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A re-appraisal of wood-fired combustion

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Abstract

Targets for a considerable increase in electricity generation from renewables have been set in order to reduce greenhouse gas emissions and fossil fuel dependence. Extensive planting of willow, poplar and alder as energy crops has been planned for power generation plants which use wood as the fuel. The current trend is to use gasification or pyrolysis technology, but alternatively a case may be made for wood combustion, if wood becomes readily available. A range of wood-fired circulating fluidised bed combustion (CFBC) plants, using from 10 to 10,000 dry tonne equivalent (DTE)/day, was examined using the ECLIPSE process simulation package. Various factors, such as wood moisture content, harvest yield, afforestation level (AL) and discounted cash flow rate (DCF) were investigated to test their influence on the efficiency and the economics of the systems. Steam cycle conditions and wood moisture content were found to have the biggest effects on the system efficiencies; DCF and AL had the largest influences on the economics. Plants which could handle more than 500 dry tonnes/day could be economically viable; those using more than 1000 dry tonnes wood/day could be competitive with large-scale, conventional coal-fired plants, if sufficient wood were available.

Keywords: Wood Combustion; Biomass; Renewable Energy; Electricity Generation

1. Introduction

Pressure to reduce greenhouse gas emissions and to increase sustainable energy production have led to the promotion of renewable energy. The European Commission has set the targets of doubling the share of renewables in overall energy production from 6% in 1997 to 12% by 2010, and of renewable electricity from the current 14.5–23.5% in 2010 overall in the EU. The UK has the much more modest target of 10% of electricity from renewables by 2010, but the current level is less than 3%. In the UK renewable energy use grew by over 4% in 1998 and has more than doubled since 1990 (DTI, 1999). Renewable electricity accounted for 2.5% of UK electricity supplies in 1998 compared with 2% in 1997). The UK Department of Trade and Industry (DTI) published, in February 2000, a technology assessment in their "New and renewable energy: Conclusions in response to the public consultation". This assessment prioritised the potential of the various renewables in terms of their state of development and ability to assist in achieving the UK's targets in CO_2 emissions reduction and electricity generation from renewables. The DTI concluded that some biomass residues were near term i.e., technologies closest to being competitive in the UK or with immediate export potential, and that some biomass residues and energy crops were medium term i.e., additional technologies which could contribute by 2010 and would be needed to meet a 10% UK target, or with export potential. The biomass sector is clearly important to the UK's environmental and energy commitments in the coming decade. However, there are still many challenges to be faced in order to achieve commercial electricity generation from most of the biomass technologies. The UK government, in the Utilities Bill published in January 2000, will oblige electricity supply companies to buy a certain percentage of their power from renewable sources, so that 10% of electricity will come from renewables by 2010. As a result of these and other, measures, there would appear to be a renewed climate of interest in biomass.

Recent interest in wood gasification and pyrolysis for power generation has in turn spurred the development of energy crops. Short rotation forestry (SRF) plantations of fast-growing, high-yield clones of willow, poplar or alder are "springing up", but demand currently outstrips supply in the UK. Should coppiced wood be-

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come readily and cheaply available, it could prove useful to reconsider wood combustion for electricity generation instead of the less-proven gasification or pyrolysis.

