reduced since 2004, decreasing by 5.2% from 17214 PJ to 6858 PJ.

Current production of renewable energy and energy from biomass

The total production of renewable energy in 2008 was 251 PJ, equivalent to 2.6% of the primary energy supply. The amount of renewable energy produced in the UK has increased by 240% since 2000 from 105 PJ (1.1% of total primary energy supply). Biomass contributed 205 PJ of energy in 2008 equivalent to 2.1 % of total primary energy supply and 67.7% of all renewable energy. The amount of energy produced from biomass has increased 245% from 84 PJ since 2000, however, biomass, as a proportion of total renewable energy, has declined since 2003, from 86.9% of all renewable energy to 67.7% of all renewable energy produced.

Imported/exported biomass for bioenergy

The UK does not usually classify imported biomass according to its end use, so it is not possible to ascertain the total amount of biomass imported into the UK for energy purposes. The exception is for straw, SRC and other plant based biomass (for example palm kernel expeller, olive and shea residues) where 17.4 PJ was imported in 2008. This is equivalent to 46% of the total amount of this material used in the UK, representing 0.18% of total primary energy supply in the UK in 2008 and 6.9% of the total biomass demand for energy purposes. Based on the difference between total biomass energy use in the UK and the amount of UK feedstock used for energy generation, we believe that in 2008, 40% of biomass was derived from UK and 60% from imports. There are no figures available for the amount of biomass exported out of the UK for bioenergy purposes, although we believe that this is negligible.

Imported/exported biofuels

In 2008, total demand for biofuel in the UK was 34.4 PJ, representing 0.35% of UK total primary energy supply. The majority of biofuel used in the UK in 2008 was biodiesel. Biodiesel made up 85.9% of all biofuels used in the UK (29.5 PJ) and bioethanol made up the remaining 14.1% of all biofuels used (4.9 PJ). Domestic production of biofuels was 12.3 PJ or 35.6% of total biofuel demand, whilst another 22.1 PJ of biofuels were imported, equivalent to 64.5% of demand. There were no exports of biofuel from the UK reported for 2008, although there were exports in 2006 and 2007 of 1.8 PJ and 1.4 PJ respectively.

[1] Total primary energy supply refers to the amount of energy available for conversion to other forms of energy and includes conversion, transmission and energy loss by final users.

[2] Final consumption is on an energy supplied basis and measures the energy content of the fuels, both primary and secondary, supplied to final users. Thus it is net of fuel industry own use and conversion, transmission and distribution losses, but it includes conversion losses by final users.

The majority biofuels are derived from feedstocks produced outside of the UK. Figures show that in the period from April 2008 to April 2009, 7.8% of biofuels used in the UK, equivalent to 2.7 PJ, was derived from domestic feedstock. The rest, equivalent to 31.8 PJ, was derived from imported material. Around 94% of biodiesel used and 82% of bioethanol was derived from imported materials in 2008/2009. The country of origin of feedstocks used for the production of biofuels supplied in 2008/2009, according to the UK's Renewable Fuels Agency is indicated in the table below.

Table UK1. Country of origin of feedstocks used for the production of biofuels supplied in 2008/2009

Country of Origin	Biodiesel Feedstocks Supplied (%)	Bioethanol Feedstocks Supplied (%)
Argentina	7	-
Belgium	<1	-
Brazil	1	79
Canada	2	-
Denmark	<1	-
France	4	-
Germany	14	-
Indonesia	2	-
Ireland	<1	<1
Malaysia	5	-
Malawi	-	<1
Netherlands	<1	-
Pakistan	-	<1
Russia	1	-
Sweden	<1	<1
Ukraine	1	-
United Kingdom	6	18
United States	34	-
Unknown	23	<1

Table UK2. Current bioenergy production in UK:

Use	Year	Unit	Amount	% of total bioenergy	Feedstock(s)	Number of plants (2010)
Power	2008	PJ	135	65.8	Landfill gas, sewerage sludge digestion, Municipal solid waste combustion (biodegradable component), animal biomass (farm waste, poultry litter, and meat and bone combustion), plant biomass (includes straw and energy crops), biofuels.	14 (dedicated biomass plants)
Heat	2008	PJ	36	17.4	Landfill gas, sewerage sludge digestion, wood combustion, animal biomass (farm waste digestion, meat and bone combustion, sewerage sludge combustion), plant biomass	-

					(straw, energy crops and paper and packaging)	
CHP*	2008	PJ	-	-	Biomass; sewerage gas; other biogases; municipal waste and refuse derived fuels (non-biogenic)	-
Bioethanol[1]	2008	PJ	0.205	2.4	Sugar beet, sugar cane, cheese whey, molasses, sulphite.	2
Biodiesel	2008	PJ	1.24	14.4	Oilseed rape, tallow, used cooking oil, soy, palm oil, sunflower.	6
Biogas	2008	PJ	-	-	Biomass; sewage gas; other biogases; municipal waste and refuse derived fuels	-

- Figures for amount of power and heat are for 2008
- In 2008, 2,373 GWh (8.54 PJ) of energy was produced using renewables in CHP. However, it is not possible to determine the amount of energy produced by biomass in CHP applications because this category also contains non-biomass derived RDF fuels.
- The UK's first wheat ethanol plant began production in 2010, although the British Sugar sugar beet to ethanol plant has been operating since 2007.

