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THE ECONOMICS OF BIOMASS IN IRELAND

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1. Introduction

This paper is one of a series of studies undertaken as part of an ALTENER financed research programme into the economics of biomass in Ireland. The empirical data on likely costs and benefits are drawn from the work of the other participants in the project: research by TEAGASC identified the likely farm gate cost of biomass; Hyperion examined the cost of transport and the possible availability of other sources of biomass; ESBI researched the evidence on the cost of generation using biomass.

This paper examines the economic costs and benefits to society of growing wood biomass for use in electricity generation in Ireland. The analysis concentrates on the issues which will determine the long-term viability of this form of enterprise. If market prices for inputs and outputs reflected the true economic costs of wood biomass and of the production and consumption of other forms of energy it would not be necessary to undertake such a study; market prices would reflect the costs and benefits to society and the volume of biomass grown (if any) would be determined optimally by market forces. However, there are a range of factors which result in prices deviating quite far from their true economic and social cost. Chief among these is the environmental externality associated with combustion of fossil fuels.

The potential costs of global warming are not reflected in the price paid for fossil fuels and, as a result, there is an undue incentive to use them to provide energy. A second possible argument why the full costs and benefits of wood biomass may not be reflected in market prices for inputs and outputs is a concern with security of supply of energy within Ireland. It may be worth paying a premium price for energy to ensure that sources are diversified with a significant proportion of domestic consumption being met from domestic supplies of primary energy. If current prices do not reflect the likely path of energy prices in the future then low energy prices to-day may result in a sub-optimal amount of research and development into alternative energy sources. Finally, there are a range of other factors which result in market prices deviating from the true economic and social costs of outputs and inputs; chief among these is the distortionary effect of the CAP on agricultural production and, as a result, on the price of land for biomass.

In carrying out a study of the economics of biomass it is important to take account of the fact that the socially optimal level of biomass production may be different when viewed from the point of view of the Irish government (and Irish society) than when viewed from the point of view of the EU. If the biomass project were to be introduced only within Ireland then it could be safely assumed that it would not change the market prices for the output of the agricultural sector, for wood products and for energy. This is due to the very small size of Irish supply and demand for most relevant products in the context of an EU (or a world) market. The Irish government could then aim to maximise Irish welfare conditional on a given external environment. For example, the costs imposed on EU taxpayers by the inefficiencies of the CAP would not be relevant to such a study.

However, if the study of the economics of biomass is viewed from the point of view of the EU then the effects of major changes in supply and demand for agricultural and wood products on their prices will be significant. In addition, the dead-weight losses of the CAP would be relevant to any calculus of welfare changes arising from increased production of biomass.

Because of its importance as a backdrop for the analysis in the rest of the paper, the outlook for the energy sector is discussed in section 2. Section 3 considers the ways in which relevant market prices may deviate from the true economic or social costs. Section 4 sets out a theoretical framework to consider the economics of biomass. Section 5 builds on the research by other participants in the project to examine the economics of biomass in Ireland. Finally, Section 6 draws conclusions from this analysis.

2. The Outlook for the Energy Sector

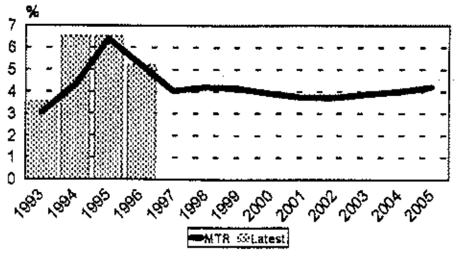
In discussing the future outlook of the energy sector in Ireland it is necessary to make some forecasts of the likely evolution of energy demand over the remainder of this decade. The most significant determinant of energy demand is likely to be the level of economic growth. As shown in Figure 1 simulations from the Medium Term Review suggest that the economy is likely to grow on average by over 4% a year in the second half of the 1990's. The responsiveness of energy demand to this level of economic growth depends on the GDP elasticity for aggregate energy. A study by Conniffe and Scott (1990) estimates a value of 0.5 for the GDP elasticity for energy demand in Ireland, suggesting that a one percentage increase in demand for GDP results in a 0.5% increase in the demand for energy. Aggregate energy is made up of the fuels: electricity, gas, coal, renewables, oil and peat. Of these fuels electricity was found to be the most responsive with an elasticity of 0.9. These results are supported by the historical data (see Table 1).

Table 1: Average annual growth rates, 1984-1993

GDP	4%
Aggregate Energy	2.5%
Electricity	3.8%

Figure 1

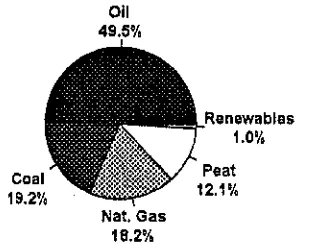
GDP at Constant Market Prices



Source: Medium Term Review

Figure 2

Shares of Total Primary Energy, 1992



Source: Dept. of Energy

The current distribution of primary energy consumption by fuel in Ireland is shown in Figure 2. The structure of Ireland's energy mix is heavily dominated by oil, with natural gas and coal each representing almost one - fifth of the fuel used. Most of the rest is accounted for by peat. This structure is broadly similar to the rest of the EC with one main exception. Whereas Ireland depends on peat for over 12% of all its primary energy requirements, the bulk of which is used as a fuel in the generation of electricity, in the rest of the EU nuclear power plays the same role. Electricity generation using peat emits the highest content of carbon per unit of energy (see Table 2). As a result Ireland's emission of CO_2 per capita is currently above the EU average (see Fitz Gerald and McCoy, 1992).

Table 2: Tonnes of CO2 per Tonne of Oil Equivalent

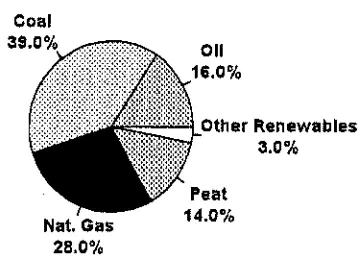
Peat	4.34
Coal	3.7
Oil	3.01
Gas	2.07

Source: Fitz Gerald and McCoy, 1992

This difference has special significance when considering the future of the electricity sector in Ireland. Under the environmental sustainability provision the Irish government is currently committed to limiting the growth in CO_2 emissions to 20% above 1990 levels by the year 2000. Based on a GDP elasticity of 0.9 for electricity demand then an expected growth scenario as described above would result in the demand for electricity increasing by around 20% over the remainder of the decade. Such a forecast of relatively rapid growth will result in the need for significant additional generating capacity. At present the ESB has 4500MW of generating capacity supplying a peak load of 3000MW. If we assume that peak load on the system will remain at its present ratio of two-thirds of installed capacity then a growth scenario as described above would require the installation of approximately 850-950 MW of additional capacity over the remainder of this decade. Such a scenario could cause substantial increases in CO_2 emissions in this sector, depending on the fuel type used.

Figure 3

Contribution of Fuels to Electricity Production



Source: Dept. of Energy, 1992

The current distribution of fuels used in electricity generation is shown in Figure 3.

Generation is mainly from coal (39%), with natural gas (28%), oil (16%), peat (14%) and renewables (3%) providing the remainder. This situation is radically different to 1980 when the bulk of the electricity generation was dependent on oil. This change has involved a major shift towards the use of indigenous natural gas and the use of imported coal. Security of supply has traditionally been involved with the need to diversify energy supplies away from the dependence on a small number of suppliers and with the promotion of use of primary energy sourced domestically. Measured in terms of these objectives, this policy has been successful over the last decade. However the situation is likely to change over the next decade as the supply of gas from the Marathon field is exhausted.

The installation of the new pipe line to Scotland will allow gas to maintain its share in the generation of electricity. However any significant increase in the use of gas may be insecure due to the dependence on a single pipeline. This raises the important question of how an additional 850-950 MW of generation capacity will be met. The absence of interconnection of the electricity system with other European networks means that the possibility of sourcing electricity from neighbouring systems does not exist. Coal which has the second highest content of carbon content per unit of energy (see Table 2) already accounts for almost two-fifths of fuel used. The use of peat in electricity generation is not only expensive but, as discussed above, it emits a disproportionately high level of CO_2. An alternative solution is to increase the use of renewable sources.