Wood offers advantages over fossil fuels with regard to emissions. The sulphur content of wood is minimal, so SO_x emissions are negligible. Studies on coal in circulating fluidised bed combustion systems (CFBC) have shown that NO emission levels depend on temperature and excess air (Leckner et al., 1992; Åmand and Leckner, 1992; Wójtowicz et al., 1993), whereas with wood there is no temperature dependence (Leckner and Karlsson, 1993). There is little nitrogen in wood, so if combustion temperatures are controlled to avoid oxidation of nitrogen from the air, overall NO_x emissions will also be low. CO emissions from biomass have been found to be lower than those from coal in a CFBC plant using a cyclone (Leckner and Karlsson, 1993). Keeping excess air at a relatively low level of 15%, combined with the use of appropriate air staging, helps reduce NO emissions, and elevating the temperature downstream of the cyclone reduces CO and other hydrocarbon emissions when using wood chip (Lyngfelt and Leckner, 1999). Wood can also be grown sustainably, whereby the wood taken from a plantation and used in a combustion plant can be replaced over a short time-scale i.e., using SRF practices plantations are harvested typically on a three-year cycle. This implies that an equivalent amount of CO_2 to that produced in combustion will be taken up during the growth of the replacement wood, and that wood can be considered neutral with regard to CO_2 emissions. In fact, if wood-fired plants replace fossil fuel plants, a reduction in CO_2 emissions may be considered to occur, as well as a saving in the non-renewable fossil fuel resource. This may prove to be an important consideration in making wood combustion a technology of choice for complying with climate change legislation or for obtaining green tax credits.

Recently considerable interest has been shown in the gasification of wood and its use in integrated gasification combined cycle (IGCC) systems, which are inherently more efficient than the more straightforward combustion plants. There are, however, drawbacks. Wood gasification provides a gas with a low calorific value. The gas turbines may have to be adapted for the use of low calorific value gas by increasing the expander throughout. The combustor of the gas turbine may need to be considerably enlarged and its configuration altered. The gasifier would have to be large and, perhaps, pressurised for optimum efficiency. Capital costs for wood-fired IGCC systems would be high for these reasons, and may mean that the electricity produced would be no cheaper than that produced by the less efficient, combustion plants, which cost less to build. For these reasons it may prove rewarding to re-examine the case for using wood-fired combustion plants.

2. Method of assessment

The ECLIPSE package of process simulation programmes for the personal computer (Williams and McMullan, 1996) was used to make technical, environmental and economic assessments of these wood combustion systems. ECLIPSE is the techno-economic method of choice in the "clean coal technologies" programmes of the European Commission. For each system a separate mass and energy balance was made. A calculation of utilities (electricity, cooling water, etc.) used by conventional power generation equipment was made by ECLIPSE, and data specific to biomass technology were estimated (Bridgwater and Double, 1991) and inputted to complete the technical analysis. Environmental data on emissions were also obtained from these technical data. Next the capital costs were calculated either from the ECLIPSE databases or inputted where non-standard equipment was utilised (Solantausta et al., 1995). Finally fuel and other stream costs were added, and the economic analysis performed (including the break-even electricity selling price at zero net present value – here referred to as the cost of electricity (COE)).

In this paper various factors influencing the suitability of wood combustion for power production are examined. For example the possibility of achieving any economies of scale i.e., increasing efficiency through using larger power plants is investigated and compared with efficiency gains from altering the steam cycle conditions. Also, the level of afforestation required to achieve the desired wood input levels is analysed by looking at the annual yield of the trees used and the availability of feedstock as plant requirements increase. Transportation distance varies with plant size and the afforestation level, so the variation in feedstock costs with transportation distance must be addressed. The moisture content of the wood affects both the plant efficiency, due to the amount of energy needed to drive off the moisture and thus be unavailable for conversion, and the economics of the fuel cost, since higher moisture content means more water and less dry matter are being transported.

Certain quantitative values have been assumed as "typical" for a wood combustion plant experiencing a West European climate. The influence of using less conservative, but still realistic, quantities for the "assumed values" e.g., for the wood moisture content, afforestation levels, plantation yields, Discounted Cash Flow (DCF) rate and Contingency is assessed here.

3. Process description

A "typical" wood combustion power plant is assumed to operate as follows. Willow from a nearby coppice plantation is harvested, chipped and transported to the power station. It is stored in piles of chips in the open, in sufficient quantities for 5–14 days throughout. This wood, which is assumed to have a moisture content of approximately 100% (on a dry basis, equivalent to 50% on a wet basis), is taken from storage, screened and then transferred pneumatically to buffer storage ready for use in the circulating fluidised bed combustor.