Table UK3. Breakdown of national biomass energy use on feedstock:

Source	Year	Unit (Mm^3 or kton)	Amount	% of biomass energy reported above
Round wood	2008	kton	300	
Forest wood chips	2008	kton	-	
Wood industry residues	2009	kton	211	
Wood pellets/briquettes	2008	kton	118	
Black liquor and sludge	2009	toe	0.02	
Wastes (organic fraction)	-	-	-	
Straw/agricultural residues	2008	kton	200	
Sugar beet/sugar cane	2008	kton	700	
Cereals (grain, corn)	-	-	-	
Other (recycled wood)	2008	kton	278	
Other (Poultry Litter and Meat and Bone Meal)	2009	kton	760	

The figures above relate to UK derived feedstocks used for energy purposes only and exclude imported material. Whilst reasonable data is available indicating the amount of UK feedstocks used for bioenergy, the amount of material imported for bioenergy is unknown as UK statistics do not distinguish imports according to end use, especially for wood materials. Surveys have shown that substantially larger quantities of wood biomass are used for energy uses than suggested in the table above, suggesting that the UK is heavily dependent upon imported biomass to generate energy (see Page 3).

- In the UK bioenergy statistics, there is no distinction between the amount of UK roundwood and forest wood chips used for energy, and there are no figures for the amount of energy produced from forest wood derived from brash (although it is expected to be small).

- In general, figures for wood pellet and briquette use are estimates and can therefore vary considerably between sources. Estimates of UK production of pellets for 2008, for example, vary from 90,000 tonnes to 125,000 tonnes whilst estimated capacity for 2008 was estimated at 218,000 tonnes.
- The UK has no fully integrated kraft pulp mills so there is no production of black liquor. We have assumed that sludge is the residues from paper reuse. To our knowledge, Shotton, in North Wales (20 MWe) and Slough Heat and Power (12 MWe) are the only UK plants generating energy from paper waste.
- The amount of straw, sugar beet, meat and bone meal and poultry litter used for energy purposes have been based on capacity rather than actual production.

The UK's first wheat to ethanol plant began production in 2010 so we have not reported the production of energy from cereals in the table above. This plant will use around 1 million tonnes of wheat per year.

The table below shows the total amount of both domestic and imported biomass used for energy in the UK in 2008. The categories vary from those presented in the table above. The data below was expressed in terms of ktoe, and we have calculated the amount of biomass this equates to for ease of comparison with the table above.

Table UK4. Domestic and imported biomass used for energy in the UK:

- All biomass is reported in as received tonnage.
- Wood energy content is assumed to be 3,306 kWh per tonne (based on industrial use)

Source	Year	Amount	Amount	Unit (kton/Mm^3)	% total biomass energy
Wood waste	2008	108	382	Kton	3.7
Wood	2008	359	1,271	Kton	8.3
Poultry litter, meat and bone and farm waste	2008	296	1,417	Kton	6.8
Straw, SRC and plant waste	2008	843	2,367	Kton	20.8
Sewerage gas	2008	245	222.4	Mm^3	5.3
Landfill gas	2008	1,574	1,707.0	Mm^3	36.7
Liquid biofuels	2008	825	971	Kton	19

- Poultry litter, meat and bone meal and farm waste energy content is assumed to be 2,444 kWh per tonne (based on poultry litter).
- Straw, SRC and plant waste energy content is assumed to be 4,167 kWh per tonne (based on straw use).
- We have assumed that biogas has an energy content of 38.6 MJ/m^3

Biomass used for non-energy purpose

Table UK5. Use of biomass for non-energy purpose:

Use*	Year	Unit	Amount
Wood for particle boards	2008	Thousand m^3	2,810
Wood for pulp and paper	2008	Thousand tonnes	333
Wastes from pulp and paper	2007/2008	Thousand tonnes	3,207
Chemicals from biomass	2008	Thousand tonnes	51,692
Cereal production	2009	Thousand tonnes	22,037[3]
Sugar production	2009	Thousand tonnes	8,330[3]
Starch production	2008	Thousand tonnes	896.6
Oilseed production	2009	Thousand tonnes	1,994[3]
Algae production	-	-	-