This paper examines the feasibility of growing wood biomass for use in electricity generation in Ireland. The main attraction of biomass is that it is essentially carbon dioxide neutral. While CO_2 is released on combustion, it is reabsorbed during the production process. Thus biomass appears to be an attractive option in meeting EU protocols on CO_2 emissions and is consistent with the government's policy objective of reducing dependence on imported fuel.

In examining the economics of biomass the range of costs which will be important include the cost of biomass itself, the price of competing fuels and the prices of inputs used in the production of wood biomass. Turning first to the price of competing fuels: the 1995 IEA World Energy outlook suggests that the price of oil (measured in constant 1993 prices) is expected to rise from about \$17 per barrel this year to \$28 by 2005. The prices of gas and coal in Europe are expected to follow this trend. This is an important background when making long term investment decisions concerning biomass. In the case of the inputs used in the production of biomass it would be wise to consider how potential changes in the CAP could affect the economics of biomass production in the future.

3. Market prices and Externalities

This Section considers the reasons why market prices may differ from the true economic cost to society of outputs and inputs. In examining the economics of biomass the range of prices which will be important covers the price of biomass itself, the prices of competing products, especially those of agricultural output and other forms of energy, and the prices of the inputs which are used in the production of wood biomass. The prices of the inputs used in the production of biomass are affected to a significant extent by the operation of the EU CAP.

The output price of biomass and that of other alternative forms of primary energy differ from their true cost to society because of their differing environmental impacts. The implications of environmental externalities for the economics of wood biomass are discussed first. We then turn to the possible distortion in the price of the inputs used in biomass production. The price of labour could overestimate the full cost to society of increased employment in the sector because of the current high level of unemployment. The rent payable for land used in growing biomass is affected by the distortions inherent in the EU CAP. Finally the price of other inputs may not reflect the full costs to society; in particular, the price paid for fertiliser does not take account of the adverse environmental impact of fertiliser use on water courses.

Environmental Externalities

The interest in biomass arises from a concern that traditional fossil fuel forms of energy may be causing permanent environmental damage through raising the concentration of carbon dioxide in the atmosphere. The price paid for existing fossil fuels does not take account of this potential environmental damage. Biomass, on the other hand, by absorbing carbon from the atmosphere, helps reduce the global warming problem. Even when burnt to provide energy the net impact of biomass production and consumption on global warming should be close to zero[1]. In comparing the economics of biomass with that of other forms of energy production this environmental externality should, ideally, be taken into account.

However, the scientific evidence on the damage which such emissions cause is not very strong giving rise to considerable uncertainty. Even if there were certainty about the process of global warming it would still be no simple task to quantify the potential cost to society arising from the pollution. (Nordhaus, 1991, has attempted such an exercise for the US.) This makes it difficult to choose the optimal level of pollution or abatement.

In this study we take a different approach and we concentrate on the cost of reducing carbon emissions through greater use of biomass. If a schedule of the marginal cost of abatement is known for biomass then this can be compared to a schedule of the marginal cost of other methods of reducing emissions, such as the introduction of a carbon tax. Once the marginal cost schedules are known for biomass and other forms of abatement, then policy makers can choose the mix of policy instruments which achieves a given level of abatement at minimum cost; that is the cost of a marginal change in pollution as a result of the use of each of the instruments would be equal.[2]

Rent

The CAP, as currently constituted, involves large subsidies to farmers in the EU, paid for by EU citizens through taxes and by EU consumers through higher food prices; farmers' incomes are raised by creating a market environment where prices are above the world market clearing level. Economic theory indicates that where subsidies are paid to (or taxes imposed on) the production process and one factor of production is fixed, all the incidence of the subsidy (or tax) will fall on the fixed factor. In this case land is ultimately a fixed factor and the substantial supplement to farm incomes which the CAP provides[3] means that the returns from owning agricultural land are much greater than they would be in a free market environment. While the situation is complicated by the changes in the CAP over the last decade which restrict output by individual farmers and from individual farms, the high level of income support is reflected in the rental value of agricultural land. It is only if the CAP were abolished, or if it moved

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1 The carbon released in burning biomass should be balanced by the carbon sequestered by its growth.

2 If the cost of global warming were known then abatement procedures should be adopted up to the point where their marginal cost equals the marginal cost of global warming (Scott, 1992).

3 Currently over 50% of Irish farmers' incomes comes as a straight transfer from the EU under the CAP.

to complete separation of income support from production, that rent of agricultural land would approach an undistorted "market clearing" price.

From the point of view of the EU, considering EU welfare, the true rental value of land (cost to society) is much lower than the current market value as each hectare used to produce biomass may have little effect on EU net output of agricultural produce.[4] Thus the true price of land which correctly reflects its effects on EU welfare (and cost in terms of output foregone in alternative uses) may differ considerably from the current market price. Where the concern is EU welfare this should be taken into account in considering the economics of biomass.

When considering Irish welfare, where the dead-weight loss inherent in the operation of the CAP is paid for by citizens of other EU states, the choices open to an Irish government are constrained by the operation of the CAP. The government's objective is to maximise Irish welfare, conditional on the CAP. In such a case the high rent payable for agricultural land reflects the benefits to farmers and the nation as a whole from the high CAP prices. If land were priced at below its current market value then there would be a real danger that resources would be shifted from agricultural production to biomass production in such a way that the loss in revenue (both from sales and from transfers) under the CAP would be greater than the gains from production of biomass. The fact that the welfare of the EU might be enhanced would not compensate for the loss of welfare of Irish citizens.

While the Irish government may not be concerned with the costs to the EU of the CAP, the prospect that it will change in the future suggests that the appropriate rental value of land to use in considering the economics of biomass may well be lower than the current market price. It seems likely that some time in the next decade the expansion of the EU will necessitate a radical transformation of the agricultural sector moving the sector towards a situation where it is more open to world trade (Kearney *et al.*, 1995). In making long-term investment decisions concerning biomass it would be most unwise to rely on the CAP remaining intact for the foreseeable future.

Thus the inefficiency inherent in the CAP means that the appropriate rental value of land to use in calculating the costs and benefits to society from growing biomass is lower than the current market price. If the welfare to be considered is that of the EU, rather than merely Irish welfare, the difference may be very considerable. This means that in calculating the true economic costs of producing biomass the supply curve for policy makers in Ireland may lie above that for the EU as the Irish people do not have to pay all the costs of the inefficiency inherent in the CAP.

While recent changes in the CAP have artificially reduced the value of certain land used for set aside purposes, it would be inappropriate to assume a zero rental value for this land in considering the supply curve for biomass as it seems improbable that this regime will persist indefinitely.

The Cost of Labour

In the case of the price of labour the major possibility for a divergence between the market and the social price arises from the existence of a high level of unemployment. Potentially the pool of unemployed labour represents a wasted resource. However, in

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[4] It may even reduce the subsidy paid to farmers. See Callaway and McCarl, 1994, for details of how biomass production in the US could reduce the fiscal burden of agricultural policies.

developing a methodology for examining the costs and benefits of industrial projects in Ireland, Honohan, *et al.*, 1995, indicate that the shadow price of labour is probably not far from the market price. Even though unemployment is high, the flexibility of labour supply in Ireland means that to-day the direct impact of additional employment on the numbers unemployed is likely to be low. Both migration and labour force participation decisions by women and students are sensitive to labour market conditions.[5]

It is well known that self-employed labour in the agricultural sector shows little mobility out of (or into) the sector. In the short to medium term it is a quasi-fixed factor, though in the very long-term it could be expected to change through a reduction in entry into farming (see Boyle, 1992b for a model of the Irish agricultural sector which treats self-employed labour as one of a number of quasi-fixed factors). As a result, it may be expected that self-employed labour in the sector is under-utilised. Because some of the labour already employed in agriculture is underemployed there is the possibility that the increase in employment in biomass production could be achieved through increased utilisation of the labour supply already in agriculture. However, this gain would be fully reflected in the income of self-employed labour. This suggests that use of the market price for labour is generally appropriate for projects such as growing biomass.

