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UK biomass energy since 1990: the mismatch between project types and policy objectives

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Abstract

Biomass energy is expected to play an important role in achieving the UK government's ambitious targets to boost renewables. Since 1990, the main UK support mechanism for renewables has been the non-fossil fuel obligation (NFFO). With only seven of 22 NFFO contracts for fibrous biomass energy projects now operational, the level of real progress has been disappointing. The government's renewables policy has changed over the years and is now based on five objectives. The paper aims to assess what types of biomass energy systems would be most suitable to achieve those objectives. The assessment shows that the nature of the supported developments was inconsistent with most individual objectives. To an important extent this was due to inherent operational contradictions between these objectives. It is argued that the rationale for supporting renewables should primarily lie in reducing greenhouse gas emissions or in energy diversity and security. Support for the rural economy, the development of export technologies and increased competitiveness of renewables, should be seen as desirable longer-term outcomes from the development of a biomass energy sector. By treating these as equals (and even as superiors) to the objectives of climate change and energy diversity, the UK government has actually crippled the development of the biomass energy sector.

Keywords: Biomass energy; NFFO; Renewables policy

1. Introduction

In the aftermath of the first oil crisis, the UK government started a support programme for renewable energy. Until 1990, this programme came mainly in the form of R&D but the "development of renewable energy technologies in the UK, apart from hydro in Scotland and pumped storage in Wales, was very limited" (Mitchell, 1996, p. 168). In the period between 1989 and 2001, limited R&D work continued but the main UK programme to stimulate the use of renewable energy has been the non-fossil fuel obligation (NFFO). Under the five bidding rounds which constituted the NFFO programme (for a description of NFFO, see Mitchell, 1995, 1996; Fouquet, 1998; Connor, 2003), electricity produced from a range of renewable sources could be sold to regional electricity companies at a premium, funded through a levy on fossil fuel. Of a total of 3640 MWe of various types of renewables contracted under the NFFO programme, only 977 MWe was in production on the first of January 2002 (Fig. 1). This amount constitutes about 85% of electricity generated from renewable resources (Meyer, 2003). With renewable electricity now standing at 3% of national electricity production, NFFO has helped the UK to move from 15th to 14th amongst the 15 EU states with regards to the proportion of energy provided by renewables (Connor, 2003).

Some of the early commentators on NFFO argued that the stated target of 1500 MW DCN by 2000 (DOE, 1993) was 'easily attainable' considering the huge interest shown by the private sector (Porter and Steen, 1996) or at least 'unchallenging' and 'short-sighted' in its limited ambition (Elliott, 1996). But this target which was formulated for the first four NFFO rounds (Porter, 1998), was not even achieved with all five rounds in place. The expectation that two-thirds of NFFO 4–5 will come on-line (Mitchell, 1996) now appears rather optimistic. The government's intermediate target of 5% electricity from renewables by March 2003 has now been missed by about 40%.

This very poor level of performance now stands in stark contrast with Tony Blair's ambition to "show

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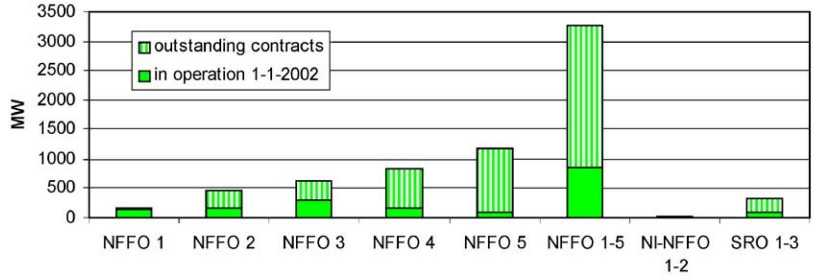

Fig. 1. NFFO contracts awarded and capacity in operation by 1-1-2002 (*source*: DTI, 2002). NI-NFFO and SRO are the Northern Irish and Scottish equivalents of the NFFO.

leadership by putting the UK on a path to a 60% reduction in its carbon dioxide emissions by 2060'' (DTI, 2003, p. 3). It also questions the feasibility of other government targets stated in the Energy White Paper (DTI, 2003), such as cutting CO_2 emissions by 20% below 1990 levels by 2010, producing 10% of electricity from renewables by 2010 and the 'aim' (rather than 'target') for 20% electricity from renewables by 2020.[1]

In order to make the quantum leap needed to achieve the government's targets, the deployment of renewables must be speeded up dramatically and lessons must be learned from past mistakes. One common point of criticism on the government's energy policy is the fact that it is often motivated by vague and/or multiple objectives (e.g. Porter, 1998; Wordsworth and Grubb, 2003; Helm, 2003). Indeed, the NFFO was originally not at all designed to stimulate renewable energy. It was first developed in 1989 as an instrument to support nuclear energy. When renewable energy was first included in NFFO in 1990, the relative amount of funding was only 0.5% of the support for nuclear. It could be questioned to which extent the inclusion of renewables did not mainly serve as a green disguise for the fact that consumer bills were inflated by 10% to cover the expenses of running and decommissioning nuclear plants. But over time, this relative contribution grew to 10% and in 1998 EU legislation forced the UK government to abandon support for nuclear through the NFFO (see Mitchell, 1995). Over the years, renewable energy became also more clearly supported in formal terms. Table 1 demonstrates how stated objectives with relation to renewable energy changed over the years. Support for UK industry and energy diversity and security remained core objectives, but environmental concerns gained importance. In 1994, emissions were mentioned in the general sense, but by 2000 this has become more specifically focused on the emissions of greenhouse gases (GHG).