Approximately 15% excess air is used in the combustor to ensure complete combustion. The conditions used in the simulation for the steam turbines are those of commercially available turbines for the anticipated power output. These steam conditions are generally determined by the type and size of boiler used (Lake, 1993). In only the two largest power stations, using 5000 and 10,000 dry tonnes of wood /day, was steam reheating included, together with multiple-stage feed-water preheating. In all of the other power stations a single low-pressure feed-water heater was assumed. The superheated steam inlet conditions at the high-pressure steam turbine for the different processes are shown in Table 1 in the summary of technical results.

4. Techno-economic simulations

Whilst power generation from wood is perceived to be neutral with respect to greenhouse gas emissions, this table gives the level of gaseous emissions which would be emitted from the power station stack. The capital cost estimates are study estimates, with an accuracy of ±30%. A summary of the economic data is given in Table 2.

5. Base load penalty and steam cycle conditions

The data in Tables 1 and 2 show quite clearly the effect of economy of scale and of steam cycle conditions on the technical and economic performance of a wood-fired power generation plant. The efficiency of the smaller power stations is adversely affected by the intrinsically lower efficiency of the steam cycle and by the high base load penalty.

The magnitude of the base load penalty can be demonstrated for the 10 DTE/day plant by using the same steam cycle as was selected for the 1000 DTE/day plant. When the steam conditions are changed from 23 bar and 350°C to 80 bar and 520°C, the efficiency of the 10 DTE/day plant increases from 17.5% to 23.4% compared with 25.4% for the 1000 DTE/day plant. Similarly, the efficiency of the 5000 DTE/day plant falls from 31.1% to 25.5% when its steam conditions are changed from 160 bar and 538°C to those of the 1000 DTE/day plant (80 bar, 520°C). There is no difference in efficiency between the 500 DTE/day plant and the 2000 DTE/day for the same steam conditions (80 bar, 520°C), or from 5000 DTE/day to 10,000 DTE/day with the same steam conditions (160 bar, 538°C). *It is clear that the steam cycle conditions, rather than the plant size, have the major influence on the overall efficiency of the power plant for all but the smallest sizes.* Electrical efficiency versus plant size is plotted in Fig. 1.

Likewise the capital costs of the smaller power stations are relatively much higher. It is not until the wood feed rate approaches 5000 DTE/day that the technical and economic performance figures come close to those for a conventional fossil fuel fired power station.

Table 1
Technical data for wood combustion plants

Plant size (DTE/day)	10	100	500	1000	2000	5000	10,000
Steam pressure (bar)	23	60	80	80	80	160	160
Steam temperature (C)	350	480	520	520	520	538	538
Heat input (MW, LHV)	2.0	20.1	100.5	201.1	402.1	1005.3	2010.6
Gross electrical output (MW)	0.43	5.3	28.1	56.2	112.3	338.6	676.5
Ancillary electrical consumption							
Receipt/storage/dryer/solids removal (MW)	0.04	0.2	0.5	0.8	1.4	3.3	5.9
Fans/compressors (MW)	0.03	0.3	1.3	2.6	5.2	11.3	22.5
Condensate pumps (MW)	0.0	0.0	0.4	0.8	1.6	7.5	15.2
Cooling water (MW)	0.01	0.1	0.4	0.8	1.6	3.7	7.4
Total ancillary (MW)	0.08	0.6	2.6	5.0	9.8	25.8	51.0
Overall results							
Net electrical output (MW)	0.35	4.7	25.5	51.2	102.5	312.8	625.5
Overall Efficiency (%)	17.5	23.1	25.4	25.4	25.5	31.1	31.1
Gaseous emissions							
CO_2 (g/kWh)	2190	1650	1500	1500	1490	1220	1220
SO_2 (g/kWh)	0	0	0	0	0	0	0
NO_x (g/kWh)	3.1	2.6	2.4	2.4	2.4	2.0	2.0

Table 2
Economic data for wood combustion plants[a]

