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# Env-2E02: Exploration into the Potential of Energy Generation in the UK from Biomass

## Introduction

The definition of biomass from the Energy White Paper is "anything derived from plant or animal matter and includes agricultural, forestry wastes/residues and energy crops. It can be used for fuel directly by burning or extraction of combustible oils". Waste materials from agriculture and forestry can contribute in some part towards the UK's energy demand. This however is just a very small amount, the 1978-1980 average potential was a mere 363.4GJ. Technologies have improved in the last twenty-five years, but if anything the amount of agricultural land and woodland has diminished, and so I do not anticipate this value to have altered greatly in that time. To accomplish any significant energy supply from biomass, energy crops have to be considered. In the UK's climate the main energy crops are short rotation coppice, oilseed rape, beet, sugar cane, cereal crops, and miscanthus.

Biomass is classed as a renewable resource, but is only such if used in a sustainable manner. Before biomass power stations can be built, the resources surrounding the area have to be able to produce an adequate supply. Not only must there be enough biomass to run the plant, but there must be the right amount of crops growing continuously at the same rate needed to replace what is being burnt. Biomass does have a major benefit above all other renewables. It is the only renewable resource which has the capability to be stored until it is needed. However, unlike wind when the power output can be accurately calculated at differing wind speeds, the calorific content per tonne for energy crops can be highly variable. This is largely due to water content, which clearly due to rainfall cannot be controlled reasonably. By this I mean that the energy required to cover, drain, and light the crops will make such a scheme economically unviable. Biomass is also the only form of renewable energy that involves combustion. This means that there is the release of $CO_2$, which is well known as one of the greenhouse gases responsible for global warming. Biomass has been previously described as $CO_2$ neutral, as the $CO_2$ emitted via combustion is absorbed by the crops which are yet to be harvested. These calculations did not include the fuel used by lorries to transport the biomass, or the construction of the power station. More recent carbon dioxide emissions are shown in figure 1.

| | Production | Transport | Conversion | Clean-up | Total |
|---|---|---|---|---|---|
| Biomass | 59 | 17 | 0.7 | 0.2 | 77 |
| Coal | 97 | | 957 | 0.04 | 1054 |
| Gas | 15 | | 396 | 0 | 411 |

Figure 1. Comparison of $CO_2$ equivalent emissions from biomass, coal and natural gas to electricity chains (g $CO_2$eq/kWhe). Plant efficiencies: Biomass 32%, Coal 38%, Natural Gas 52%

The UK currently already has a limited number of biomass powered, or partially biomass powered power stations. This includes the world's largest straw burning power station, which is situated in Ely. The power station is 38MW, and generates 270GWh annually, the final project cost came to £60M. To fuel the power station 200,000 tonnes of straw is needed each year. Half of the required straw is produced by the station's sister company Anglia Straw, the remaining 50% is supplied by local farmers. The Ely station has also successfully burned both oilseed rape and miscanthus. The station has also proved the worth of biomass, as it maintains the highest load factor of any renewable energy plant.

## Technology

Biomass can be separated into three different sectors. These are biopower, biofuels, and biobased chemicals and materials. Only biopower and biofuels are relevant as far as energy generation is concerned. Biopower is the direct combustion of biomass, but has an extremely low plant efficiency of just ~32%. This efficiency can be increased if the biomass is used as a part of co-firing. This is where the crop is fed into a coal power station, and burnt along with the coal. Co-firing also has the lowest financial implications as it does not involve the construction of new power stations, and fewer deliveries of crops would be required by lorries each day. Efficiency improves drastically, up to 80%, when biomass is used within a combined cycle gas turbine (CCGT) environment, figure 2. In such a system the biomass is converted into hot pressurised combustion gases. These gases are processed to prevent corrosion of the system which if left untreated could become costly. The gases are then burned with an inflow of air, before entering the gas turbine. The pressure of the gas turns the turbine at a very high speed, this motion generates electricity. In a normal combustion plant the steam would then be released, but in this system the heat from the gas is recovered using water in the heat exchanger. After this point the gas can be released from a stack without further cleaning. A by-product from this process is a non-toxic ash. This ash can be mixed with compost to help grow the next crop of biomass.