- There has been a decline of 26% in the amount of virgin material used in the pulp and paper making industry in the UK over the past five years. Production has been falling dramatically, falling 25% between 2005 and 2006, to just over 5% a year from 2007 to today. Most significant has been that hardwoods are no longer used, with softwood derived from sawmills and roundwood being the principal materials used.
- There have been significant decreases in the amount of paper produced from virgin materials in the UK, with imported pulp or recycled paper accounting for 0.9 million tonnes and domestic production 0.3 million tonnes. Overall, this industry has contracted by 40.6% since 2005, with a 1.6% decrease in production between 2008 and 2009.
- It is difficult to assess the scale of biomass processing for chemicals markets as much of this information is commercially sensitive. The largest chemical markets for biomass is erucimide produced from High Erucic Acid Rape (HEAR), and oils from linseed, with smaller amounts of algae derived chemicals. We have based the figures above on HEAR and Linseed production in 2007. The amount of biomass used by the high value, low volume sector has not been assessed.
- There are currently two semi-commercial scale microalgae demonstrator facilities, both of which have come online since late 2009. We estimate that these produce less than 10 tonnes each for non-energy purposes. Likewise, the capacity of hatcheries for shellfish and mollusc farming is unknown, as is the amount of macroalgae harvested for the production of alginates.
- Sugar production in the UK has decreased over the past 10 years by around 15%. The area of sugar beet crop has declined in the same period from 173 thousand ha in 2000 to 119 thousand ha in 2009, a decrease of 31% but this has been partially compensated by an increase in yield from 52 tonnes per ha to 70 tonnes per ha, an increase of 135%.
- Wheat is the principal cereal crop in the UK. Production has varied according to market demands, but has remained largely stable since 2000 at between 14 million tonnes to 16 million tonnes. Barley production has generally declined since the mid 1990's as the low prices for this crop has often made production uneconomic. In 2000, barley production was

[3] We have based these figures on the total production of these crops in the UK and include use for food, industrial and energy purposes.

6.5 million tonnes and despite a gradual decrease in production of barley over the past 10 years, barley production increased in both 2008 and 2009 to 6.8 million tonnes reversing this trend.

- Oilseed rape was introduced as a crop in the UK in the 1970s. The area has generally increased over the past 20 years, although productivity has remained static at around 3 tonnes per ha. In the past 10 years there has been a dramatic significant increase in OSR production, from 1.2 million tonnes to 2.0 million tonnes, a rise of 202%. Linseed production has exhibited considerable volatility on an annual basis varying between 17 thousand tonnes to 78 thousand tonnes in the same period.

Policy issues related to biomass, bioenergy or biorefineries

- Policy targets for energy – renewable energy, bioenergy, biofuels
- Policies regarding biomass production and use for bioenergy
- Policies regarding biorefineries or biomass derived products (materials and chemicals)

The Climate Change Act of 2008 provides an obligation for the reduction of UK greenhouse gas emissions by at least 80% from 1990 level by 2050. The Low-Carbon Transition Plan, published in July 2009, contains a number of strategies under which these ambitious targets will be met and encompasses the use of biomass for the production of heat and electricity, for transport fuels and for materials as well as measures to increase biomass production. These policies and how they link in with EU targets, are explained below.

Renewable Energy Directive

The EU Renewable Energy Directive (RED) requires the UK to source 15% of its energy (based on energy content) from renewable sources by 2020. Biomass will be an important part of meeting these targets. The UK has traditionally had a very low base of renewables used in energy generation so meeting this target will require considerable increases in the UK uptake of renewables. The Renewable Energy Strategy 2009 (RES) underlines the how the UK Government will promote the uptake of renewable energy and materials in transport, electricity and heat sectors. An implementation plan building on the RES will feed into the UK's national Renewables Delivery Plan for achieving the national targets agreed in the RED. The UK has introduced a number of schemes to incentivise the uptake of renewable fuels, energy and heat within the UK. There is considerable flexibility to how the RES targets will be met and the market will decide the relative uptake of renewables in each of these sectors. Indicative figures suggest that renewables will meet 10% of transport, 30% electricity and 12% heat energy needs by 2020.

The Renewables Obligation was introduced in 2002 to provide a mechanism to increase the amount of renewable energy produced in the UK. The RO scheme will run to 2037, although individual projects are only supported for 20 years. The production of renewable electricity through the RO is promoted through Renewables Obligation Certificates (ROCs). These are tradable certificates which are awarded for every MWh (or part of) of electricity produced and which can be sold to provide a financial reward for energy generators who meet their obligations under the RO. Under the Renewables Obligation Order of 2009, ROCs have been banded according to the development status of the technology used to produce power. Thus, emerging technologies such as advanced gasification, pyrolysis and anaerobic digestion are eligible for 2 ROCs/MWh whereas established technologies such as landfill gas and co-firing of biomass are eligable for 0.25 ROCs/MWh and 0.5 ROC/MWh respectively. Furthermore, there is a limit on the amount and type of biomass which can be used in co-firing to prevent destabilisation of the biomass and ROC market by such developed technologies. Currently, in order to receive ROCs, no more than 12.5% of energy can be derived from biomass unless it is from dedicated energy crops either with or without the use of CHP. The banded ROCs and co-firing cap thus help incentivise the uptake of less established technologies, and promote the use of waste and energy crop materials for energy production. The UK Government recently announced its intention to support the generation of renewable electricity from biomass through the 'grandfathering'[4] of support under the Renewables Obligation for electricity from dedicated biomass, energy from waste, anaerobic digestion and advanced conversion technologies, such as pyrolysis and gasification.