Power station size (DTE/day)	10	100	500	1000	2000	5000	10,000
Wood reception/storage	0.3	1.4	4.7	7.6	18.5	35.1	57.1
CFBC and steam generator	0.8	3.7	13.3	22.9	42.3	106.8	224.2
Steam turbines	1.1	2.8	9.0	10.5	13.5	55.5	111.0
Condenser/condensate system	0.1	0.4	1.1	1.9	3.3	14.5	27.9
Utilities systems	0	0.2	0.6	1.3	2.4	5.4	10.7
Miscellaneous items	0	0.1	0.3	0.6	1.3	4.0	7.0
Total capital cost	2.3	8.6	29.0	44.8	81.3	221.3	437.9
Specific investment (£/kW)	6680	1850	1130	880	790	710	700

[a] Note: The cost unit is £M sterling except where stipulated otherwise.

6. Afforestation levels

Wood, especially wet wood, has too low an intrinsic value to justify transport over long distances. Therefore, in addition to the efficiency and cost, an important consideration is the availability of the wood feedstock. For simplicity it has been assumed that the power plant is located in the centre of a heavily wooded area. High afforestation levels would probably be only available around the smaller power plants, and would fall significantly for the larger plants. This would have a significant effect on catchment area, transportation distance and the transportation part of the fuel cost. Assuming a yield of 10 dry tonnes/ha/year for a power plant situated in the centre of the plantation, forest areas, forest radii, average transportation distances and transportation costs have been estimated for 100%, 20%, 10% and 5% afforestation (see Table 3).

The US DOE (1993) investigated the effect on land use and transportation of fuel of building a 150 MW biomass power plant (which would need about 2500 DTE/day of wood fuel). According to the DOE, one hundred "energy farms", each a plantation of one square mile and sited within a radius of 25 miles of the power plant, could fuel the plant sustainably, while covering only 5% (the AL) of the land area in this circular area.

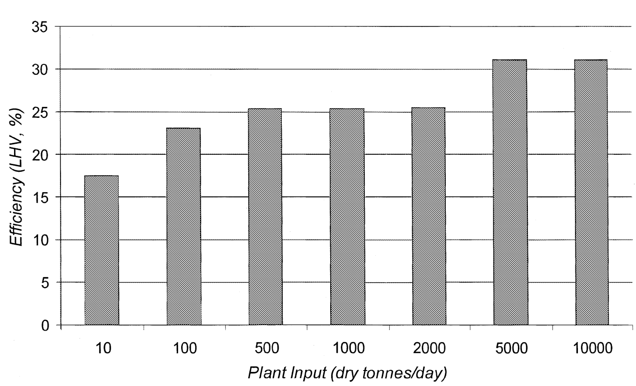

Fig. 1. Electricity efficiency vs plant size (wood input).

7. The effect of transportation on feedstock costs

Wood feedstock costs can be calculated for the average transportation distances required for the various plant sizes using a standard fixed cost for harvesting and chipping plus £0.31/tonne/km for transportation (McIlveen-Wright, 1995). These feedstock costs are then used with the other economic data to calculate the dependence of Cost of Electricity (COE) on transportation, as displayed in Table 3.

From Table 3 it can also be seen that the COE for the 1000 DTE/day 100% forestation case and the 10,000 DTE/day 20% forestation cases differ by less than 5%, and that comparing the 5% forestation case of the 10,000 DTE/day process with the 100% forestation case of the 500 DTE/day plant shows that the economies of scale achieved by building the larger power station have been cancelled out by the increased transportation cost for the wood fuel.

8. Availability of feedstock

For the 10 and 100 dry tonnes of wood per day processes feedstock should be relatively easy to obtain and transportation costs would be low.

For the 10,000 dry tonnes/day plant, 400,000 ha of forest would be required even at 100% afforestation. A single forest of this size gives the minimum feedstock cost, but it is unlikely that such a large forest, dedicated to energy crops for electricity generation, would be planted in Western Europe. With 20% afforestation, which would seem to be more realistic for Europe, an area two-thirds the size of Belgium would still be needed to supply the wood for one power plant of this size! At this level of afforestation (20%), the 1000 dry tonnes per day process is only marginally less attractive in terms of COE, so no economy of scale is achieved by building the 10,000 DTE/day plant rather than the 1000 DTE/day plant.