A possible benefit from biomass production, which would not be captured by normal market prices, is that the employment would be spread throughout rural areas where the possibility of increasing employment through other channels is very limited. The Irish government currently spends significant sums of money on the regional policy objective of promoting employment outside the major urban areas. In the case of the production of peat for electricity generation a major factor underlying the implicit subsidy paid for peat (Nic Giolla Choille, 1993) is the desire to protect existing employment opportunities in the relevant rural areas.[6] If biomass could provide replacement employment locally equal to that generated by peat production and if this employment required a subsidy less than or equal to that payable for peat, the superior environmental benefits of biomass over peat for electricity generation would ensure a welfare gain.

The Cost of Other Inputs

The price of fertiliser used by the agricultural (and the biomass) sector does not adequately reflect the environmental externalities associated with its use, especially its negative impact on water courses. If a switch to biomass from agricultural production were to reduce the volume of fertilisers employed this would obviously be beneficial. The most appropriate way of dealing with this problem would be to calculate the supply curve for agricultural output and biomass assuming a fertiliser price which takes account of the environmental externalities. However, information on the measurement of this externality which would allow such an approach is lacking.

At the level of the Irish economy it is unlikely that changes in the share of land devoted to agriculture and biomass would have any effect on fertiliser prices. However, at the level of the EU a major change in pattern of production could have an effect on input prices. When considering the welfare impact of biomass within an EU context

[5] In the long term demographic change may result in a change in the structure of the labour market. This must be borne in mind when assessing the benefits of increased employment in the next decade.

[6] The other justification given for this policy is the desire to promote energy self-sufficiency through exploiting domestic sources of primary energy.

appropriate allowance should be made for this factor though it is likely to play a much smaller role than the effect of the CAP directly on rent.

Finally, the cost of transporting biomass to the location where its is consumed involves the intensive use of the rural transport infrastructure. While this infrastructure is not charged for by local authorities, intensive use will increase the cost of maintenance and this cost should be taken into account in any measurement of costs and benefits.

4. Theoretical Framework

This Section establishes a model of the supply and demand for biomass from which we can obtain the cost of reducing carbon emissions. In each case we want to take account of factors which may cause market prices to deviate from their true price or cost to society, the one exception being environmental externalities due to global warming which are, as indicated above, handled separately. We first consider the factors affecting the supply of biomass, including the market for agricultural output and the markets for inputs; we then examine the demand for biomass and the interaction between the two will determine the market clearing price and the marginal cost of achieving different levels of abatement of carbon emissions.

Supply of Biomass

We assume that producers in the agricultural sector (a) and the biomass sector (b) are profit maximisers in the long run and that their behaviour can be modelled by a profit function.[7] It is also assumed that they produce 2 homogeneous goods, agricultural output and biomass (including timber), and the 4 inputs used in producing agricultural output and biomass are homogeneous and mobile between sectors; there is no sector specific factor of production. We later relax the homogeneity assumption in respect of land.

$$\Pi_a = f_1(p_a, p_l, p_r, p_k, p_m, t) \qquad (1)$$

$$\frac{\delta\Pi_a}{\delta p_a} = Q_a,\ \frac{\delta\Pi_a}{\delta p_l} = L_a,\ \frac{\delta\Pi_a}{\delta p_r} = R_a,\ \frac{\delta\Pi_a}{\delta p_k} = K_a,\ \frac{\delta\Pi_a}{\delta p_m} = M_a \qquad (2)$$

$$\Pi_b = f_2(p_b, p_l, p_r, p_k, p_m, t) \qquad (3)$$

$$\frac{\delta\Pi_b}{\delta p_b} = Q_b,\ \frac{\delta\Pi_b}{\delta p_l} = L_b,\ \frac{\delta\Pi_b}{\delta p_r} = R_b,\ \frac{\delta\Pi_b}{\delta p_k} = K_b,\ \frac{\delta\Pi_b}{\delta p_m} = M_b \qquad (4)$$

Q_a = Agricultural output,	Q_b = Biomass output,	P_a = Price of agricultural output,
P_b = Price of biomass,	P_a = Profit in agriculture,	P_b = Profit in biomass,
p_l = Price of labour,	p_r = Price of land,	p_k = Price of capital,
p_m = Price of materials,	L = Labour,	R = Land,
K = Capital,	M = Materials	

By differentiating the profit functions for the two sectors with respect to the price of output and the price of the inputs we can obtain the output and input demand equations for the two sectors (equations 2 and 4) as a function of the input and output prices (Hotelling's Lemma, Diewert, 1974). Technical progress is proxied by time (t). The subscripts a and b applied to the different input volumes (L, R, K, and M) indicate the inputs used in each sector (there are no sector specific factors of production).

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[7] Assuming constant returns to scale and that the profit functions are homogeneous of degree one in prices.

$$R_a + R_b = R \tag{5}$$

$$R_a = f_3(p_a,\ p_l,\ p_r,\ p_k,\ p_m) \tag{6}$$

$$R_b = f_4(p_b,\ p_l,\ p_r,\ p_k,\ p_m) \tag{7}$$

$$p_r = f_5(p_a,\ p_b,\ p_l,\ p_k,\ p_m,\ R) \tag{8}$$

The factor land (R) is in fixed supply within Ireland. Thus the demand for land from the two sectors, agriculture and biomass, will always equal the supply of land (5). The demand for land by the agricultural and the biomass sectors, derived by differentiating equations 1 and 3 respectively, is given explicitly in equations 6 and 7. Substituting equations 6 and 7 into equation 5, the price of land (rent) can be obtained as a function of the output prices of the two sectors, the input prices of the other factors (labour, capital and materials) and the supply of land within Ireland, R (equation 8).[8]

$$Q_b^s = f_6(p_a; p_b,\ p_l,\ p_k,\ p_m,\ R) \tag{9}$$

$$\frac{\delta Q_b}{\delta p_a} < 0,\ \frac{\delta Q_b}{\delta p_b} > 0,\ \frac{\delta Q_b}{\delta p_l} < 0,\ \frac{\delta Q_b}{\delta p_k} < 0,\ \frac{\delta Q_b}{\delta p_m} < 0,\ \frac{\delta Q_b}{\delta R} > 0 \tag{10}$$

$$Q_a^s = f_7(p_a, p_b,\ p_l,\ p_k,\ p_m,\ R) \tag{11}$$

In equation 9 the supply of biomass can now be expressed as a function of its own output price, the price of the inputs excluding land, the total supply of land and the price of agricultural output. The superscript s indicates that this is the supply function for biomass. (A similar equation can be derived for agricultural supply, 11.)

Because of the fixed supply of land (R), the supply of biomass is affected by the price payable for agricultural output.[9] This means that the effect of the CAP in raising agricultural output prices above the world market clearing levels has a direct effect on the supply of biomass. As shown in equation 10 an increase in agricultural output prices reduces the supply of biomass. This is due to the constraint that land is in fixed supply so that increased output in one sector will require a rise in rent to bid land away from the other sector.

$$Q_a^d = g_1(p_a) \tag{12}$$

$$p_a = g_2(Q_a^s) \tag{13}$$

$$\text{for the EU } \frac{\delta g_2}{\delta Q_a} \leq 0\ \text{, for Ireland } \frac{\delta g_2}{\delta Q_a} = 0 \tag{14}$$

Equation 12 shows the demand for agricultural output as a function of its price. Equations 11 and 12 can then be solved to obtain the market clearing supply of agricultural output, Q_a. The demand equation can also be solved for the price of output in terms of supply (13). In a free market a reduction in agricultural supply would result in an increase in the price paid for that output (14) but in the EU for many products it might only serve to reduce the budgetary costs of the CAP. However, the demand function

8 This places certain restrictions on the functional forms of equations 1 and 3.

9 In estimating such a system of equations, because the supply of land in Ireland is effectively fixed over time, the intercept in any equation for supply of biomass will incorporate the effects of the supply of land.

facing the Irish agricultural sector is rather different as changes in domestic supply are assumed to have little or no effect on the EU price; Ireland is assumed to be a price-taker on the EU market.