Small scale generation of electricity is incentivised under the Feed in Tariff (FiT) scheme which was introduced in April 2010. The FiT scheme provides support for technologies upto 5MW, and electricity

[4] 'Grandfathering' is a policy intent not to amend support under the Renewables Obligation (RO) for a generator once it has been accredited by Ofgem. This provides investors with the confidence that the Government's policy is not to amend the level of support they receive at a future banding review.

suppliers need to pay generators on the number of kWh they produce. An additional tariff off 3p/kWh is available where electricity is exported to the grid. An incentive encouraging the use of renewable heat will be introduced in April 2011, known as the Renewable Heat Incentive (RHI). The RHI is under consultation, but will include a fixed tariff for every kWh of heat produced. The level and length of this incentive will vary according to fuel type and system used.

The development of Energy from Waste technologies is gaining increasing momentum in the UK due to the Government's combined desire to reduce landfill and to produce energy. The use of biomass waste is an important componant of waste streams. Energy from Waste technologies include anaerobic digestion, pyrolysis and gasification. A cross-government Energy from Waste project has been initiated to develop a clear policy regarding energy from waste and to ensure that renewable energy targets can be met in an economically and environmentally sustainable manner.

Anaerobic Digestion has the potential to combine both environmental and climate change uses, through waste mitigation, avoiding methane emissions from agriculture and the production of renewable fuels and energy. In 2010, the UK Government published an Implementation Plan to provide a framework for action by Government and other stakeholders in facilitating the uptake of AD in England. £10 million of funding from the Environmental Transformation Fund has been provided under the Anaerobic Digestion Demonstation Programme and will be available until 2011 to finance innovative AD plants.

Renewable Fuels

The Renewable Transport Fuel Obligation was introduced in April 2008 and placed a legal obligation on obligated road transport fuel suppliers to acquire a specified proportion of their fuel sales from renewable sources. These targets have been set to 3.63% (by volume) for 2010/11, reaching 5.26% (by volume) by 2013/14 after the Gallagher Review of the Indirect Effects of Biofuel Production raised concerns over the sustainability of biofuels production. An obligated supplier must prove to the Renewable Fuels Agency (RFA) who administer the RTFO that it has met its Obligation by producing Renewable Transport Fuel Certificates (RTFCs) at the end of the year. One RTFC is awarded for every litre of biofuel supplied that is reported to the RFA, and an obligated supplier can obtain them either by supplying biofuel itself, or by trading with other biofuel suppliers. Suppliers who fail to meet their obligation must pay a fine of 30p per litre. The RTFO places a considerable emphasis on ensuring that biofuels are sustainably produced and have a high GHG savings and as such, the RTFO requires companies to submit reports on the origin and sustainability of their fuels. The supply of such information is currently not mandatory, although will be introduced as part of the Renewable Energy Directive in December 2010.

Biomass Strategy

The UK Biomass Strategy was published in 2007, and provides the overarching framework for the supply and utilisation of biomass for fuels, energy and industrial products in the UK. The strategy is multifaceted with actions to significantly increase biomass availability, improve end use efficiency, and improve the supply chain for biomass based products. The need to secure biomass in an environmentally sustainable manner is a key focus of the strategy. Thus there is a significant emphasis on the planting of perennial energy crops, and the exploitation of biomass resources which have previously been overlooked including harvested wood from unmanaged woodlands, recovery and utilisation of waste wood and recovery and use of organic wastes such as slurries and food waste.

Biorefineries and Biomass Derived Products

There is no explicit policy encouraging the biorefinery concept in the UK, although several aspects of biorefineries, for example industrial biotechnology, are covered under wider policy goals. The Industrial Biotechnology Innovation and Growth Team (IB-IGT) was a cross industry consortia which aimed to

promote the uptake of industrial biotechnology within the UK. It acknowledged that the Industrial Biotechnology area is a rapidly developing market internationally and whilst the UK has a relatively large chemical industry, and a strong and innovative research base, there has been relatively little uptake of industrial biotechnology commercially in the UK. The IB-IGT developed a series of recommendations for how industrial biotechnology can aid the competitiveness of chemical and chemicals using sectors, for example, by ensuring that UK companies are better positioned to develop opportunities within the growing IB sector, joining up government, societies and other stakeholders and to develop a green bio-based economy. These recommendations were submitted to Government who outlined a series of measures within IB2025: Maximizing UK Opportunities from Industrial Biotechnology in a Low Carbon Economy published in June 2009. A key action resulting from the IB-IGT was the development of an £12 million open access demonstration fermentation facility in the UK at Centre for Process Innovation in Teesside, with a capacity of 10,000 litres. In addition, an Industrial Biotechnology fund of £2.5 to 5 million per year was established for companies wishing to gain access to the demonstration facilities to scale up specific technologies