Table 3
Catchment areas, transportation distances, wood feedstock costs and COE

Plant input	1 DTE/day				10 DTE/day				100 DTE/day				500 DTE/day			
Afforestation (%)	100	20	10	5	100	20	10	5	100	20	10	5	100	20	10	5
Catchment area (10^3 ha)	0.04	0.2	0.4	0.7	0.4	1.8	3.7	7.3	3.7	18.3	36.5	73.0	18.3	91.3	182.5	365
Forest radius (km)	0.3	0.8	1.1	1.5	1.1	2.4	3.4	4.8	3.4	7.6	10.8	15.2	7.6	17.0	24.1	34.1
Average transport distance (km)	0.2	0.5	0.8	1.1	0.8	1.7	2.4	3.4	2.4	5.4	7.6	10.8	5.4	12.1	17.0	24.1
Transport cost (£/dry tonne)	0.07	0.17	0.24	0.34	0.24	0.53	0.74	1.05	0.74	1.67	2.34	3.35	1.67	3.75	5.27	7.47
Total feedstock cost (£/dry tonne)	19.9	20.0	20.0	20.1	20.0	20.3	20.5	20.9	20.5	21.5	22.1	23.2	21.5	23.6	25.1	27.3
COE (p/kWh)	N/A	N/A	N/A	N/A	21.70	21.73	21.76	21.80	7.20	7.29	7.35	7.45	5.06	5.23	5.35	5.53
	1000 DTE/day				2000 DTE/day				5000 DTE/day				10,000 DTE/day			
	100	20	10	5	100	20	10	5	100	20	10	5	100	20	10	5
Catchment area (10^3 ha)	36.5	182.5	365	730	73	365	730	1460	182.5	912.5	1825	3650	365	1825	3650	7300
Forest radius (km)	10.8	24.1	34.1	48.2	15.2	34.1	48.2	68.2	24.1	53.9	76.2	107.8	34.1	76.2	107.8	152.4
Average transport distance (km)	7.6	17.0	24.1	34.1	10.8	24.1	34.1	48.2	17.0	38.1	53.9	76.2	24.1	53.9	76.2	107.8
Transport cost (£/dry tonne)	2.34	5.27	7.47	10.6	3.35	7.47	10.57	14.94	5.27	11.81	16.71	22.90	7.5	16.7	22.9	34.7
Total feed-stock cost (£/dry tonne)	22.1	25.1	27.3	30.4	23.2	27.3	30.4	34.7	25.1	31.6	36.5	42.7	27.3	36.5	2.7	54.5
COE (p/kWh)	4.35	4.60	4.78	5.04	4.20	4.54	4.79	5.15	3.74	4.17	4.50	4.92	3.86	4.48	4.90	5.69

9. Moisture content

A series of simulations were made for a 500 DTE/day wood combustion plant, with wood of a different moisture content being used on each occasion. The amount of heat transferred from the combustion of the wood to the steam cycle depends on the moisture content of the wood feedstock, as energy must be used to drive off the moisture in the drying and heating stage of combustion and raise it to the outlet temperature of the combustor. Radiant energy from the flames during combustion is transferred to boiler tubes lining the combustor walls and is used to vaporise water coming from the steam drum. The volume of wood increases with moisture content, requiring larger, more expensive equipment and also increasing transportation costs. The moisture content of the wood feedstock has a significant effect. The higher the moisture content, the lower the efficiency of the combustion process (see Fig. 2). In Fig. 3 it can be seen that the COE falls with decreasing moisture content, and that COE could be reduced by up to 20% by using wood feedstock of 15% MC_D instead of 100% MC_D.

The 10 DTE/day and 100 DTE/day direct wood combustion processes used to generate electricity are not attractive as can be seen from their COE values in Table 3.