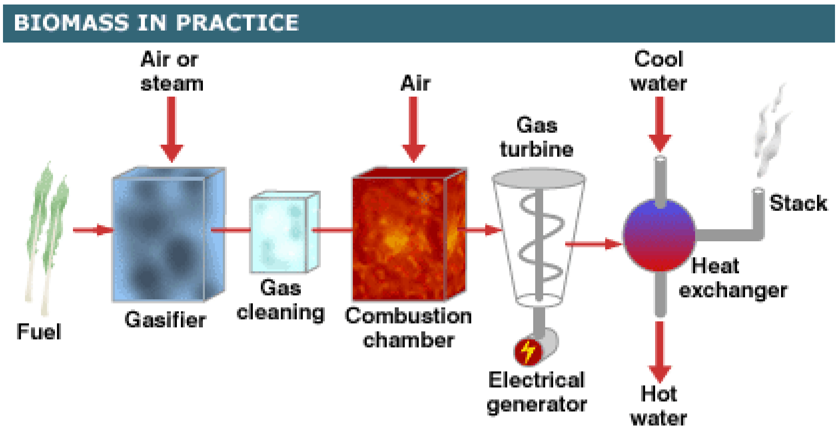


Figure 2. Biomass in a CCGT

As well as biopower, biomass can be converted into biofuel, which consists of three elements. These are biodiesel, bioethanol, and biosyngas.

Biodiesel can be used neat in vehicles, after an initial gradual introduction, or mixed with traditional fuels. This is an attractive process as it does not involve the expense of converting existing vehicles. Oilseed rape is the most common biomass used to create oilseed rape, and is easily grown throughout the UK. The crops used for biomass can be grown at a rate of 10-20tonnes/ha/yr and generally has a calorific value of 10GJ per tonne. These figures are highly variable due to growing conditions and water content of the crop. The efficiency rate for biofuel is significantly higher than that of biopower, ~50%, but still not close to the efficiency which can be generated in a CCGT system.

Biodiesel is created by a chemical process known as transesterification. This is where glycerine is separated from the fat or vegetable oil of the biomass, leaving behind two products, methyl esters (biodiesel), and glycerine. Glycerine has proved to be a valuable by-product as it can be sold to be used in soap and other products. The process of separation is an organic reaction, where the derived oils are combined with an alcohol, either ethanol or methanol, in the presence of a catalyst to form ethyl or methyl ester. It is these products which can be used as neat fuel, or blended with conventional diesel fuel.

Bioethanol, unlike biodiesel is largely derived from sugar beet. A second difference between the two fuels is that it can not be used to run a vehicle in a neat form. Regular cars can run on a blend of 10-15% bioethanol mixed with normal petrol, or, if a car has been converted it is possible to run on 85% bioethanol. It is derived by converting the carbohydrate element of biomass into sugar. Through a fermentation process this is then converted into sugar. The process is shown in more detail in figure 3.