Biorefinery related funding programs

The UK has a range of funding programmes which encompass biorefinery related activities. However, only the Integrated Biorefining Technologies Initiative (IBTI) has funding specifically for biorefinery research. The majority of these programmes are for basic and applied research. These funding programmes are described in more detail below. The UK has invested significant amounts in the development of pilot and demonstration activities to bring the results of research forward (described on Page 15)

Integrated Biorefining Research and Technology Club (IBTI)

The IBTI Club funds basic research , with funding of £6 million over 5 years. IBTI Club is a joint initiative of the BBSRC, EPSRC and a consortia of leading companies. Launched in 2008, it aims to catalyse the development of biorefining technologies, supporting research which has been identified as being strategically important by the BBSRC and its industrial members. The research focusses on three main topics: 1) optimising feedstock composition to produce a feedstock for which maximum value can be derived; 2) integrative bio-processing, to develop more efficient substrate utilisation; 3) chemical separation technologies and enhancing product value through the development of higher value chemicals.

Renewable Materials LINK

Renewable Materials LINK is a collaborative research scheme which aims to deliver high quality pre-commercial research in areas with potential for commercialisation. Renewable Materials LINK is sponsored by Defra, DECC and BBSRC. The programme focuses on funding innovative, near market research and development which furthers the use of renewable materials for industrial purposes . LINK programmes typically focus on an area of potential market failure and thus carry an element of risk which would not otherwise be attractive to private sector. The LINK scheme provides 50% match funding from government, the rest must be matched in kind or from cash contribution from industry. The Renewable Materials LINK scheme has so far provided £10 million for projects, which in total give a total project fund of £22.4 million. Projects funded include an assessment of the commercial viability of chemicals from different biomass feedstocks, a project investigating the potential to use forage grasses for the production of bioethanol, and the use of rosemary to provide antioxidant chemicals.

Technology Strategy Board

The Technology Strategy Board funds pre-commercial applied research and development, and has earmarked £ 5 million for biorefining related research in 2010 and 2011. The development of business led projects to produce high value chemicals through industrial biotechnology has been earmarked £2.5 million for 2010. Support is principally for high quality and innovative multidisciplinary feasibility studies leading to commercial deployment within two to four years. The call is for a wide range of end uses including personal care, lubricants, platform and fine chemicals. Whilst biofuels are excluded, projects using co-products or byproducts from biofuels are included. Succesful projects will be followed up in a further round of funding worth 2.5 million in 2011, aimed at further commercialisation of research.

BSBEC

BBSRC Sustainable Bioenergy Centre (BSBEC) funds basic research and has a budget of £27 million over 5 years from 2009-2014. The Centre's remit is to consider the major areas of biological research underpinning the development of bioenergy, from biomass crop improvement to bioprocessing, and covering the social,

economic and legal implications of bioenergy production and use. The centre is a partnership between several leading UK academic institutions, research institutes and major companies. The centre brings together six world-class research groups indicated below and creates a network with expertise and specialist resources that span the bioenergy pipeline from growing biomass to fermentation for biofuels.

Theme	**Research Topic**	**Leader**
Perennial Energy Crops	Increasing the yield and composition of perennial energy crops for bioenergy.	Rothamsted Research
Cell Wall Sugars	Plant and enzyme improvement for increased conversion of biomass to fermentable sugars.	University of Cambridge
Cell Wall Lignin	Altering lignin composition of plants for increased conversion.	University of Dundee at SCRI
Lignocellulosic conversion to bioethanol	Investigating new strains for fermentation, release of sugars by enzymes and green engineering.	University of Nottingham
Second Generation Bacterial Biofuels	Production of biobutanol from lignocellulosic materials by enhancing lignocellulose breakdown and improving fermentation of sugars to biobutanol.	University of Newcastle
Marine Wood Borer Enzyme Discovery	Development of novel enzymes from marine wood borers for lignocellulose breakdown.	University of York

Supergen Biomass and Bioenergy

The Supergen programme was set up by the Engineering and Physical Sciences Research Council (EPSRC) in partnership with BBSRC, Economic and Social Research Council (ESRC), Natural Environment Research Council (NERC) and the Carbon Trust to encourage the development of sustainable power generation and supply. Supergen Biomass and Bioenergy is one of the 13 consortia which have been set up and consists of partners from academia and industry. The programme focuses on research throughout the biomass and bioenergy supply chain, from biomass production to the use of the final energy product, for example power, heat and transport fuels largely investigating physical and thermochemical conversion processes. Phase I gained a better appreciation of the interfaces between biomass, its cultivation and the impact on thermal conversion processes and products. Phase II of this project includes research into the potential use of marine biomass, transport fuels and biorefineries.