In Fig. 4. COE values, chosen at the most appropriate forestation level for each plant size, are shown as option "A". The 10 DTE/day value is not shown, as it is so high. (For the 100 and 500 DTE/day plant size the COEs for the 100% afforestation level are shown; for the 1000 and 2000 DTE/day plant the 20% afforestation COE values; and for the 5000 and 10,000 DTE/day plant the 5% afforestation COEs are taken).

This curve for Option A has a broad minimum, extending from around 1000 to 3000 DTE/day, with the COE falling below 4.6 p/kWh in this range.

The direct wood combustion systems, which would use 500, 1000 and 2000 DTE/day, would have reasonable performance and costs. This is probably the most appropriate range of plant sizes, which could be justified, both by the economics and the feedstock

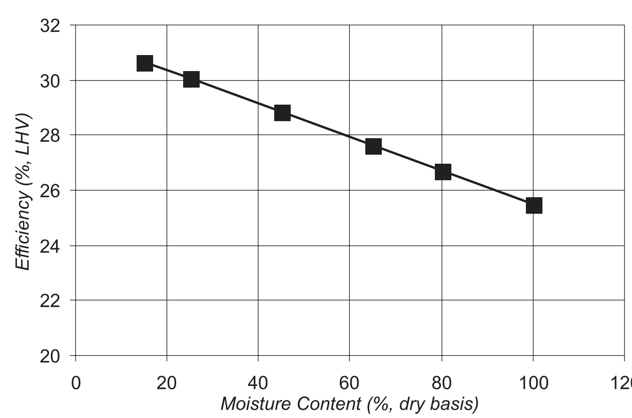

Fig. 2. Electrical efficiency vs moisture content for 500 DTE/day plant.

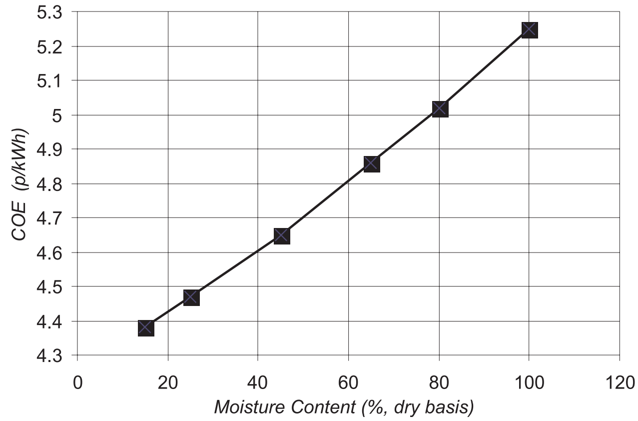

Fig. 3. Cost of electricity vs moisture content for the 500 DTE/day plant.

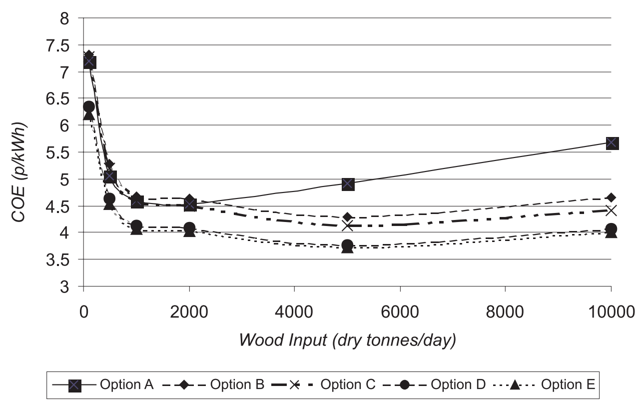

Fig. 4. COE vs plant size. The effect of changes to "assumed values". Wood MC_D is 100%.

availability, for power generation by wood combustion in Europe.