So how, and to what extent, did UK policy achieve these objectives to date? The fact that the UK has missed some of its targets already, indicates that the speed and magnitude of the developments have been disappointing. However, that does not provide us with the insights needed to identify better ways to achieve the government's objectives. There is a need to develop a better understanding why government intervention through instruments such as NFFO has failed to create the desired amount of renewable energy generation. In the literature, a number of barriers for developers have been identified, especially the problems of gaining planning permission (Sinclair and Löfstedt, 2001; Upreti, 2004; Alder, 2001) or raising capital (Butson, 1998; Knight, 1998).

But a more fundamental issue than the identification and removal of barriers is the need to identify how the range of renewable energy options can be best utilised to achieve those government objectives, i.e. has policy actually sought to stimulated the most appropriate renewable energy systems?

After wind, biomass is expected to be the biggest contributor to renewable energy provision in 2010 (Connor, 2003). Contrary to wind energy, the utilisation of biomass energy can take place through a range of different conversion technologies. These different technologies can provide different services and may perform differently with regards to the objectives stated by the government. The performance of different technologies with regards to the stated objectives is of particular interest because NFFO was explicitly targeted at specific technologies and biofuels.

The aim of this paper is to evaluate the UK energy policy with regards to the support and utilisation of biomass energy under NFFO.

The next section will describe the biomass energy plants selected and built during the NFFO programme. The five subsequent sections will explore the extent to which these plants were the most appropriate biomass energy systems to serve the five DTI (2000) objectives quoted in Table 1.

[1] UK targets for renewable electricity are still modest in comparison to those of the EU. The EU Directive on the promotion of electricity from renewable sources (EU, 2001) aims to increase the contribution of renewables to electricity production to 22.1% by 2010.

Table 1
Stated objectives of the UK government with regards to their policy on renewable energy

DE (1988):
1. Stimulate the full economic exploitation of alternative energy resources in the UK.
2. Establish and develop options for the future.
3. Encourage UK industry to develop capabilities for the domestic and export markets.

DTI (1994) (in Mitchell 1996):
Government policy is to stimulate the development of new and renewable energy technologies where they have the prospect of being economically attractive and environmentally acceptable in order to contribute to:
1. Diverse, secure and sustainable energy supplies.
2. Reduction in emissions of pollutants.
3. Encouragement of internationally competitive renewables industries.

The purpose of the NFFO orders is to create an initial market so that in the not too distant future the most promising renewables can compete without financial support. This requires a steady convergence under successive orders between the price paid under the NFFO and the market price. This will only be achieved if there is competition in the allocation of NFFO contracts.

The most recent objectives for the support of renewables were formulated for the Renewables Obligation (RO) which superseded the NFFO in 2001 (DTI, 2000):
1. To assist the UK to meet national and international targets for the reduction of emissions including greenhouse gases.
2. To help provide secure, diverse, sustainable and competitive energy supplies.
3. To stimulate the development of new technologies necessary to provide the basis for continuing growth of the contribution from renewables into the longer term.
4. To assist the UK renewables industry to become competitive in home and export markets and, in doing so, provide employment.
5. To make a contribution to rural development.

2. Biomass energy plants built during the NFFO programme

The main source of biomass for electricity generation under NFFO has been fibrous biomass. In this paper, we will limit ourselves to fibrous biomass such as residues from existing production methods in forestry (e.g. bark, branches, thinnings) and agriculture (e.g. straw), and dedicated energy crops (e.g. miscanthus, short rotation coppice).[2] We will not consider fibrous biomass residues from industry, although some companies, spurred by the rising costs of waste disposal, have built on-site plants to convert their wood waste into useful energy. NFFO did support several anaerobic digestion (AD) plants for wet agricultural wastes, but these too are outside the scope of this paper.

Under the NFFO and its equivalent schemes in Scotland (Scottish Renewables Obligation; SRO) and Northern Ireland (NI-NFFO), a total of 22 contracts were awarded for fibrous biomass energy systems. Fibrous biomass projects were not eligible under any of the technology bands in NFFO 2 and 5 and NI-NFFO 1. While NFFO and SRO only supported electricity generation from biomass, the NI-NFFO also supported biomass CHP. In the remainder of this paper we will refer to NFFO as the entire programme, including Scotland and Northern Ireland.

The seven NFFO projects which are now operational have been built by EPR Limited (Westfield, Ely), Fibrowatt (Eye, Glandford, Thetford), B9 Energy (Blackwater Museum) and Biomass Engineering Ltd. (Brook Hall Estate). The ARBRE plant in Eggborough was completed in 2001, ran into technical difficulties during commissioning and has consequently been declared insolvent in August 2002. Its future is unknown at the moment.[3] The only other biomass energy plant which is being built at the moment can be found in Beddington, south London. This plant is built by B9 Energy and is in size and technology similar to that of the NI-NFFO project at Blackwater Museum. The CHP plant in Beddington is part of 'BedZED', a zero-emission mixed housing development. The BedZED plant is unique in the UK as it is fuelled by tree cuttings from urban parks and is not supported by NFFO or any other direct subsidies (BedZED did receive direct support for PV arrays).