Carbon Trust

The Carbon Trust has funded the Pyrolysis Challenge and the Algal Biofuels Challenge, multi-million pound collaborative projects which aim for the rapid commercialization of these technologies. The Pyrolysis Challenge aims to, over the next 3-5 years, produce pyrolysis oil with enhanced properties so that it can be used by existing infrastructure, either through modifying the pyrolysis procedure to produce a better quality oil, or to upgrade the oil before, or at, a refinery. The Algal Biofuels Challenge, which began in 2010, aims to commercialise the use of algae as an alternative to fossil fuel by 2020. The programme is split into two key phases. The first phase will concentrate on the development of suitable microalgae strains and cultivation systems, whilst the second phase is expected to result in the demonstration of the research conducted in phase 1.

Running commercial biorefineries

Table UK6. Examples of the most representative existing biorefineries – preferable not conventional biofuel production facilities or traditional use of biomass (e.g. pulp and paper):

Company	Feedstock	Products	Description	Size
British Sugar	Sugar Beet	Sugar products (400,000 tonnes) bioethanol (55,000 tonnes), animal feed (100,000 tonnes), lime, tomatoes (70 million), topsoil (65,000 tonnes), betaine, stones	Wissington produces a wide range of products from 3 million tonnes of sugar beet, utilizing every part of the crop. The plant also exhibits considerable integration with other processes, for example, CO_2 and low grade heat from the factory is channeled into adjacent greenhouses which are used for tomato production.	3 million tonnes sugar beet per annum
Ensus	Wheat	Bioethanol (over 320,000 tonnes), DDGS 350,000 tonnes) and industrial carbon dioxide (300,000 tonnes)	Ensus operate the EU's largest cereal grain biorefinery. The plant is located on Teesside in North East England and began production in 2010.	Over 1 million tonnes of feed wheat per annum
Cargill	Wheat	Starch, distillers grains, glucose syrup, ethanol (potable), gluten	Cargill acquired the Cerestar starch factory and sweeteners site in Manchester in 2002. Fermentable sugars are used to produce bioethanol at the adjacent Royal Nedalco plant.	750,000 tonnes of feed wheat per annum
Roquette	Wheat	Starch, distillers grains, glucose	Wheat starch processing plant located in the centre of the UK feed wheat growing area.	150,000 tonnes of feed wheat per annum

Demo and pilot plants

Table UK7. Examples of the most representative demo and pilot plants:

Company	Feedstock	Products	Description	Status (demo/pilot)
TMO Renewables	Mixed	Ethanol	Demonstration facility with a nominal maximum capacity of 1 million gallons per year. Technology comprises of fully integrated pretreatment, enzyme hydrolysis and thermophillic fermentation steps, for a range of biomass derived sugars including polymers.	Demo
Butamax	Starch and sugar crops	Biobutanol	Demonstration facility will have a nominal capacity of 150,000 litres (121.5 tonnes) per year and will be located at Hull.	Demo (due online 2010)
NIBF/SUSPROC	Mixed	Mixed	£12 million open access trial and development centre for industrial biotechnology. Fermentation facilities will be up to 10,000 litres (10 tonnes) capacity and will focus on the production of fuels and plant derived chemicals.	Demo (due online November 2010)
Anaerobic Digestion Development Centre	Organic Wastes	Mixed	Reconfigurable AD open access facility, which will allow testing of different feedstocks, different temperatures, different digester configurations at the 100 tonnes per year scale.	Pilot (due online late 2010)
Scottish Bioenergy Ventures	Algae	High protein animal feed, fertilizer or AD	Uses waste water and flue gas and CO_2 from fermentation to grow algae in photobioreactors.	Pilot
Boots	Algae	Biomass	Photobioreactor facility covering 32 m^2, using flue gas from an onsite gas-fired CHP plant.	Pilot

Major RTD activities

Table UK8. Major RTD activities:

