BIOENERGY – ENVIRONMENTAL BENEFITS AND IMPACTS

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Abstract

The world's biomass plays a very basic role in maintaining the environment, so it is important to consider not only the benefits of bioenergy but the possible deleterious effects, global or local, of our interference with these natural processes. Space does not allow a detailed account of every effect of every form of bioenergy, so we'll concentrate in the following on the most significant benefits and impacts, considering first atmospheric emissions and then other aspects.

Key words: bioenergy, environmental, carbon dioxide, methane, biomass

ATMOSPHERIC EMISSIONS

Carbon dioxide

The concept of 'fixing' atmospheric CO_2 by planting trees on a very large scale has attracted much attention. There is little doubt that the halting of deforestation and the replanting of large areas of trees would bring many environmental benefits, but absorption of carbon dioxide by a new forest plantation is a once-and-for all measure, 'buying time' by fixng atmospheric CO_2 while the trees mature, say for 40-60 years. A wider bioenergy strategy, concentrating on the substitution of biofuels for fossil fuels may be a more effective lasting solution.

To analyse the benefits of substitution, it is essential to assess all th effects in a life cycle abalysis, We'll start with just one form of energy in one context: electricity generating plants that are either current or near to commercial implementation in the UK. Table 1 shows the emissions of carbon dioxide and the two amin sources of acid rain, sulphur dioxide and oxides of nitrogen. The data are life cycle emissions per unit of electrical output, taking into account all the processes involved. For instance, the totals for energy crops include emissions associated with fertilizer production and the use of fossil fuel in processing or transporting the fuel. But there is also 'credit' for the CO_2 removed from the atmosphere by the growing crop. As can be seen, even the best systems are not carbon/neutral. But all the bioenergy systems, even MSW combustion, have lower CO_2 emissions than any of the fossil fuel plants. And it is easy to show that if the annual 270 GWh from the straw-fired power station, it will be reducing UK annual CO_2 emissions by a quarter of million tones.

Table 1.

Net life cycle emissions from electricity generation in the UK

	Emissions/g kWh^{-1}		
	CO_2	SO_2	NO_x
Combustion, steam turbine			
- poultry litter	10	2,42	3,90
- straw	13	0,88	1,55
- forestry residues	29	0,11	1,95
- MSW (EfW)	364	2,54	3,30
Anaerobic digestion, gas engine			
- sewage gas	4	1.13	2,01
- animal slurry	31	1.12	2,38
- landfill gas	49	0,34	2,60
Gasification, BIGCC[1]			
- energy crops	14	0,06	0,43
- forestry residues	24	0,06	0,57
Fossil fuels			
- natural gas: CCGT[2]	446	0,0	0,5
- coal: 'best practice'	955	11.8	4,3
- coal: FGD & low NO_x[3]	987	1,5	2,9

(1) BIGCC – biomass integrated gasification combined cycle; (2) CCGT – combined – cycle gas turbine; (3) Flue gas desulphurization and low NO_x burners

Sursa: adapted from ETSU, 1999

Such CO_2 reductions are the obvious benefits of bioenergy, whether used for power generation as here or directly for heat or for conversion to liquid fuel. But we must also look at other emissions. Nitrogen oxides (NO_x) are an inevitable product of the combustion of any fuel, because four-fifths of the air is nitrogen. High temperatures – in furnaces or internal combustion engines – increase NO_x production, and bioenergy systems will need to meet the same 'clean-up' requirements as those using fossil fuels. This also applies to the removal of particulates.

Methane

An important emission from Table 1 is methane. As we have seen, this powerful greenhouse gas is a product of the anaerobic digestion of biomass – whether naturally, as in a pond, or as a consequence of human activities. Its relationship to the use of bioenergy is rather complicated. Dung heaps are the result of our keeping animals for food, and landfills are the result of our accumulation of wastes. In neither case is the extraction of energy responsible for the methane emissions. Indeed, combustion of the gas is more nearly the solution than the problem. A molecule of $CH_4$is nearly 30 times as effective as a molecule of CO_2 in trapping the earth's radiated heat, and full combustion effectively replaces each CH_4 molecul by a CO_2 molecule. To take one example, combustion of landfill gas is estimated to have reduced UK greenhouse gas emissions by the equivalent of some 20 Mt of carbon in 2002. Without this, total UK greenhouse gas emissions in that year would have been morethan 10% higher.