The possible effect of changing agricultural supply on agricultural prices has implications for equation 9 determining the supply of biomass. In the case of Ireland, acting on its own, an increase in the price of biomass would reduce agricultural production. On the assumption that Ireland is a price taker on the agricultural market, the price for agricultural output would be unchanged. By contrast, at the level of the EU, a major shift to biomass (and a consequential reduction in agricultural production) would first reduce the budgetary cost of the CAP. However, as compensation of farmers is gradually decoupled from output, the market for individual products will become more sensitive to supply and demand and an increase in biomass output would raise the price of agricultural output. This rise in agricultural prices would tend to offset part of the response of the supply of biomass to the increase in the price of biomass. However, in the short-run a reduction in the budgetary cost of the CAP would not feed back onto the market for biomass. This means that in the long run, even with similar production technologies, a bigger percentage increase in price for biomass will be required at an EU level than in Ireland to achieve the same percentage response in terms of output; the supply curve for biomass for the EU will be steeper than that facing Ireland.[10]

The Market for Other Inputs

The derivation of the supply function for biomass, discussed above, allowed for the fact that the price of agricultural output may change with changes in supply and the price of land will change with changing sectoral demand for land. However, there remains the possibility that the price of other factors of production may change with changing demand from the agricultural and the biomass sectors.

If labour were a homogeneous factor which was variable in the short-run, so that it was always paid its marginal product, then small changes in total employment would be unlikely to significantly alter its price; the agriculture and biomass sectors are, after all, relatively small employers in the context of the EU and even of the Irish economy. However, there is considerable evidence that self-employed labour is a quasi-fixed factor in the agricultural sector (see Boyle, 1992b); that is, it does not move in and out of the sector rapidly in response to changing labour requirements. Given the rate of technical change in the sector and the limitation on increasing production, this means that there is substantial underemployment. To the extent that changes in labour input occur through a reduction in underemployment in the agricultural sector, the price paid for this labour may be lower than the current market price for employed labour. However, if the combined demand for labour from the agricultural and the biomass sectors rises, so that employment actually increases, then the increased employment will only take place at the going wage rate in the economy.

Because of the constraint that the supply of land is fixed, increased output from one of the two sectors, and the resulting increase in employment, is likely, *ceteris paribus*, to be partially offset by a reduction in output and employment in the other sector. The study by Convery and Dripchak, 1983 suggested that biomass production, if substituting for agricultural production, could lead to a loss of employment, especially in initial years. However, the study of existing areas of forestry by Kearney and O'Connor,

[10] All of this assumes that the technology of production in both Ireland and the EU is the same.

1993, suggests that in the long run increased production of timber may be associated with some net increase in employment over the level it would otherwise have been in rural areas. In this case any surplus of unused self-employed labour may be insufficient to operate the business. In any event, in the long-run even self-employed labour in the agricultural sector is variable and the appropriate long-term measure of the cost of labour is likely to be the current wage rate. Certainly, at the margin, employment is likely to be made up of employees paid the going wage rate.

Given the mobility of capital between sectors and countries the price of capital can safely be taken as exogenous.

The agricultural and biomass sectors account for all of the demand for fertiliser used within individual EU economies. The market in fertiliser is a world-wide market and, while changes in demand within Ireland would have little impact on prices, changes at an EU level would probably affect demand and, therefore, price. The effect of this on the shape of the supply curve for biomass will depend on the relative importance of fertiliser in the production process of the two sectors.

If biomass production is less fertiliser intensive than agricultural production, the effects of underpricing fertilisers through a failure to take account of environmental externalities is probably to raise agricultural production above its socially optimal level. The corollary is that the production of biomass may be reduced below its socially optimal level.[11]

Selection of Land for Biomass

So far we have assumed that land is a homogeneous factor of production. However, it is self-evident that the physical productivity of land differs greatly from one location to another within the country.

$$\Pi_a^i = f_1^i(p_a, p_l, R^i, p_k, p_m, t^i) \qquad (15)$$

$$\frac{\delta \Pi_a^i}{\delta R^i} = p_{Ra}^i \qquad (16)$$

$$\Pi_b^i = f_2^i(p_b, p_l, R^i, p_k, p_m, t^i) \qquad (17)$$

$$\frac{\delta \Pi_b^i}{\delta R^i} = p_{Rb}^i \qquad (18)$$

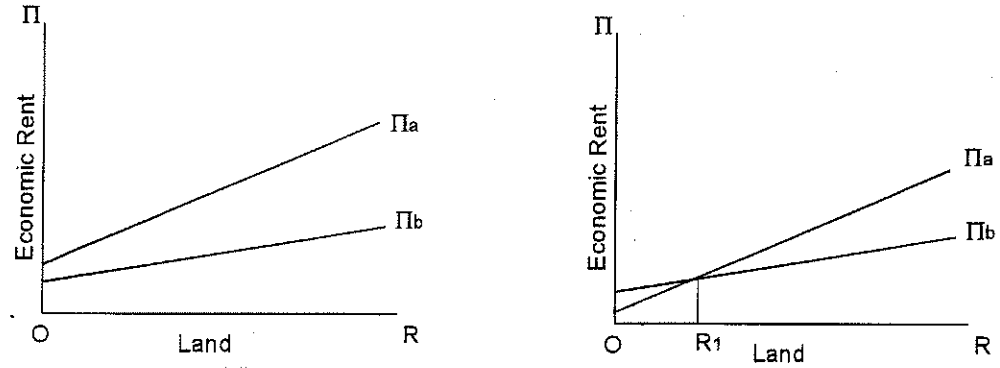
Equation 15 describes the profit which can be earned in location i from producing the agricultural good using the land at location i, R^i. In this case the profit function is *restricted* in the sense that it describes the profit maximising decision by the *firm* where the quantity of land available is fixed. When the profit function is differentiated with respect to the quantity of land at location i one obtains the shadow price or rent payable for the land at that location when it is used to produce the agricultural product. Equation 17 describes the profit which can be obtained at location i from using the land to produce biomass and equation 18 determines the rent for the land in that use. The choice of crop to grow will be determined by which use produces the greatest rent for the land at that location.

[11] If the socially optimal level of biomass production is zero then there is no distortion.

Some types of land which can produce very little when used for agricultural production (with an implied low rent) can potentially produce a relatively high yield in producing biomass (Convery and Dripchak, 1983). In other cases the economic rent from soils traditionally classed as "good" when used in agricultural production (due to a high yield) may show a much greater differential when compared to the economic rent in use in growing biomass.

Figure 4: Profitability of Land in Alternative Uses

(a) CAP **(b) No CAP**



The process of allocating land to different uses is illustrated in Figure 4. It shows the economic rent per unit of land when it is used to produce agricultural goods or biomass. The land is ordered on the x axis by its physical productivity, from very low productivity at the origin to high productivity at R.[12] In Figure 4(a) it is assumed that the CAP operates as at present; in Figure 4(b) it is assumed that the CAP is changed to substantially reduce the returns to agricultural production and/or there is a subsidy paid for biomass production. In the case illustrated in Figure 4(a) the rent is higher in all cases from using the land for agricultural production. However, with the different profitability conditions in Figure 4(b) land up to R_1 is used for biomass and the remainder of the land is used to produce agricultural output.

This means that the opportunity cost of using land to grow biomass will differ depending on the physical characteristics of the land and, even if the prices of the other inputs are constant, the supply curve for biomass will be rising; as the quantity supplied increases land will have to be bid away from growing agricultural produce at an increasing cost in terms of lost agricultural output.

Demand for Biomass

$$Q_b^d = g_3(p_b,\ Y) \tag{19}$$

$$\frac{\delta g_3}{\delta p_b} < 0 \tag{20}$$

The demand for biomass is a function of the price of biomass and total income or GNP (Y). Equation 19 together with the assumption of market clearing also implies[13] that an increase in supply will drive down the price of biomass. The sensitivity of this relationship depends on a number of different factors. Biomass, because of its high volume to weight and volume to value ratio, is not a readily traded commodity in its raw form.

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12 In practice no such simple relationship exists. However, the principle that owners will choose the most profitable use for their land, as set out above, still holds.

13 This places certain restrictions on the functional form of the demand function.

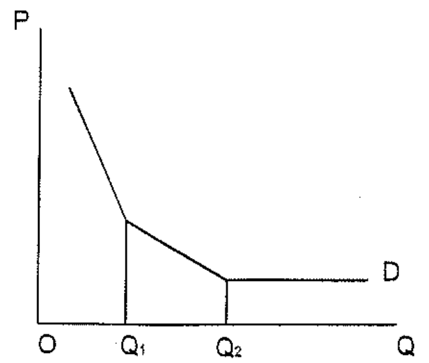
The characteristics of the demand curve for biomass will be influenced by the demand for it from the domestic sectors which use it as an input: wood biomass is currently being used to produce timber products; it can also be used to generate energy. Each of these different uses will display different demand curves for biomass reflecting the characteristics of the markets for their final products - timber products and energy. It seems likely that for higher prices biomass will only be used as an input into the timber products sector and the shape of the demand curve will be affected by the characteristics of the input demand from that sector. However, if the price falls low enough the shape of the demand curve will be determined by the characteristics of the demand from the energy production sector.