Name of project	Type of project	National coordinator	Description	Duration	Size (€s, US$)
Integrated Biorefining Research and Technology Club	National	BBSRC	Several fundamental research projects on aspects of biorefining including: the utilisation of wheat and oilseed straw co-products for bioalcohol production, aromatic chemicals from lignin, *in-silico* studies of lignocellulosic biofuel processes and engineering oilseeds to synthesize designer waxes. http://www.bbsrc.ac.uk/ibticlub/	2008-2012	€7.2M ($9M)
Supergen Bioenergy	National	Aston University	Aims to provide a recognised focus for UK biomass and bioenergy activities that unites key stakeholders and academia through leading edge research in renewable energy. http://www.supergen-bioenergy.net/	2009-2011	€8M ($9.7M)
BBSRC Sustainable Bioenergy Centre (BSBEC)	National	BBSRC	The Centre underpins development in the important and emerging bioenergy sector. It is made up of 12 universities and institutes and 14 industrial partners. http://www.bsbec.bbsrc.ac.uk/	2009-2013	€31.4 ($39.5M)
HOOCH	National	Institute of Food Research	Project developing, evaluating and supporting the commercial exploitation of tailored approaches for converting different sources of agri-food-chain waste lignocellulose into advanced biofuels. http://www.hooch.org.uk	2008-2012	€1.9M ($2.4M)
Grassohol	National	IBERS	Project investigating the conversion of high sugar perennial ryegrass to alcohol based transport fuel. http://www.grassohol.org/	2008-2011	€1.1 M ($1.4M)
Assessing Biomass to Chemicals	National	North East Process Industry Cluster	Project assessing the commercial viability of full scale manufacture for a number of bio-based feedstocks. Will produce estimated capital and operating costs for the most feasible options.	2010-2013	€1.9 M ($2.3M)
BioMara	EU Interreg IVA	Scottish Association for Marine Sciences	Project investigating the feasibility and viability of using macroalgae and microalgae as a source of energy. www.biomara.org	2009-2013	€6 M ($7.5M)
Algal Biofuels Challenge	National	Carbon Trust	Multi-partner project investigating how to overcome the technical bottlenecks related to algae production at scale, in saline, open ponds, for biofuel	2010-2013/4	€21M ($27.3M)

			production.		
Pyrolysis Challenge	National	Carbon Trust	Project investigating the upgrading of pyrolysis oil for incorporation into the existing infrastructure.	2010-2013/4	€8.5M ($10.6)
Sustoil	EU FP7	Green Chemistry Centre of Excellence, University of York	Project investigating how to maximize the value of EU oil crops to energy, fuels, heat, high value chemicals and food, maximizing value of side streams. http://www.sustoil.org/	2007-2010	€1M ($1.3M)
Star COLIBRI	EU FP7	Green Chemistry Centre of Excellence, University of York	Study aiming to map and cluster biorefinery projects in the EU, investigating influences on the current biorefinery field and helping to shape European policy. http://www.star-colibri.eu/	2009-2011	€2.4 M ($3.1M)

Stakeholders

Table UK9. Major stakeholders in the country and eventually include a short description:

Name	Short Description
Industry	
British Sugar	British Sugar produce a wide range of products from sugar beet including sugar, bioethanol, livestock feed, betaine. British Sugar also exhibit considerable process integration with waste CO_2 and heat being used for tomato production.
Ensus	Europe's largest wheat biorefinery producing ethanol, livestock feed and carbon dioxide located on Teesside.
IBTI Club	IBTI Club funds novel and strategic research into optimization of feedstock quality, integrative bio processing and enhancing product value. The current members are: Biocaldol, BP, British Sugar, Croda, Green Biologics, HGCA, InCrops, KWS, Syngenta and TMO Renewables, with EPSRC, BBRSC and Bioscience KTN.
Ineos Bio	Plans for a waste to ethanol demo plant in the North East of England, due online in 2012 and a commercial plant in 2014. Waste is gasified to produce a syngas which is then fermented to ethanol. Power is also produced.
Renewable Energy Association	Leading UK association for the development of renewable energy for fuels, energy and heat applications, with over 500 corporate members. Play an active role in lobbying on energy policies on behalf of members.
North East Process Industries Cluster (NEPIC)	Facilitates the development of the North East Process Industries, by promoting the region as an inward investment location and promoting partnership formation between cluster members. Instrumental in developing opportunities for biofuels, bioenergy and biorefining in the region.
Innovia Films	Leading global producer of cellulose films
Research Institutes	
IBERS	Strengths in energy crop breeding, biomass conversion and biorefining, particularly in grasses, Miscanthus and willow.
National Institute of Agricultural Botany (NIAB)	Centre of excellence in research in plant breeding, agronomy and plant derived products based in Cambridge.
Porter Alliance	A multidisciplinary group of biologists, chemists, engineers, mathematicians, policy and economic experts from IBERS, Rothamsted Research, John Innes Centre and Imperial College, London, with partners from the universities of York, Southampton, Aston and Cambridge.
Universities	
BBSRC Sustainable Bioenergy Centre	Multi-institute centre which brings together 6 world class research groups investigating the production and utilisation of biomass for biofuels and bioenergy.
Aston University	The Bioenergy Research Group (BERG) is a centre of excellence on thermochemical conversion of biomass, to fuels, chemicals and energy. Particular expertise in pyrolysis and gasification.
Centre for Novel Agricultural Products (CNAP) University of York.	Strategic research is primarily targeted at plants for biorenewable feedstocks, plants for health and plants for phytoremediation. CNAP is the principal stakeholder in the proposed Biorenewables Development