In this context, there is controversy about the relative merits of landfill and MSW combustion (EfW). As Table 1 shows, life cycle CO_2 emissions th the atmosphere. Depending on the collection efficiency, these could add the equivalent of another 100-200 $gkWh^{-1}$ th the actual CO_2 emission shown in Table 1. However, as we shall see, criteria other than greenhouse emissions may determine the future roles of these two technologies.

Other emissions

There are also other important atmospheric emissions which are released at lower concentrations from the combustion of MSW and landfill gas – and to lesser degree in the combustion of any biomass. These include heavy metals and organic compounds (such as dioxins) than can potentially cause a wide range of health effects. Other sources of pollution include the fly ash residue from MSW combustion, which has a relatively high concentration of heavy metals and needs special disposal (e.g. in controlled or hayardous waste landfill sites). And there may be liquid effluents, from flue gas cleaning, for instance, that must be treated before release.

However, it has been estimated that EfW accounts for only 0,1% of UK dioxin emissions, and a Swiss study found that domestic bonfires were a greater source there than controlled MSW incineration. Both the Uk and the EU are enforcing increasingly strigent emission standards and the installation of pollution control technology; but there are concerns that the standards are not always maintained – and history shows that, as data improve, the accepted ‘safe’ levels of such pollutants tend to become lower and lower.

LAND USE

Biomass is one of the most land-greedy energy sources, and it has been suggested that using land for other forms of renewable energy may do more to mitigate the impacts of CO_2. Comparing bioenergy yields with those of other ‘low density’ renewable can be illuminating. Consider, for nstance, the land neede for an annual electrical output of ten million kWh – the equivalent of a 1,5 MW power station. An array of PV modules might need an area of some 40 ha to provide this, and a windfarm slightly more: perhaps 100 ha. With reasonable yields and conversion efficiencies, the land area of energy crops required to fuel this power plant would be in the range 300 – 1000 ha (3 – 10 km^2).

Area is of course not the only consideration, and in any case., the above three systems are unlikely to be competing for the same land. PV arrays are currently more likely to occupy rooftops than large areas of countryside, and wind turbines are often on high land that is also used for other purposes – grazing, or even woodland. The energy crop, as we have seen, may be on farm land that is surplus to food requirements.

In the case of energy crops, particularly oil-seed rape and short rotation coppice, there are concerns about the effect on the agricultural landscape, the reduction in biological diversity and the high inputs of fertilizers and pesticides. But proponents of bioenergy point out that coppices can use different tree species interspersed with indigenous vegetation, and that the life cycle fertilizer demand is perhaps one tenth of that of a cereal (food) crop. It is also claimed that diversity of animal life is greater, particularly for coppice. There is also interest in coppice as a biofilter, improving groundwater quality, and for land treatment of sewage sludge.

ENERGY BALANCE

The terms energy balance, energy payback ratio, or sometimes just energyratio are used to describe the relationship between the energy output of a system and the energy inputs needed to operate it (usually from fossil fuels). The concept came to the fore when doubts arose concerning some of the early fuel-from-biomass projects introduced following the oil price increases of the 1970s. There were claims that, when all enegy inputs (fertilizers, harvesting, transport, processing, etc.) were taken into account, the fossil-fuel energy input for same schemes was actually greater than their bioenergy output.

The ratio of output to input will of course depend on the type of system, and the extent of the processing involved. In particular, ratios will normally be lower if the final 'output' is electricity, rather than the heat content of a biofuel. Over the full range of renewable sources, the ratio of output to input can vary from as little as 1:1 to as much as 300:1 (this for some hydroelectric plants). Woody energy crops perform well, with ratios between 10:1 and 20:1 on a heat putput basis, but biodiesel may achieve only 3:1, whilst ethanol from grain barely breaks even at just over 1:1. When wastes are the input, the question arises of how much of the energy input to attribute to the energy extraction system. Where this is only a small fraction of the energy that would be used in any case, the result can be a high ratio. The value of 30:1 for electricity from woody sawmill wastes is an example.

Payback ratios can be improved by well-designed systems. Part of the biofuel output can, for instance, replace fossil fuels in supplying heat for the processes – as in the anaerobic digestion of wet wastes, or the use of bagasse instead of coal to provide process heat for ethanol production from sugar cane.

The energy balance of a biomass energy system is also a reflection of its environmental impact. The greater the outputs, the greater the quantity of fossil fuel displaced. The lower the inputs, the lower the extra demands put upon the environment by the biomass system.

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