The potential for trade in timber products will restrict the sensitivity of the price to local supply conditions. On the assumption of price-taking behaviour in Ireland the demand curve should be downward sloping but fairly flat; at an EU level it could be expected to have a steeper slope.

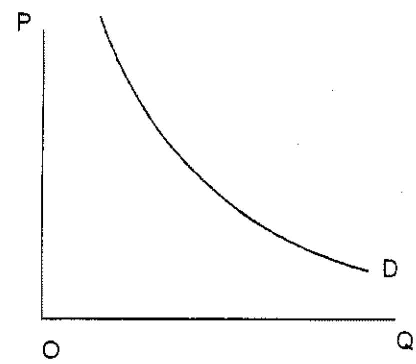
In using biomass for energy production the range of technologies available throughout the world is similar. Under these circumstances the price payable for biomass will be substantially determined by the price paid for the energy produced from biomass. This will differ from country to country depending on the characteristics of the energy system and the subsidy paid for reducing carbon emissions (or tax on carbon emissions). The shape of this demand function will then depend on the shape of the long-run supply function for electricity. It seems likely that the long-run marginal cost of electricity will be fairly constant over quite a wide range of production. If this is the case it will mean that the demand for energy from biomass will also be quite flat over that range.

Figure 5: Shape of the Demand Curve

(a) Ireland



(b) EU

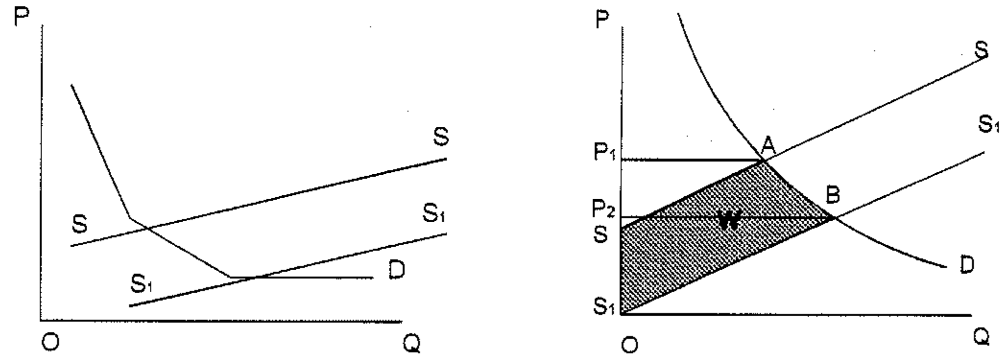


As shown in Figure 5, the demand for biomass in Ireland is probably made up of a series of different demand curves reflecting the alternative uses of biomass, both energy and non-energy. The higher value non-energy demand, which is currently observed for forestry products, may show a normal downward slope with volume demanded rising as the price falls so that OQ_1 is used in manufacturing high value wood products, Q_1Q_2 manufacturing lower value wood products and demand from the energy sector absorbing anything over Q_2. The potential use of biomass for energy production will then provide a floor with a fairly flat segment of the demand curve indicating an ability to absorb large quantities of biomass at a very low price.

When an aggregate demand curve is produced for the EU this is likely to be closer to a continuous downward sloping curve reflecting the wide variety of potential uses for biomass across the EU and the variety of structures of energy production in different locations in Europe.

Figure 6: Supply and Demand for Biomass

(a) Ireland **(b) EU**



Market Equilibrium and Welfare

The equations determining the supply and demand for biomass (9 and 19) can be solved for the equilibrium price and quantity of biomass (21).

$$p_b = h_1(Q_b, p_a, p_l, p_k, p_m, R, Y) \quad (21)$$

The discussion above suggests that the supply curve for biomass in Ireland will be upward sloping and fairly flat, as shown in Figure 6(a). The effect of the CAP has been to shift the curve inwards from S_1S_1 to SS because the price obtainable for the alternative use of land in agricultural production is substantially enhanced so that, at any given price, the supply of biomass has been reduced. However, it is not within the power of the Irish government to remove this distortion, even if it chose so to do.

Figure 6(b) shows the supply curve for the EU, SS, which has a steeper slope than that for Ireland, reflecting the fact that the price of agricultural inputs will react to major changes in the biomass sector. In Figure 6(b) S_1S_1 is the supply curve for biomass in the absence of the CAP. The price of biomass has been raised from P_2 in the absence of the CAP to P_1 with a commensurate reduction in production. The welfare loss through production foregone is shown by the shaded area W. This welfare loss consists of both the producer and the consumer surplus foregone. However, in arriving at an overall assessment of the welfare effects of the CAP this welfare loss in the biomass market must be considered jointly with the welfare effects of the CAP on the market for agricultural produce; the loss of producer surplus will be offset by the gain to producers of agricultural products from the higher price regime of the CAP. However, the loss of consumer surplus is not offset by changes in the market for agricultural produce and the overall welfare effects of the CAP are undoubtedly negative (Anderson *et al.*, 1994).

If a subsidy is paid per unit of output, raising the price for biomass received by the producer, the effect will be to offset the distortion caused by the CAP, for example shifting the supply curve from SS to S_1S_1. However, the cost will be a substantial charge on the tax payer, either in Ireland or the EU, so that the welfare loss W arising from the CAP will, at best, be only partially offset. The effect of a subsidy to biomass will be to reduce the output in the agricultural sector, cutting the cost to consumers and EU taxpayers of the level of CAP support (see Callaway and McCarl, 1994 for an analysis of this effect in the context of the US.)

If the subsidy is paid for by Irish taxpayers, while the reduction in the burden of the CAP accrues to the EU, it is likely that there will be a further welfare loss in Ireland as the dead-weight loss incurred in levying taxation to pay for the subsidy replaces the loss in welfare directly due to the CAP (W). It is only if the reduction in the negative environmental externality (carbon emissions) is worth more than the cost of the subsidy that there will be a welfare gain from subsidising biomass production. On the other hand, if the subsidy is paid for by EU taxpayers, who will benefit from any reduction in the burden of the CAP, then the welfare effects will be less clear-cut and there could be a welfare gain, especially when account is taken of the environmental effects.

Looking forward to the next decade when the CAP may well be dismantled to allow expansion of the EU (Boyle, 1992a and Kearney, 1995), the environment for forestry and biomass could change radically. In such circumstances the supply curve would be shifted outwards to S_1S_1. If this is thought to be a likely scenario then it could well affect decisions on investment in biomass. Because such investments take considerable time to mature, future changes in the CAP could crucially affect calculations of viability.

Marginal Cost of CO_2 Abatement

The relationship between the growth of wood biomass and carbon sequestration depends on how the wood biomass is used. If it is used to produce timber products, or even left to rot in place, the extent of carbon sequestration will be difficult to measure. It will certainly necessitate extensive scientific study. However, if the biomass is used to replace fossil fuels in generating energy, in particular electrical energy, then the estimation of the effects on carbon emissions is more straightforward.