The effectiveness of NFFO can be most directly assessed by looking at how many biomass energy developments have been realised in the UK as a result of NFFO. Less than a third (7/22) of the awarded projects were operational in spring 2003 (see Table 2). In terms of output, the seven projects represent 105 MW, or 44% of the NFFO fibrous biomass contracts. A full

[2] NFFO also supported energy from municipal waste and landfill gas, but we do not define these as 'biomass' here.

[3] In the spring of 2003, the liquidator sold the plant to DAS GreenEnergy, a specially formed subsidiary of Biodevelopment International, a US company which is developing renewables projects in various countries.

Table 2
NFFO contracts awarded to fibrous biomass electricity projects

Contract	Fuel	Location	County	MW	Operational
NFFO-1	PL	Eye	Suffolk	12.7	Yes
NFFO-1	PL	Glandford	Humberside	12.7	Yes
NFFO-3	FR/SRC	Eye	Suffolk	5.5	No
NFFO-3	FR/SRC	Cricklade	Wiltshire	5.5	No
NFFO-3	FR/SRC	Eggborough	Yorkshire	8	No
NFFO-3	Straw	Ely	Cambridgeshire	31	Yes
NFFO-3	PL	Thetford	Norfolk	38.5	Yes
NFFO-3	PL	Corby	Northamptonshire	14.3	No
NFFO-3	PL	Nunn Mills Road	Northamptonshire	8.8	No
NFFO-3	PL	Wellington	Somerset	10.9	No
NFFO-4	FR	Consett	Durham	10	No
NFFO-4	FR/SRC	Thorton-le-Dale	North Yorkshire	6	No
NFFO-4	FR/SRC	Hexham	Northumberland	10	No
NFFO-4	FR	Falstone	Northumberland	6	No
NFFO-4	FR	Carlisle	Cumbria	20	No
NFFO-4	FR	Brecon	Powys	0.25	No
NFFO-4	FR	Newbridge on Wye	Powys	15	No
NI-2	FR/SRC	Brook Hall Estate	Londonderry	0.10	Yes
NI-2	FR/SRC	Blackwater Museum	Armagh	0.20	Yes
SRO-1	PL	Westfield	Fife	9.8	Yes
SRO-2	FR	Brodick	Isle of Arran	2	No
SRO-3	FR	Dalcross	Highlands	12.9	No

Note: Fuels include poultry litter (PL), forestry residues (FR) and short rotation coppice (SRC). SRO and NI relate to the Scottish and Northern Irish variations of the NFFO scheme.

decade after the issuance of the first NFFO contracts, these figures would suggest that NFFO has been neither a resounding success nor a complete failure in developing a biomass energy sector. But considering the fact that this output is only 5% of the estimated 2 GW of electricity which could be generated from the agricultural (poultry litter and straw) and forestry wastes which are currently not utilised (RCEP, 2000), it is evident that very little of the true biomass energy potential in the UK has been unlocked. At this rate, biomass will not be able to fulfil its role in achieving the 10% renewable electricity target by 2010.

The limited *size* of the biomass developments in the UK means that in practice biomass has only been able to play a limited role in contributing to the five objectives of government policy. In the following five sections we will discuss the potential suitability of the different *types* of biomass plants to fulfil these five objectives.

2.1. Objective 1: to assist the UK to meet national and international targets for the reduction of emissions including greenhouse gases

Emissions from fibrous biomass energy systems are much lower than those from a fossil fuel energy system, with the possible exception (dependent on the actual technologies and fuels) of particulates and NO_x. As they are explicitly mentioned in this objective, we will limit our focus here to GHG, especially CO_2. The ability of a project to reduce GHG emissions depends on the performance of the plant in comparison to the baseline, i.e. on the GHG emissions from fossil fuel which would have taken place in the absence of the project. The baseline is discussed first, followed by the performance of the plant.

2.1.1. The baseline situation

The reduction of GHG emissions is potentially the greatest if the baseline situation is an old inefficient plant which uses a fuel with a high emission factor. Of all fossil fuels, coal has the highest input emission factor of around 350 kg CO_2/MWh, and gas has the lowest input emission factor of around 200 kg CO_2/MWh (McInnes, 1996). The output emission factor of electricity plants operating in the UK is around 910 kg CO_2/MWh for coal and 390 kg CO_2/MWh for combined cycle gas (Mott MacDonald, 2001). This means that the most beneficial projects are most likely to be those which displace old coal-fired electricity or old coal-fired heat.