	Centre.
Green Chemistry Centre of Excellence, University of York	Aims to promote the development and implementation of green and sustainable chemistry and related technologies into new products and processes.
Satake Centre for Grain Process Engineering	Centre based at the University of Manchester which is investigating primary and secondary cereal processing and novel uses for cereals and their co-products.
University of Bath	The Centre for Sustainable Chemical Technologies has expertise in biomass materials and chemicals production, chemical synthesis of fuels and LCA of fuels.
BC	Based at the Bangor University, BC investigates resins, plastics and coatings, fine chemicals and uses for forest products.
Warwick Innovative Manufacturing Research Centre (Warwick IMRC)	Investigates the use of renewable and bio-based materials in high value manufacturing applications.
CoEBio3 (University of Manchester)	Centre of excellence for biocatalysis, biotransformations and biocatalytic manufacture. Open access facility for both academic and industrial groups.
University of Nottingham	Expertise in brewing science and microbial biobutanol production which is being utilized within BSBEC.
University of Newcastle	The SWAN Centre brings together the Universities research on energy with expertise in AD, pyrolysis, biorefining, process intensification, algae and gasification.
Governmental Organizations	
Department of Energy and Climate Change (DECC)	Government department responsible for energy generation, security of supply and the decarbonisation of the UK's energy supply. Leads on the use of biorenewable materials for energy and industrial purposes.
Department for Environment, Food and Rural Affairs (Defra)	Government department responsible for farming and environmental matters. Defra are leading the development of Anaerobic Digestion policy and implementation.
Department of Business, Innovation and Skills (BIS)	Government department promoting the growth of British industry, innovation and skills.
Department for Transport	Government department responsible for UK policy on transport biofuels.
Research Councils UK Energy Programme	A partnership of the UK's research councils funding basic research. The Research Councils Energy Programme is a whole systems approach to understanding energy systems and to understand how the UK can meet its energy and emissions targets. The Energy Programme has so far funded 76 projects worth £14.4 million over a wide range of energy related topics.
Technology Strategy Board	Non-departmental body reporting to the Department of Business, Innovation and Skills, responsible for the promotion of technology innovation through knowledge transfer and by funding industrially relevant, near market collaborative research and development.
NNFCC	The UK's centre for renewable fuels, chemicals and materials. An independent centre, offering high end technical and scientific expertise, for government, industry and academia to support and catalyze the development of a bio-based economy through supply chain development and sector promotion.
Chemistry Innovation KTN	Chemistry Innovation is a national Knowledge Transfer Network (KTN) established in 2006 to stimulate and support product and process innovation in the UK chemistry-using industries.
Bioscience KTN	The main role of the Biosciences KTN is to accelerate the rate of bioscience technology exchange into and within the UK.
Non-governmental Organizations (NGOs)	

Others	
InCrops	Promotes crop derived bio-renewable near market research, supply chain development and product development in the East of England.
British Bioalcohols Group	The British Bioalcohols group aims to exploit agri-food-chain biomass such as wheat or oilseed rape straw for the production of second generation bioalcohols. The group is made up of University of East Anglia, Institute of Food Research, John Innes Centre and Renewables East. The group coordinates the HOOCH project.
AHRB – HGCA (Home Grown Cereals Authority)	Levy board which supports research activities relating to maximizing the use of cereal and oilseeds and their co-products in industrial applications.

Other issues/updates

This report has highlighted the UK's existing work on biorefining and has shown the significant investment the UK is making in this area both in R&D and technology demonstration. So far, 2010 has seen several exciting announcements which demonstrate the growing interest in biorefining in the UK. Sedalco UK, a joint venture between Syral and ETEA groups, have announced that they will produce potable alcohol at a disused citric acid plant in Selby, Yorkshire. The plant will utilize wheat to produce potable ethanol and a series of value added products from the grain residues. The Biorenewables Development Centre, a joint initiative between the Centre for Novel Agricultural Products, FERA and Science City in York, is an ambitious project which will combine a pilot scale demonstration facility, a centre for research and development into biorenewables and a network of industrial partners to develop industrially relevant opportunities in technologies and products.

Perhaps the most exciting however, is the significant strides the UK is taking in the development of advanced biofuels from waste products. Ineos Bio has announced that they will build a small commercial scale plant on Teesside, due online in 2012. Approximately 150,000 tonnes of waste will be gasified to form a syngas which will be fermented to 30,000 tonnes of ethanol per annum from 150,000 tonnes of municipal solid waste. The Ineos Bio project has received funding local and national government including a £500,000 grant from the Environmental Transformation Fund British Airways have announced that they intend to build a waste to jet fuel plant, due online in 2014, and possibly sited in East London. This plant will use plasma gasification followed by a Fischer Tropsch step to produce 16 million gallons (59.6 thousand tonnes) of green jet fuel (kerosene) from 500,000 tonnes of municipal waste.