In the case where wood biomass is used to replace electricity generated from oil the extent of the reduction in carbon emissions will be a simple function of the oil saved. Assuming constant returns to scale in the production of electricity from the two fuels then the carbon sequestered or carbon abated (C) is a linear function of the quantity of biomass consumed (equation 22). The cost of the carbon abated will be equal to the subsidy necessary to ensure the production of the biomass.

$$C = \frac{1}{\alpha} Q_b \tag{22}$$

$$p_b^d = g_4(\alpha C, E) \tag{23}$$

$$p_b^s = f_8(\alpha C, p_a, p_l, p_m, p_k, R) \tag{24}$$

The subsidy is determined as a function of the quantity of carbon abated, the supply schedule and the demand schedule for biomass. Using equation 22 substitute for Q_b in equation 19 which determines demand for biomass. The result is equation 23 which determines the price consumers of biomass are prepared to pay for the required amount of biomass. Similarly, substituting for Q_b in equation 9 using equation 22, the supply price necessary to produce the required supply of biomass is determined as equation 24.

$$S = (p_b^s - p_b^d)\alpha C \tag{25}$$

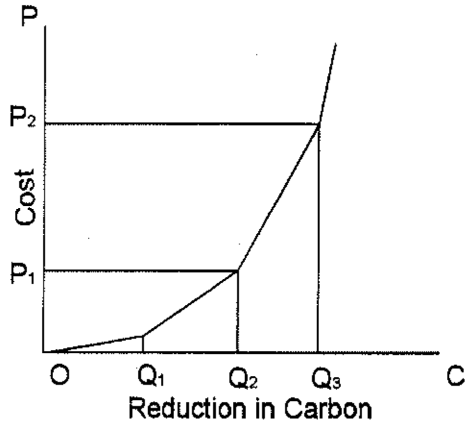
$$\frac{S}{C} = (p_b^s - p_b^d)\alpha \tag{26}$$

The subsidy, S, necessary to produce a volume of carbon abatement, C, through use of biomass is equal to the difference between the supply price and the demand price multiplied by the quantity of biomass (25). The subsidy per unit of carbon abated is then given in equation 26.

$$\frac{\delta S}{\delta C}=\left\{\left(\frac{\delta p_b^s}{\delta Q_b}\frac{\delta Q_b}{\delta C}\right)-\left(\frac{\delta p_b^d}{\delta Q_b}\frac{\delta Q_b}{\delta C}\right)\right\}\alpha C+(p_b^s-p_b^d)\alpha=\left\{\frac{\delta p_b^s}{\delta Q_b}-\frac{\delta p_b^d}{\delta Q_b}\right\}\alpha^2 C+\frac{S}{C} \quad (27)$$

The marginal cost of carbon abatement is then obtained by differentiating equation 25 with respect to C giving equation 27. In equation 27 the first term in the braces is positive, a higher price is needed to induce an increase in supply, and the second term is negative. As a result marginal cost is increasing with rising abatement. When the marginal cost curve obtained from equation 27 is combined with that for other methods of abatement a marginal cost curve for carbon abatement for the economy as a whole using all methods of abatement can be derived.

Figure 7: Marginal Cost of Carbon Reduction



An example of such a schedule is shown in Figure 7. The first two segments of the marginal cost curve for carbon abatement are assumed to be achieved through other means, such as energy taxes or increased energy efficiency, with a marginal cost of P_1. A reduction in emissions from Q_2 to Q_3 might be achieved through increased use of biomass at a marginal cost rising to P_2. If information is available on the marginal cost curve (Figure 7) then policy makers can determine for any given level of abatement the marginal cost and the methods to be used.

5. The Estimation of Costs and Benefits of Biomass

The methodology for examining the economics of biomass in Ireland described in the previous Section is implemented in a number of stages. First the cost of producing the wood biomass is estimated at the level of both the farm gate and the generating station. The sensitivity of this output price to differences in input prices arising from varying estimates of externalities is considered. Then the cost of the electricity produced from the biomass is estimated and this is compared to the cost of producing electricity from other sources. This provides an estimate of the cost of reducing carbon emissions through using biomass. The sensitivity of these results to the introduction of a carbon tax is examined. Finally the potential role of biomass production in Irish energy policy and the most appropriate method for financing it is discussed.

Table 3: Returns to Farmer from Land, 1993

	Cattle Rearing	*Cattle Other*	*Tillage*
Value of output, £	6495	10622	42563
Farm income (adjusted), £	2839	4401	18118
Average farm size, hectares	18.1	22.6	50.0
Income per hectare, £	156.9	194.7	362.4

Source: *National Farm Survey, 1993*, Teagasc.

Shadow Price of Farmers' Input

The switching of land and resources to growing biomass from other forms of agricultural activity will only take place if farmers expect to make at least as much from biomass as from the more traditional crops. In the absence of any distortions to the market, the average return to farmers from agricultural activity on the land to be used for biomass can be obtained from the *National Farm Survey*. As shown in Table 3, in 1993 farm income from cattle rearing was £157 per hectare and for "other cattle" production it was £195 per hectare. The returns from tillage and dairying (not shown) were much higher.

Providing that the land currently used for cattle rearing is suitable for biomass production (an issue which is discussed elsewhere in the report by Teagasc) it is this land which yields the lowest income per hectare in agricultural use and which is, therefore, the most likely to be bid away into biomass production. It is this level of income per hectare (£157 in 1993) which must at least be matched by the returns from biomass if land is to be devoted to its production.[14] For farmers to switch to biomass production they would have to have the expectation of receiving at least this rate of return. To encourage them to shift out of tillage or dairying would require an expectation of very much greater returns which would have to at least match their returns from their current activity (Table 3). This makes the land currently used for cattle rearing the most likely source of land for production of biomass.

Table 4: Nominal Rates of Protection for Agricultural Produce

(No Protection = 1.0)

	1992	*2001*
Grains	1.68	1.00
Beef	1.53	1.00
Milk	2.03	1.72

Source: *European Economy*, 1994, No. 4, p. 134.

In examining the economics of biomass it is important to view the project in a wider context: the prices for agricultural crops and for energy to-day will change over time; the current levels of agricultural prices in the EU are much higher than world market

14 Obviously farmers' decision on choice of crop is affected by factors other than the expected income per hectare. For example, the extent of the labour input by the farmer will also affect the choice of crop.

clearing prices due to the operation of the CAP. From the point of view of the Irish government the CAP is a necessary background and, if it were expected to continue unchanged to the end of the next decade, current relative prices for agricultural products could be taken as a good basis for examining the prospects for biomass in the medium to long term. However, the changing political situation within the EU and the pressures for enlargement and further world trade liberalisation all make it improbable that the CAP can survive unchanged well into the next decade (see Folmer *et al.*, 1995). This must be taken into account in determining the correct prices to be used in examining the economics of biomass.

From the point of view of the EU the CAP introduces significant distortions into the European economy and the resulting prices for agricultural goods do not provide a good indicator for allocating resources efficiently. They encourage over production of agricultural goods and, through raising the rental value of land (see Boyle and McCarthy, 1993), reduce the incentive to produce other crops, such as biomass. To discover the appropriate prices to use in examining the welfare implications for the EU of increased biomass production it is necessary to peel back the effects of the CAP and to consider what prices might prevail in an undistorted EU market place.

In Anderson *et al.*, 1994, it is estimated that the price paid for beef in 1992 in the EU was 53% above the world market price (see Table 4). They suggest that even under the MacSharry package beef prices in the EU will converge towards the world level by early in the next decade. If the compensation payments currently paid to farmers were decoupled from land use[15] this could hasten the process of convergence. Such a change in output prices would affect input prices (especially feed and seed prices) and, as a result, it would also affect the intensity of use of inputs. Assuming that variable costs fell in line with falling grain prices, but that there was no change in the intensity of use of inputs, this would imply that a reduction in beef prices to world levels would reduce the return to beef farmers from their land by around 50%.[16]

This would suggest that the lower bound on the appropriate return to farmers from growing biomass, taking account of the CAP distortions, should be 50% of the rate of return which they would need based on current market prices.

Shadow Price of Labour

In an undistorted world of full employment it would not be appropriate to value the labour input at anything other than the market price. However, the high level of unemployment in Ireland might suggest that there could be a wider value to society from additional jobs created. Each new person employed in biomass might add to total employment and output, reducing the numbers unemployed with a consequential saving to the state.

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15 Decoupling involves changing the schemes for compensating farmers so that the payments are totally unrelated to the quantity produced or the volume of inputs, including land.

16 While a change in use of inputs would ameliorate this cut the fall in variable input prices could well be less than we have assumed. In another simulation using data for the 1986-88 period Martin *et al.*, 1989 estimated that the effect of the CAP was to raise land rental in the EU by around 40% above the level it would fetch if world market prices prevailed.

Table 5: Labour Input

Labour units per hectare

	Cattle Rearing	*Cattle Other*	*Tillage*	*Biomass (will*
Labour availability	0.046	0.043	0.026	
Labour needed	0.015	0.018	0.023	0.01 to 0.0

Source: *National Farm Survey, 1993,* Teagasc and estimates from this study for Biomass.