In the case of electricity, the displacement of fossil fuels by biomass is most likely to be indirect, i.e. the output from the biomass plant displaces the output by a fossil fuel plant. Alternatively, it is possible that a biomass electricity plant will directly displace an entire existing fossil fuel plant (which is subsequently decommissioned or mothballed) or in the case of increasing demand, will directly avoid the need to build a new ‘standard technology’ fossil fuel plant. Considering the current overcapacity in the UK electricity sector and the poor investment climate, it is unlikely that new fossil fuel plants will be built soon. This would suggest that the biomass plant may displace an old fossil fuel plant, but since the biomass electricity plants are relatively small in comparison to fossil fuel plants in the UK, it is difficult to imagine that such a direct displacement would take place. We can therefore assume that the new biomass electricity plants will be displacing existing output from what Kartha et al. (2002) call the 'operating margin' plant. This is typically an old plant with a low energy efficiency and therefore a high emission factor for that fuel or technology. When the average electricity plant changes as a result of new plants being built and old plants being decommissioned or refurbished, Kartha et al. (2002) speak of a 'combined margin'. In the current UK situation, it is not clear whether the biomass plants would be displacing the output of coal- or gas-fired plants.[4] The oldest and least energy efficient plants in the UK are coal-fired, and these may be expected to be the marginal plants. However, with a higher price for gas and a low price for electricity due to the New Electricity Trade Arrangements (NETA; a government initiative to increase competition in the energy sector), the relative output by coal-fired plants has increased in recent years (ENDS, 2002a), which implies that it may actually be the gas-fired plants which are the actual marginal plants under current market conditions. This means that there is a distinct possibility that existing biomass electricity plants are now displacing the output of natural gas plants which have relative low emissions, rather than coal-fired plants which have relatively high emissions.[5] In short, new biomass electricity plants are not the most effective technology to reduce GHG emissions in the UK at the moment.

There is also a third type of substitution in electricity plants, namely the direct fuel substitution through co-firing of biomass in existing coal-fired plants. Of all options for the use of biomass to generate electricity, this option is clearly the most beneficial in terms of GHG emissions reduction. Unfortunately, co-firing has not been supported under NFFO. This is a clear policy failure from the perspective of the objective to achieve emissions reduction.

For heat, two situations may occur. In the case of new demand, the project will avoid the need to build a new best available technology (BAT) plant that will have a low emission factor for that fuel/technology (what Kartha et al., 2002 call 'built margin'). For most new buildings, the standard BAT heating system is gas central heating. In the case of a retro-fit, biomass will displace whatever fuel was used previously. Under current conditions in the UK, the highest emission reduction potentials for biomass heating projects would clearly come from retro-fitting old and inefficient coal-fired heating systems with modern biomass boilers. This option is probably even better than co-firing as the new biomass-fired boiler is likely to be more efficient than the old coal-fired boiler, while co-firing in existing boilers brings no efficiency gains. But since heating projects are not eligible under NFFO, it is yet again clear that NFFO fails to stimulate the most efficient ways to reduce GHG emissions.

2.1.2. Factors in the performance of the new plant

The performance of the plant depends on its fuel efficiency, since more efficient plants allow the generation of more renewable energy out of a limited amount of available biomass. Energy efficiency depends in turn on several factors such as the type of technology, the fuel used, the type of service provided, and the size of the plant. The type of technology is discussed under the third objective of the UK renewables policy, but the other factors will be discussed in turn below.

2.1.3. Types of fuel

There have been a range of studies to identify the environmental impacts arising from the use of various types of biomass for conversion to useful energy (e.g. Groscurth et al., 2000; Kuemmel et al., 1997; Kallivroussis et al., 1996). These life cycle studies can be used to rank the different biomass fuel types in terms of their scores for different environmental impact categories. Such a ranking will typically give energy crops the poorest overall environmental performance (including GHG emissions) because of the machinery, fossil fuel and fertiliser input required to grow these crops. Biofuels produced though low-input methods (e.g. thinning or maintenance of existing woodlands which have no commercial value at the moment) will score better while the utilisation of biomass 'waste' from forestry or agriculture will have the lowest impact.

In practice, NFFO has supported a range of biomass fuels, but the fuels with the lowest impact have so far been the most successful. This may be logical since the use of 'waste' fuels carries the lowest opportunity cost, but the success with regards to the objective to reduce GHG emissions, does not appear to be intentional. The operational plants are almost solely dependent on the use of agricultural waste products. The fact that there are no plants larger than 0.5 MW running on forestry residues could be seen as a remarkable failure as this is the most widely used biofuel in developed countries with many operational plants in Scandinavia and North America. The government has attempted to stimulate energy crops through the Energy Crops Scheme (ECS). In the only significant uptake of the

[4] Biomass energy plants will not displace nuclear energy or hydro electricity, as these are 'must-run' plants with very low running costs.

[5] According to the Carbon Trust (2003), the government is currently using a fixed baseline emission factor of only 0.43 kg CO_2/kWh for electricity under the Climate Change Levy Negotiated Agreements and the Emissions Trading Scheme.

ECS to date, 1500 ha was planted in connection with the ARBRE plant. The potential loss of faith in SRC as a result of the failure of the ARBRE plant could be substantial. The over-dependency of this novel crop on a single plant, which itself was of novel technology, is clearly a mistake (ENDS, 2002b).

2.1.4. The service provided

The highest conversion efficiency for the generation of electricity is around 60% and applies to large-scale (hundreds of MW) gas-fired plants which utilise combined cycle gas turbines (CCGT). The conversion of biomass to electricity with CCGT technology would remain more small-scale. It could possibly reach an efficiency of around 40%, but that is yet to be proved commercially. In contrast, conversion efficiencies in CHP plants lie in the range of 75% for micro-CHP (e.g. BedZED) to 90% for larger plants. The conversion efficiencies of heat-only plants are comparable to those of CHP plants. These underlines yet again NFFO's deficiency in focusing only on electricity and excluding heat.