10. The effect of the "assumed values"

Until this point certain assumptions have been used in making the assessments of the various wood-fired electricity generation systems. The first assumption is that an "appropriate" level of afforestation was used for different plant sizes i.e., for plants using large amounts of wood it is unlikely that one plantation in an area could support them, whereas a single forest could support a smaller plant. These assumed afforestation levels are 100% afforestation for the 100 and 500 DTE/day plants, 20% afforestation for the 1000 and 2000 DTE/day plants and 5% for the 5000 and 10,000 DTE/day plants. Secondly, the yields from the SRF coppice plantations were taken to be 10 dry tonnes/ha/year. In addition, the Discounted Cash Flow Rate and the Contingency were each assumed to be 10% in the comparisons. Lastly, the moisture content of the wood was taken to be 100% (on a dry basis). In this section the effect of changing these assumed values to other, perhaps equally valid, values was investigated. The cumulative effect of changing these assumed values is shown as a series of Options in Fig. 4.

10.1. Varying the afforestation levels

From time to time incentives are introduced to take land out of food production and either leave it fallow or put it to use for non-food agriculture. In the recent past set-aside schemes were put in place and initially affected about 15% of the agricultural land area in Europe. Energy crops qualified for use on non-rotational set-aside land.

It may be more appropriate to assume that the incentives to plant SRF coppice on non-rotational set-aside land could influence the amount of new plantation of energy crops. For set-aside at 18%, and assuming that about 10% of the plantation area would be required for "rides" used by harvesting and planting machinery, then an afforestation level of 15% for all plant sizes may be valid. For the smaller systems, afforestation decreasing from 100% to 15% increases the transportation costs, whereas the reverse is true for the larger systems, where afforestation rises from 5% to 15%. This can be seen in Option "B" in Fig. 4, with the COE values falling (when compared to Option A) for the larger systems and increasing for the smaller.

10.2. Varying the yield

A yield of 15 dry tonnes/ha/year replaces the value of 10, which may be considered conservative, since yields of 12–20 dry tonnes/ha/year have been widely reported. This would lead to smaller forests and lower transportation costs. These changes are shown as Option "C" in Fig. 4. However, the fall in COE due to this (large) change in yield is relatively small.

10.3. Varying the discounted cash flow rate

A DCF of 7.5%, rather than 10%, may be more appropriate. Option "D" shows the use of DCF equal to 7.5%. A significant improvement over Option "C" can be observed. (An even lower DCF value could be proposed for times when inflation has dropped.)

10.4. Varying the contingency

The Contingency was changed from 10% to 5%. This is shown as Option "E" in Fig. 4. There is very little change from the values in Option "D".

The changes that have been made so far only affect the economic side of the systems and their simulations.

The next possibility is to change the moisture content, which, as was shown earlier, affects the efficiency of the system, as well as the economics.

10.5. Varying the moisture content

Moisture Contents as low as 25% can be found, even in the United Kingdom, when the wood is stored as rods in the open air before chipping. However, it is more likely that a higher value would be obtained on most occasions. For this reason an intermediate value of 55% (dry basis) is taken as an alternative value.

In Fig. 5, the curve of the "Initial Values" is the same COE distribution as Option "A" in Fig. 4 i.e., with all the original "assumed values", and Option "A" shows it for the new moisture content value of 55%. A significant change is apparent on reducing the moisture content of the wood fuel.

The sequence of economic changes which had been made for the plants using 100% Moisture Content feedstock were repeated for the lower MC systems. In Fig. 5, Option "B" refers to the change to 15% afforestation levels; Option "C" to the change in Yield to 15 dry tonnes/ha/year; Option "D" to the change in Discounted Cash Flow rate to 7.5%; Option "E" to the change in Contingency from 10% to 5%. The effects of these economic changes are similar to those seen previously with the systems using 100% MC wood.

The minimum in the curve of "Initial Values" is narrower than that of the system "E" curve, and occurs at lower plant sizes. Comparing Options "Initial Values" and "E" it can also be seen that, with the "new" versions of the assumed values (i.e., in system "E"), Wood Combustion can be considered viable for all power plant sizes above 500 dry tonnes/day. In fact, above 1000 dry tonnes/day these systems are almost competitive with coal fossil fuel-fired plants of much larger scale, on a comparison of COEs. COE fell by 18.5% for the 100 dry tonnes/day plant and 39.7% for the 10,000 dry tonnes/day plant when the "assumed values" are changed from their "initial values" to the final values in Option "E".