This matter has been investigated by Honohan *et al.*, 1995, in the context of state aid to promote industrial development and they suggest that, because of the openness of the Irish labour market, additional skilled jobs may have little impact on domestic unemployment, serving only to modify the numbers emigrating. However, to the extent that new jobs created are unskilled and the unskilled have a much lower propensity to migrate , the new jobs may result in some cut in unemployment.

In considering the appropriate price to use in valuing the labour input in biomass production the first issue to be addressed is the extent to which it will change total employment. The study done by Kearney and O'Connor, 1993, indicated that the total employment in a locality dependant on forestry may be similar to that in a comparable locality dependant on farming. However, the case of biomass is rather different as it seems likely that it will be more labour intensive than traditional forestry and also more labour intensive than cattle production (see Table 5). Thus some increase in labour input in the long term can be anticipated. The mix of skilled and unskilled labour will depend on the production process chosen.

Table 5 shows that there is considerable underemployment of labour on cattle farms, the most likely source of land for biomass production. This means that the increased labour input needed as a result of any switch of land from cattle rearing to biomass production could be met by higher utilisation of existing labour, generally, members of the farm family. The harvesting of biomass from willows will tend to take place in the winter, traditionally the time of minimum activity on the farm. This should mean that a mix of traditional agriculture and biomass production might be complementary smoothing out the seasonal fluctuations in the demand for labour on the farm. Depending on the locality, biomass production might also prove complementary to peat production as the latter fuel is normally harvested in the summer.

To the extent that any additional labour input is provided by existing farmers using their spare time the appropriate price for valuing that labour is the actual return received by the farmer - there is unlikely to be any reduction in numbers unemployed. To the extent that there is additional skilled labour employed in the production process this may serve to reduce immigration rather than unemployment.

If it is correct that biomass production will do little to reduce unemployment there still remains the possibility that the total income of farmers may rise as a result of a switch to biomass. This could result in some additional tax revenue for the government from the additional income which would be a benefit not captured in valuing the labour input at its market price. However, the low incomes of farmers in the cattle production sector may well mean that any additional tax take from an increase in income should be small.

Honohan, 1995 argues that the shadow price of labour, where new jobs are created in industry, may be 80% of the market price. While we examined the sensitivity of the cost of biomass production to such a variation in labour costs, it seems likely, for the reasons given above, that the shadow price may be close to the market price and this assumption is maintained below.

Price of Other Inputs

It was argued above that the price of fertiliser may not reflect the full costs to society of fertiliser usage due to the environmental damage which it entails. Because a shift to biomass production will involve a reduction in fertiliser usage it will confer some environmental benefits. Table 6 shows the average expenditure on fertiliser per acre in different types of farming. This shows that biomass production is likely to be less fertiliser intensive than alternative uses of the land. Thus a shift to biomass production from agriculture is likely to reduce any pollution from fertiliser use, with consequential environmental benefits.

Table 6: Fertiliser Use

Expenditure in £ per hectare

Cattle Rearing	*Cattle Other*	*Tillage*	*Biomass (willow)*
22.7	34.0	76.2	20.0

Source: *National Farm Survey, 1993*, Teagasc and estimates for biomass from this study.

We do not attempt to quantify this externality as the level of fertiliser use on the land which is likely to be devoted to biomass production is already quite low. It is sufficient that any change in land-use is likely to produce positive environmental effects through reducing pollution.

Risk and the Discount Rate

In terms of risk biomass production differs from cattle rearing in a number of different ways. From the point of view of the farmer it is a novel technology and this alone makes the expected rates of return from it less certain than for other agricultural crops. A shift to biomass production would involve some reeducation and there is always the possibility that unexpected hazards, such as pests or disease, may intervene to reduce the expected yield. While farmers understand the working of the market for cattle, there is no market currently available for biomass. The expected market would depend on the development of suitable plant to generate electricity and the market would be likely to be dominated by a single monopoly buyer leaving farmers at disadvantage in terms of market power. The combined effects of these factors will be to raise the perceived risk to the farmer of moving into biomass production. However, there would be some offset against existing risks from a diversification of crops, reducing the farmer's exposure to problems in a single crop, such as cattle production.

A decision to switch from cattle rearing to biomass production involves a significant investment with a pay-back period of many years. While capital tied up in cattle production can be liquidated fairly readily through selling the cattle, giving rise to quite a short planning horizon, this is not the case for biomass. In biomass production if willow is used the first crop will not be ready until 4 years after the initial investment and further crops from the initial planting will occur after 8, 12 and 16 years at which stage the return on the initial investment will be complete.[17] Once the land is planted any switch back to cattle rearing would necessitate costly expenditure to restore the land as well as a write off of the significant initial investment.

Because of the long pay-back for biomass investment it is necessary to discount future benefits over a considerable period to derive the net present value (NPV) for the investment for comparison with other forms of agricultural production. The costs and benefits of the investment will depend crucially on the discount rate used.

Other methods of financing biomass production could reduce the risk to the farmer. For example, a contractor could rent the land from farmers on a 16 year lease and farmers would receive a fairly certain rate of return on the land. Convery and Dripchak, 1983, indicated that farmers would prefer this option. However, in this case the risks inherent in biomass production would pass to the contractor. The contractor, in deciding on the viability of a biomass project would then have to take account of this risk by using a suitably high discount rate. For a contractor who concentrates solely on biomass the risks could actually be greater than for farmers who have a more diversified set of production possibilities.

In other fields of economic activity financial instruments have developed which allow risk to be shared over a range of different individuals and agents (e.g. insurance). However, the novel nature of biomass production and the limited market, at least initially, will make the development of such instruments difficult (Convery and Dripchak, 1983).

Because of the considerable risks involved we experiment with both a 10% and a 12% discount rate in calculating the NPV for the biomass production. This is substantially higher than the cost of capital to the government though it may be closer to the cost of borrowed capital to farmers or small businesses. We also test the sensitivity of our results to the use of a 5% discount rate, the rate used by the government in assessing the viability of investment projects.

Transport Costs

The transport of the biomass from where it is grown to the electricity generating station is assumed to be undertaken by a separate contractor and the costs of this process are separately identified. In calculating these costs account is taken of the labour, fuel and depreciation on machinery involved in the transport of the goods. In calculating transport costs no account is taken of the externalities involved in the transport of large volumes (and weight) of agricultural produce. In particular the transport of such goods on rural roads involves a burden on the rural infrastructure - the roads will suffer damage from the transport of the biomass. This infrastructural cost could be significant if there was a large scale shift to biomass production.

There are two ways of viewing this cost. It can be separately identified and included in the cost of biomass production or, alternatively, only the change in these costs from switching from agricultural production to biomass may be included.

In examining the costs and benefits of many other forms of economic activity these costs are frequently omitted. However, they are likely to be more important for biomass because of the large volume and weight of goods to be moved. In addition, as

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[17] The land will have to be replanted at that stage.

some of the infrastructural costs of collecting peat (and other fuels) are borne by the peat producer[18] failure to take account of these (external) infrastructural costs in the case of biomass could give a wrong signal in terms of the economics of electricity production compared to alternative fuels.

Cost of Electricity Production

The cost of electricity production from different fuel sources is shown in Table 7 together with the range of estimates for the cost of producing electricity from biomass. The first column shows the cost in existing plants in Ireland and the second column gives an estimate of the cost for new plant beginning production in 2000. The cost of producing in the older plants tends to be lower than for new plants due to the treatment of depreciation in the ESB accounts. The current price of electricity in Ireland is probably below its long run marginal cost and the estimated costs for new plant is probably a better basis for examining the economics of biomass.

Table 7: Cost of Electricity Production, pence per kwh

	Existing Plant	*New Plant*
Coal	2.0	3.2
Gas	2.3	3.7
Oil	2.8	NA
Peat	4.2	NA
Wind	NA	4.0
Biomass - Urban Waste	NA	2.1 to 6.1
Biomass - Lowest	NA	8.6
Biomass - Highest	NA	19.5
Allowing for Externalities		
Biomass - Lowest	NA	6.3
Biomass - Highest	NA	14.0

Source: Existing plant -*Annual Report*, 1992, ESB. The costs include depreciation. They are derived from the most efficient existing plant. In the case of peat the figures are derived from Nic Giolla Choille, 1993 and they allow for the element of sunk cost in the Bord na Mona debt. For wind the cost is taken from the bids submitted for new plant. See Barrett and Lalor, 1995 for urban waste; the range of costs depends on the cost of landfill avoided through incineration. For new plant the figures are taken from UNIPEDE "Electricity Generating Costs for plants to be Commissioned in 2000", January 1994. For wood biomass the figures are taken from the reports be Teagasc and ESBI prepared as part of this project. The externality allowed for is the effect of the CAP on the rental cost of land - the minimum return required by the farmer.