2.1.5. Scale of the plant

Larger plants have larger, more energy efficient boilers. But the energy cost of transport increases too (e.g. see Börjesson and Gustavsson, 1995). According to McIlveen-Wright et al. (2001), the 'optimal' energy efficiency of wood-fired plants is reached at around 50 MW, while further scaling up tends to result in only marginal improvements. These marginal improvements may not be justifiable in view of increased locational impacts, especially of transport. In the light of such figures, it is clear that the plants at Thetford and Ely are of optimal scale, certainly in comparison the spatial distribution of available fuel. This represents a success of UK policy for the two types of fuel which have been well utilised under NFFO.

2.2. Objective 2: to help provide secure, diverse, sustainable and competitive energy supplies

Energy security is probably the oldest and most traditional objective of energy policy. According to the Energy White Paper (DTI, 2003), it is expected that before 2006 the UK will have become a net importer of gas. By 2010 the UK will be a net importer of oil and much of the UK's economically viable deep mined coal will be exhausted. The White Paper expects energy reliability to be achieved through energy diversity. There is a need to have access to diverse sources of gas and oil, but coal is not mentioned. Probably this is in part because the world's coal resources are neither becoming scarce nor are they concentrated in the hand of a few producers, as is the case for gas and oil. The price of coal is also lower and much less volatile than that of gas and oil.

The objective of energy security is therefore best served by the deployment of renewables as substitutes for gas or oil. Oil is predominantly used as a transport fuel. At the moment, the technologies to utilise fibrous biomass as a transport fuel are either outdated (steam engines) or still at the research stage (e.g. producing alcohols through ligno-cellulosis, refining bio-oil from fast pyrolysis, producing hydrogen from biomass for use in fuel cells).

Consequently, biomass energy can benefit fuel security mainly by substituting natural gas in heating and in electricity production. As discussed in the previous section, it is not entirely clear under the current UK market conditions if biomass electricity projects would be displacing coal or gas-fired plants. However, in the case of heating, it is usually clear what the biomass would displace. Retro-fit projects should target old gas-fired heating systems. New-built heat plants would be best to reduce the need for fuel imports, as the standard alternative to biomass heat would be gas-fired heat, assuming of course that the location is near a gas-network.

But since heat is not eligible under NFFO, it is yet again clear that this policy instrument has been poorly designed to contribute to the government's objective of fuel security.

2.3. Objective 3: to stimulate the development of new technologies necessary to provide the basis for continuing growth of the contribution from renewables into the longer term

Technological innovations can offer opportunities for improving energy efficiency. A number of new technologies were stimulated under NFFO, including gasification and pyrolysis. Gasification by itself has a number of environmental benefits, including some energy efficiency improvements. Combined cycle gasification of biomass offers the greatest potential energy efficiency improvements but, as is painfully demonstrated at ARBRE, the technology is not yet commercially proven. Pyrolysis technology is not only less proven than CCGT, but the potential benefits it offers are more questionable for the UK. Most NFFO contracts for pyrolysis were either won by Border Biofuels, or later purchased by them. For example, the Morayhill project was sold by EPR Ltd., the successful developers of Ely and Westerfield, because they did not believe that there was a market for the bio-oil. Border Biofuels struggled to develop the technology and were close to bankruptcy when they were taken over by Dynamotive who have a patented technology for fast pyrolysis. On their website Dynamotive (2003), praise the benefits of bio-oil as follows:

> In island countries with large amounts of forest or agricultural waste and a strong reliance on imported

fossil energy, bio-oil has a significant advantage when there is a shortage of energy and a large number of people are without access to the main grid.

Except for being an island nation, the UK is very hard to recognise in the above description. The UK, which until now was relatively well endowed with fossil fuels, has relatively little forestry and agricultural waste, but most importantly, has no energy shortage and very few people are without access to the main grid. Even in the remote parts of the west-coast of Scotland which are not serviced by the national grid, more competitive energy alternatives can be found, including wind and hydro. It is therefore rather dubious that a total 80 MW was allocated to the development of a technology which is so unsuitable for the UK. Border Biofuels even proposed to transport some of the bio-oil which they hoped to produce at Newbridge-on-Wye (in Wales) more than 200 miles by road to the north of England to operate other plants (Hexham and Thorton-le-Dale) for which they had an NFFO contract.

The future of ARBRE still hangs in the balance,[6] while none of the pyrolysis projects appear to be any closer to approaching the building stage. It is clear that the NFFO contracts could have better been allocated to more proven and established technologies. NFFO clearly failed to deliver on the objective to develop new technologies. The argument can also be reversed as it is equally clear that the support for novel, unproven and unsuitable technologies such as CCGT and pyrolysis contributed to NFFO's failure to deliver a sizeable and viable biomass energy sector.

2.4. Objective 4: to assist the UK renewables industry to become competitive in home and export markets and, in doing so, provide employment

We will look at the following aspects of this objective, competitiveness vis-a-vis non-renewable electricity and growth in the home market, the ability to develop UK technology which is exportable, and the provision of employment.

2.4.1. Competitiveness

Much has been written about the failure of the UK government to reconcile the development of renewables and liberalisation and privatisation of the electricity market (e.g. Helm, 2002; Connor, 2003). The subsequent NFFO rounds have indeed managed to lower the price at which renewables developers were willing to produce electricity. However, liberalisation of the electricity market and especially the introduction of a spot market for electricity through the NETA has reduced the market price for electricity by 40% in the last 2 years (ENDS, 2002c). As a result, price convergence did not take place and renewables are still not competitive, and therefore not very secure or sustainable in the current policy setting. Even if price convergence had taken place, this would only be meaningful if the plants were actually built. It is now 5 years after the last NFFO round and it is clear that the expectation that two-thirds of the NFFO contracts would be built (Mitchell, 1996) has been too optimistic.