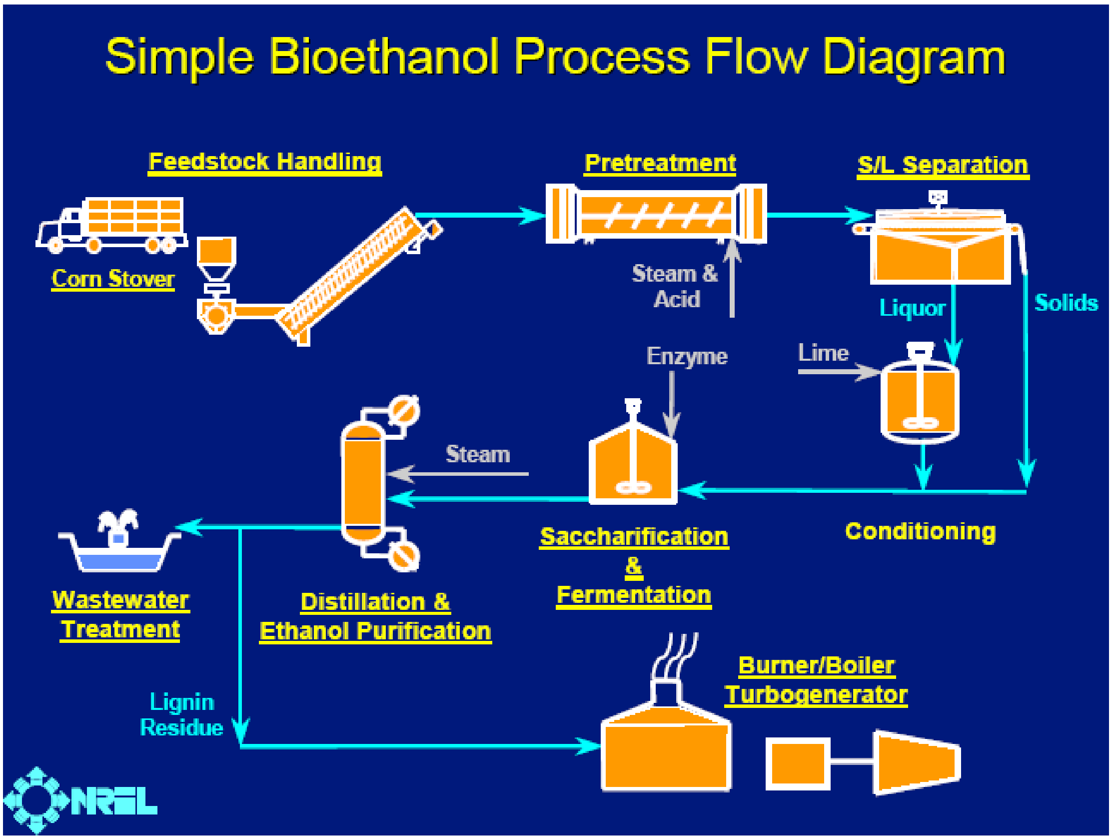


Figure 3. The process of converting biomass into bioethanol

Biomass can also be gasified to produce a synthesis gas which is mainly composed of hydrogen and carbon monoxide, this is known as syngas, or alternatively biosyngas.

From this gas, hydrogen can be recovered, or it can be catalytically converted into methanol. Along with these two methods of extracting energy, it can be converted into a liquid steam which has properties similar to diesel. This is done by using a Fischer-Tropsch catalyst, the final product has become widely known as Fischer-Tropsch diesel.

## Government Policies

The government are currently encouraging the use of biopower, and biofuels. The Energy White Paper stated that biomass represents an important potential route to accomplishing the target of a zero-carbon transport environment. It also stresses the benefits to agricultural economy, creating farming and rural employment benefits. The duty on biodiesel has so far been reduced to 20 pence/litre below the standard diesel rate, and a blend of 5% biodiesel, diesel fuel mix is becoming more widely available in the retail market. Currently some of the UK's fleets of lorries are converting to 100% biodiesel fuel. It was announced in November 2002 that the government has proposed to also reduce the duty on bioethanol by 20 pence per litre, to create an incentive towards the product. As well as the reduced tax on biomass in the form to power transport, the Renewables Obligation offers financial benefits to biomass generated power stations, something which is becoming increasingly important with the renewed focus on the Kyoto Protocol.

There is also a large financial resource open to biomass fuelled power from Research and Development Programmes and Capital Grant Measures. These include;

- £66M Bio-energy Capital Grants
- £29M Energy Crops Scheme
- £3.5M Infrastructure Scheme
- £10M Clear Skies (Domestic)
- £30M Advanced Energy from Waste Demonstrators
- £2M/yr Department of Trade and Industry Research and Development, plus University funding

Projections

Before projections can be calculated, a firm set of assumptions has to be compiled. For biomass I felt that it was necessary to assume that there would be no sudden large scale change in electricity demand or supply, such as was created during the miners strikes. This was necessary as not only does it take several years to achieve the correct planning permission, design, and build a biomass power station. Not only this, but it can take between three and five years to establish a sustainable crop resource, and often far longer if the biomass is from woodland felling. It has also been forecasted that it will take a minimum of ten years before wide scale biomass becomes economically viable. Genetically modified crops have not been considered in this study. GM crops maybe able to produce a higher calorific value per tonne, but the security of such crops from demonstrators would cause the price of the crop to increase greatly. CCGT systems have been favoured against other forms of biomass electricity production as the efficiency is extremely high, at times as high as 80%. It has also been assumed that energy crops constitute the majority of the biomass produced. This has been done as although wood has a calorific value of ~20GJ/tonne, and energy crops have a calorific value of only ~10GJ/tonne, energy crops are significantly cheaper to cultivate. They also have a ten times shorter maturity rate, three years compared to thirty years. Currently within the UK there is 17million hectares of agricultural holding, of this 3.5million hectares has been designated set-aside land. It is this land that can be exploited for growing energy crops, not land which is already being used for agricultural purposes. This is because if original crops are lost to make way for this new energy production, the prices will rise as the resource has been reduced. This could lead to cheaper crops being imported from other countries, and causing economic instability within the agriculture sector. With these assumptions considered, the UK projections for biomass generated electricity are shown in figure 4.

| Year | Projection |
|---|---|
| 2005 | 0.07PJ |
| 2010 | 8PJ |
| 2015 | 14PJ |
| 2020 | 20PJ |
| 2025 | 32PJ |
| 2030 | 40PJ |

Figure 4. Biomass generated electricity projections for the UK.

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