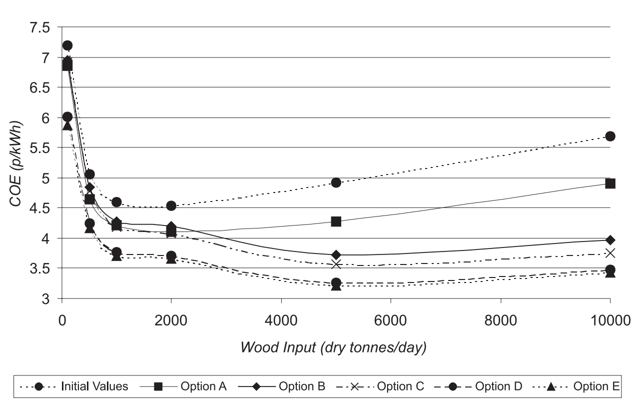

Fig. 5. COE vs plant size. The effect of changes to "assumed values". Wood MC_D is 55%.

11. The use of a drying stage

The simulations were also made for similar systems, which also used some low-pressure steam to dry the wood to 15% MC_D prior to combustion (McIlveen-Wright, 1995). For reasons of brevity they are not presented here. It can be shown that, except for the smallest one, all plants having a drying stage are more efficient than those without one, and that the efficiency gained increases with plant size. However, the specific investment is lower for a plant not having a drying stage. For plant sizes up to 500 DTE/day, the COE is lower for plants without the drying stage. As plant size increases, the efficiency gain tends to compensate for the capital expenditure on the drying stage, and the difference in COE for the wet and dried wood plant becomes insignificant and falls within the margin of error of the economic analysis. Therefore there are no economic advantages to using a drying stage, but their use could be appropriate where higher efficiency, and thus lower CO_2 emissions, have higher priority than low electricity price.

12. Conclusions

In conclusion, wood combustion plants offer such promising features as low or zero emissions; low capital costs (but low efficiencies too) since cheap conventional technology is used. In this assessment, no major innovations or developments have been assumed. Wood-fired systems with the "Initial" Assumed Values Options using between 1000 and 3000 DTE/day have Break-Even Selling Prices (COEs) low enough to make them commercially interesting. In fact, all systems using more than 100 DTE/day have lower COEs than the NFFO-3 (Non-Fossil Fuel Obligation, December 1994) average tariff of 8.65 p/kWh for electricity from coppiced wood, i.e., they could be used to sell electricity to the RECs in England and Wales and make a profit. Systems with the "Final" Assumed Values and using more than 1000 DTE/day have COEs low enough to make them nearly competitive with large-scale, conventional, coal-fired plants (3.8 p/kWh compared with 3.0 p/kWh), but these are still almost double the COEs from new, large-scale natural gas-fired combined cycle power stations (around 2 p/kWh). However, the recent UK Renewable Obligation will oblige electricity supply companies to obtain 5% of their electricity supply by 2005 from renewables, with a price cap of 4.3 p/kWh. Such wood combustion systems (systems with the "Final" Assumed Values and using more than 1000 DTE/day) could provide electricity for less than this cap price.

There are many factors that would affect the viability of any wood-fired power generation system. The influence of the wood moisture content, plantation yield, afforestation level, DCF and Contingency were examined here. It is clear that wood combustion plants could be commercially competitive at some sizes with optimistic, but realistic, values of these factors. Less favourable values, however, would decrease the range of viable plant sizes and their profitability.

Combustion systems may have been disregarded in the rush to find more efficient technology for power generation with wood as the fuel. The recent interest in wood-fired power generation has promoted the planting of coppice, and should increase the availability of wood fuel. Should low-cost, wood supplies from sustainably-managed forests become abundant, there may be a case for reconsidering wood combustion.

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