2.4.2. Employment and the non-NFFO market

The provision of employment has been disappointing because the roll-out of renewable energy plants has lagged behind expectations and targets. The level of employment is also dependent on the success of the industry to serve non-NFFO and non-UK customers. Outside NFFO, there have been very few developments in the biomass energy sector. The UK-based B9 Energy have won the contract for BedZED in a commercial (non-NFFO) bidding process, and this represents a minor domestic success.

2.4.3. Export technologies

As an indicator of the extent to which the UK renewables industry is competitive abroad, we could simply look at the export activities of those UK renewables industries that have benefited from NFFO. As Mitchell (1996) pointed out, the 8-year contract period of NFFO 1 and 2 forced companies to opt for off-the-shelf technologies in order to get the plant up and running as soon as possible. This resulted in the need to import the BAT, which typically came from countries that were more advanced in the support for and utilisation of renewables. As a consequence, these two NFFO rounds did little to support nascent UK renewables industries (Mitchell, 1996). NFFO rounds 3 and 4 offered the developer 4 years 'grace' to build the plant, followed by a 15-year contract to sell renewable electricity at a premium. While this seems a major improvement, the fact that NFFO 3 and 4 were targeting novel technologies such as gasification and pyrolysis (when NFFO 1 was supporting traditional combustion) meant that a lot more time would have been needed for the domestic development of these technologies. Most of the plants which have been built are in fact based on imported technologies. The cc-gasification technology for ARBRE came from the Swedish Alstrom, the fast pyrolysis technology would have come from the Canadian Dynamotive and the straw-burning technology came from the Danish FLS Miljo. The fluidised bed technology for the Westfield chicken-litter plant was supplied by Austrian Energy and built by Abengoa SA of Spain. The core equipments for the Fibrowatt plants were supplied by companies such as Ansaldo Energia from Spain (turbines), Foster

[6] According to the Guardian (30-5-2003), Alan Silverstein, the director of DAS GreenEnergy UK has threatened to ship the ARBRE plant to India.

Wheeler from Canada (boilers) and Detroit Stoker from the US (grate systems).

Possibly the most 'domestic' of the applied technologies were those of the two micro-CHP projects under the NI-NFFO. Of the two awarded technology developers, Biomass Engineering Ltd. and B9 Energy, the latter (albeit a joint venture with SMP and Exergetics of Sweden) is based in Northern Ireland and so is Rural Generation, a third UK company in micro-CHP. Whether or not the two local companies influenced the NI-NFFO design, the inclusion of biomass-fuelled micro-CHP in the NI-NFFO is fortunate as it is an effective technology to reduce both greenhouse gas emissions and the dependency on imported fuels.

While the conversion technology is the central feature of the plant, it sits in a package of technologies and know-how that are required for setting up and running an operational biomass energy system. Of the four developers which have delivered the seven operational biomass plants, only Fibrowatt has actually been able to export their know-how. Fibrowatt is currently developing similar chicken-litter combustion plants in the US and The Netherlands. As far as we are aware, this represents the sole UK success of the development of 'export technologies' for biomass energy under the support of NFFO.

All in all it can be concluded that support for UK renewables industry has not been particularly effective as the majority of the technologies were imported. The targeting of more advanced or novel technologies was even a greater failure as the most advanced technologies have failed to materialise. This focus on novel technologies has come at the expense of support to more mature technologies which would have helped the biomass energy sector to grow and expand.

2.5. Objective 5: to make a contribution to rural development

In 2000, the government published a new Rural White Paper, in which it set out five national objectives for rural and countryside policy:

1. To facilitate the development of dynamic, competitive and sustainable economies in the countryside, tackling poverty in rural areas.
2. To maintain and stimulate communities and secure access to services which is equitable in all the circumstances, for those who live or work in the countryside.
3. To conserve and enhance rural landscapes and the diversity and abundance of wildlife (including the habitats on which it depends).
4. To increase opportunities for people to enjoy the countryside.
5. To promote government responsiveness to rural communities through better working together between central departments, local government and government agencies and better co-operation with non-government bodies.

Below we will discuss the possible relevance of biomass energy for each of these objectives.

2.5.1. Rural economy and rural poverty

This may be the main objective which may be furthered through the development of appropriate biomass energy projects. The variation in benefits to the rural economy depends to an important extent on the type fuel and the energy service provided.

The utilisation of waste biomass from forestry or agriculture will nearly always create some new jobs. It will also provide additional income to landowners, which in part is likely to be spent in the local economy. The net employment impacts of energy crops depends on the land use that is displaced. Of all the biomass sources currently exploited, the highest direct employment benefits probably arise from growing energy crops on set-aside land or in a mixed agro-forestry system, since this would not impede on the labour requirements of the land prior to its use for energy crops.

In terms of service provided, the most effective way in which biomass energy could contribute to the rural economy would probably lie in the use of biomass for local heating. The localised supply chain and possible value added activities (e.g. production of wood pellets for automated domestic heaters) would retain more money in the local economy. Also, since heating is small and beneficial to the nearest inhabitants, it would not raise much opposition[7] and could potentially improve the green image of the area to the benefit of tourism.[8] Unfortunately, such developments were not sponsored under NFFO.

The question also arises about the distributional impacts of the economic benefits. Agricultural and forestry wastes provide additional income to wheat farmers, chicken farmers and the (possibly absentee?) owners of larger woodlands. These people are already relatively well off. To assist the rural poor, more attention should be paid to the assistance of more marginal farm enterprises (small farms, hill farms) to engage in the production of biomass for energy.[9] Most

[7] Planning permission is not required for small on-farm renewable energy developments (ETSU, 1996).

[8] The large-scale electricity project at Newbridge actually failed to win planning permission in part because the local inhabitants feared negative impacts on tourism (Upreti, 2004).

[9] This will have obvious impacts on the geographical distribution of biomass energy developments. Currently, the about 80% of the plant capacity is based in East Anglia, which, not incidentally, has the most productive agricultural lands in the UK. But is East Anglia the most obvious priority area for rural development?

of the rural poor are not part of the farming community and they are most likely to benefit from the creation of low-skill jobs and the lowering of their heating bills. This points yet again in the direction of local heating as the most promising pathway. It may also suggest that there may be an important opportunity in the utilisation of currently non-productive woodland resources (e.g. existing farm woodlands), as thinning and maintenance of such small-scale woodlands is labour intensive and the opportunities for mechanisation (as with SRC) are limited.

Questions can furthermore be raised about the longer-term risks of encouraging SRC plantings on set-aside land. Set-aside land is typically the worst quality of arable land, and there is a risk that without the set-aside payments, farmers will convert SRC plantations back to food crops. SRC plantations have a productive life span of more than 15 years, while the set-aside arrangements are part of the EU's Common Agricultural Policy (CAP), which is due for major revision in 2006. The viability of the majority of the SRC plantations is thus not only dependent on the market for biomass energy (which can be directly created by government intervention) but also on EU-wide negotiations on agricultural reform, where support for such a minor sub-sector could be quite difficult to secure.

2.5.2. Equitable access to services

This objective runs to a great extent parallel to the first objective, since improving the rural economy and creating jobs for the rural poor will clearly help to maintain communities and improve equitable access to services. As mentioned above, the provision of local fuel for heating services may be a pathway to reduce fuel poverty in rural areas.

2.5.3. Conservation of landscape and biodiversity

Under certain circumstances, biomass energy can be beneficial for this objective. SRC has greater potential to encourage wildlife diversity than any other row crop currently grown by UK farmers (ETSU, 1996). When grown on set-aside land, the benefits of SRC are more questionable. Where SRC is grown on lowland wet grassland or unimproved grassland, biodiversity is likely to be reduced. But the impacts of SRC are not simply dependent on the previous land use, but also on the complex interactions with the various nearby habitats.

In most cases, the use of agricultural and forestry wastes is not likely to benefit biodiversity. Ploughing excess straw into the field, and leaving forestry wastes in situ will be beneficial to soil biodiversity. The overall biodiversity impacts of agro-forestry (McAdams et al., 1999), or of thinning and maintenance of small-scale woodlands which were previously unproductive, are likely to be low.

2.5.4. Enjoying the landscape

With regard to people's opportunity to enjoy the landscape (objective four), the impacts of biomass energy are almost invariably negative. Most people do not like to see mono-culture plantations, nor do they like to see woodlands being cut down. As is the case with most changes of the rural landscape, public views of biomass energy developments are complex. People's perceptions depend on their understanding of the issues and the associations they make are influenced by their values and previous experiences. Some may associate SRC with clean energy and a 'green' countryside, while others will associate it with a new and ugly blot on the 'traditional' landscape resulting from an industrial development (Upreti and van der Horst, 2004). Again, the impacts of biomass energy are likely to be biggest for SRC and other energy crops. The use of agricultural and forestry wastes will have little impact on the landscape. The production of biomass though the management of small-scale woodlands and agro-forestry will have some impacts, but is likely to be less controversial than SRC.

2.5.5. Joint-up government

This objective is mainly relevant to the ways in which various government departments and agencies collaborate with each other effectively. This is of little relevance to biomass energy, apart from the lack of joint-up thinking exposed in the implementation of biomass projects. Institutional barriers to renewables include the implementation of NETA and the occasional lack of clear or unequivocal endorsement of renewable energy developments by the Environment Agency.[10] Another such example is the 'missing link' between regional renewable energy targets on the one hand, and the regional targets for building new houses on the other, despite the government's explicit target of 10,000 MW CHP by 2010.

3. Conclusions

The above analysis demonstrates that the developments in biomass energy in the UK in the last decade have been disappointing, both in volume and in nature. NFFO did not support the most promising technologies, such as co-firing of biomass in existing coal-fired electricity plants, retro-fitting biomass burners in coal-fired heating systems (both for the objective to reduce GHG emissions), or new-built biomass heating systems (for the objective to increase fuel security). Most of the granted NFFO contract did not actually result in the delivery of operational plants.

[10] For example, in the case of AD of cow dung, the developer blamed the Environment Agency to have changed their minds at least twice regarding whether or not the plant produced 'waste' (Argus, 2002).

Support for the biomass energy sector can help to provide some benefits simultaneously, such as the emission reductions of CO_2 and other pollutants and a reduction of dependency on fuel imports. However, in the UK, this policy appears to have been held to ransom by the myopic pursuit of the 'traditional' objectives of MAFF and DTI to support farmers and export industries, respectively. The fact that the imported technologies invariably came from countries which have supported biomass energy for a long time, implies that a similar success may be possible in the UK *in the long run.* It is highly likely that a sizeable and thriving biomass energy sector will result in a boost for export technologies and for 'rural development'. However, these two policy objectives appear to dominate the design of NFFO. Whether or not they really are the main underlying motives for renewable energy policy, in NFFO they acted in the role of important preconditions for support to the emerging biomass sector rather than the role of longer-term co-benefits to be aimed at. Consequently, the design and implementation of UK biomass policy has resulted in a slow and stunted growth for the biomass sector over the last decade and has failed to deliver a convincing amount of benefits to the environment, the rural economy or the industrial sector.

The biomass energy plants which have actually reached production phase in the UK since 1990 concern 'established' technologies with low technological risk, utilising mainly the cheapest type of fuel; agricultural waste. With the exception of the occasional direct subsidy to the plant (as in the case of ARBRE), abandoned NFFO contracts do not drain the public purse. However, the 'seizing up' of the more experimental and potentially advanced developments favoured by the later NFFOs (pyrolysis, CCGT) has had a negative impact on the whole sector. The 'bad news' can put biomass energy pioneers out of business, persuade financiers to withdraw further financial support, discourage farmers to plant SRC and potentially block the assignment of biomass resources to more feasible projects.

From an effectiveness point of view, it would have been better to allow all technologies and fuels compete in all NFFO rounds. The results could have been beneficial to technologies such as co-firing and biomass heating and the sector would have almost certainly have been larger. The incentives in the last decade where apparently insufficient to effectively stimulate the development of more novel technologies such as gasification and fuel types such as SRC. It could be argued that such 'novelties' should be targeted separately through R&D, rather than being used to interfere with the implementation of more proven technologies in an embryonic sector. The designers of NFFO overlooked the simple fact that a sector has to grow before it can diversify.

The importance of NFFO as an instrument for learning by doing and inducing technological change should however not be overlooked. All stakeholders involved now know a lot more about renewable energy, its possibilities and limitations than they did in 1990. NFFO has exposed a range of barriers to renewables. Flagged up by the nascent renewables industry, some of these have subsequently been tackled by the authorities. For example, the specification of the plant site in NFFO contracts was eventually lifted to improve the chance of winning planning permission and the contract period for selling electricity at the NFFO price was extended from 8 to 15 years to increase the financial viability of projects.

Over the last 3 years, the UK government has launched a range of new initiatives and instruments to move towards a low-carbon economy. Some of these initiatives are consistent with the critique in this paper. For example, the RO which superseded the NFFO does support co-firing but demands that 75% of the biomass should come from energy crops by 2006. In response to complaints that this severely limits the short-term viability of co-firing, the government has subsequently committed to a statutory consultation on this requirement by 2003. The Energy White Paper (DTI, 2003) recognises that biomass energy may not be economically viable before the mid-2010s. The Energy White Paper still envisages an important role for biomass energy by 2020, along with on-shore and off-shore wind. That role is expected to lie in "local generation, in part from medium to small local/community power plant" (p. 18), and the role of CHP and heat are explicitly mentioned. Although the Energy White Paper is vague about both the scale of 'medium' plant and the potential role of biomass pyrolysis or gasification technologies,[11] and remains remarkably optimistic about the viability of energy crops, it clearly has taken account of many of the lessons learned over the last decade.

In recent years the UK government has invested much political capital in the development of a more sustainable energy future and a low-carbon economy. But will the range of new initiatives and incentives be enough to turn the current EU laggard in renewable energy into a "leader" in emission reductions (Tony Blair in DTI, 2003, p. 3) with a "strong, world-beating" renewables industry (Patricia Hewitt in DTI, 2000, p. 2)? Questions have been raised about the government's political will to really provide the financial support that is needed to achieve the renewables targets they have set. The

[11] The White Paper pays attention to various novel and experimental technologies but references to biomass pyrolysis or biomass gasification are noticeably absent. The glossary in the back even describes Integrated Gasification Combined Cycle (IGCC), as a technology which "can be designed to use a range of raw fuels, including coal, oil products and wastes" (DTI, 2003, p. 128); why are there no references to biomass or to the ARBRE plant?

government's recent interventions to rescue British Energy (the nuclear generator) can be easily contrasted with their hands-off attitude towards the bankruptcy of the 'flagship' ARBRE project (e.g. Guardian, 2003). A recent report by the Parliament's Select Committee on Science and Technology (2003), dominated by Labour's own PMs, criticised the government for its lack of serious commitment to combating climate change (FT, 2003; Renew, 2003). The Committee believes that there is no prospect of achieving the government's targets on renewable energy with the current policies and market conditions.

The Energy White Paper is certainly ambitious, and its vague wording suggests that some lessons have been learned from the backing of inappropriate technologies for biomass energy at least. But in the light of the government's overall poor performance in boosting renewables since 1990, the Committee's concerns sound uncomfortably familiar. It remains to be seen if the government is not attempting yet again to support a new set of novel technologies with assumed 'export potential' (mainly marine technologies this time) without providing the necessary long-term financial, institutional and regulatory support to make it work.

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