The price for biomass is affected by the range of estimates, discussed above, for the farm-gate cost of biomass and also by the range of possible technologies which could be used to generate electricity from the biomass. The price of biomass is also shown with and without adjustment for certain externalities, in this case adjusting the returns to farmers to take account of possible incorrect signals from current agricultural prices.

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[18] A significant volume of peat is moved on Bord na Mona owned railways.

As shown in the Table 7 electricity generated from biomass is likely to be substantially more expensive than that generated using other fuels or technologies. Even allowing for the possibility that the rental value of land is artificially boosted by the CAP, biomass is still much more expensive as a fuel source. However, the estimates shown above make no allowance for the environmental damage caused by carbon emissions from fossil fuels.

The cheapest electricity produced using biomass would be in the case of a 30MW plant involving gasification of biomass residues integrated with a gas turbine combined cycle generating system. Cost is lowest when a discount rate of 5% is assumed, reflecting an environment where the state carries all the risks. Smaller plants, different technology, and a higher discount rate all add significantly to cost.

In Table 8 we examine the sensitivity of the price of electricity to variations in some of the crucial assumptions. This Table indicates that the discount rate used to calculate the present value of the costs and income flow to the farmer over the life-time of the project has a significant effect on the price of electricity. This highlights the importance of risk, reflected in the difference in discount rates, in assessing such an investment.

Table 8: The Effect of Different Factors on the Price of Electricity from Biomass

	Difference in pence per unit from highest to the lowest estimate
Discount rate - risk	1.2
Returns to farmers	2.3 to 5.6*
Generating technology	4.6 to 8.3

* The range depends on the generating technology and discount rate chosen

A much bigger contributor to the wide range of estimates of the potential costs for electricity generation using biomass is the returns required by the farmer. On the basis of the current market for agricultural produce, farmers' incomes are boosted by the CAP. However, if the CAP is wound down as Anderson *et al.*, 1994, suggest the potential returns from agricultural use of land will fall significantly which could alter the economics of biomass (see Table 8).

This also means that from the point of view of the EU the economics of biomass look more attractive than from the national point of view. Any shift from agricultural production to biomass could actually save expenditure on the CAP[19] while in the case of the Irish government no such potential savings are possible.

A vital factor affecting costs is the choice of electricity generator and the potential for further development of that technology. As shown in Table 8, the choice of the size of the electricity generating station and of the technology to be used to fire it has a very big effect on the estimated delivered price of electricity from biomass.

The potential yield from the land used to grow biomass also has a limited impact on the range of estimates of its cost. However, it is less important than the other factors considered here.

As indicated earlier the true cost to society of the labour employed in biomass production would probably be close to the actual market price. In any event, a limited

[19] See Callaway and McCarl, 1994 for estimates of the potential savings in the US.

variation in the assumptions concerning labour's shadow price would make only a relatively small difference to the cost of electricity when compared to the effects of the other factors considered in Table 8.

Table 9: Effects of a 50% Rise in Fuel Prices on Electricity Prices

	pence per kwh	
Fuel Prices:	*Current*	*50% Increase*
Coal	2.0	2.5
Gas	2.3	3.1
Oil	2.8	3.6
Wind	4.0	4.0
Peat	4.2	5.6
Biomass		no change

Table 9 shows the effects of a 50% rise in fuel prices (discussed in Section 2) on the cost of electricity generated from fossil fuels. The prices of electricity from these different sources are still well below the range of possible prices for electricity from biomass. This suggests that for the foreseeable future biomass will remain an expensive option for electricity generation and development of this source will depend on the potential environmental benefits from reducing net carbon emissions.

Cost of Carbon Reduction

Given the high cost under present circumstances of generating electricity from biomass it seems unlikely that it could prove economic to invest in that technology over the next decade were there not environmental benefits to be obtained from it. If biomass is substituted for other fuels then the carbon which those fuels would have omitted remains fixed in the fossil fuel saved. It is this saving of emissions which represents the major attraction of biomass based energy.[20] Quantifying the benefits of this reduction in emissions is not feasible. As a result, we consider two more limited approaches to handling the potential environmental benefits from biomass: in one case we examine the potential impact on the economics of biomass from the introduction of a carbon tax along the lines of that originally proposed by the EU Commission (Fitz Gerald and McCoy, 1992); in the second we consider rough estimates of the cost of carbon abatement from different technologies deriving an implicit schedule for the marginal cost of abatement along the lines of Figure 7.

While the carbon tax originally proposed by the Commission failed to gain acceptance within the EU it is still a possibility that a variant of such a tax will be imposed within the next decade. The increasing evidence that global warming is taking place raises the urgency of such measures. The tax proposed by the EU commission would not be sufficient to halt global warming (see Burniaux *et al.* 1992) but it is useful to illustrate the magnitude of the impact which a carbon tax could have on the economics of biomass in the long run.

[20] The long-run environmental impact of using the wood biomass for other purposes (pulp or chipboard etc.) is more difficult to assess.

Table 10: Effects of Original EU Carbon Tax on Electricity Prices

	pence per kwh	
Fuel Prices:	*Current*	*Carbon Tax*
Coal	2.0	3.1
Gas	2.3	3.2
Wind	4.0	4.0
Peat	4.2	5.9
Biomass		6.3 to 19.5

In Table 10 we show the full effects[21] of the EU proposal on the price of electricity generated from different sources. While it would narrow the gap between the cost of biomass based electricity and the cost of electricity generated from fossil fuels it would still leave a large gap between the highest fossil fuel price (for peat) and the lowest price for biomass. However, even at the level proposed by the Commission and even if it were imposed world-wide, the carbon tax would still not be sufficient to halt the trend to global warming. As a result, in the long run it is possible that the tax could be very much greater than originally proposed reflecting the possible serious effects on the world of global warming and the high cost of actually halting it. However, the time scale on such changes is so long that it would be premature to make any decisions on biomass on that basis.

Table 11: Cost of Reducing Carbon Emissions With Different Technologies

	Cost per Tonne CO_2 £	*Total Tonnes CO_2*
Carbon tax	Saves Money	780,000
Windmills for gas	41.3	310,000
Windmills for peat	-1.7	890,000
Biomass - wood for gas[1]	228.8	870,000
Biomass - wood for peat	63.5	2,490,000

[1] Assumes a biomass cost of production of 11.5 pence a unit

The second approach to considering the wider environmental benefits expected to flow from investment in biomass is to estimate how much it costs through using biomass to reduce carbon emissions and to compare this to the cost of reducing carbon emissions by other means. In Table 11 we give some very crude figures for the cost per tonne of carbon avoided using different approaches. We also give an estimate of the total amount of carbon emissions which could be avoided using each method at the quoted price. In the table we only present data for the methods for which estimates are available for Ireland.

The best method of reducing carbon emissions may well be measures which encourage increased energy efficiency and saving (see Scott, 1993 for an estimate of potential savings by households). The range of possible measures includes demand side management and investment in energy saving[22]. After the most obvious such

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[21] The tax was to rise to a maximum in 2000. These figures are based on the level of the proposed tax in 2000.

[22] The ESB estimate that in 1994 143GWh of electricity were saved at a cost of £8 million spent on

opportunities are exploited (or to encourage their exploitation) a carbon tax is probably the next most desirable policy measure. It is estimated that a shift from taxing labour to taxing carbon through the full introduction of the original tax proposed by the Commission would actually produce a small increase in GNP and employment while reducing carbon emissions by over three quarters of a million tonnes of CO_2 (Fitz Gerald and McCoy, 1992). Thus significant reduction in emissions can be achieved at little or no economic cost using such methods. An even higher tax than that proposed by the Commission would produce a greater reduction in emissions but the economic costs of such a change would begin to rise as the tax was increased to higher and higher levels.

After energy saving and energy taxation there are a very wide range of other measures which could be taken to reduce carbon emissions including fuel switching from peat and coal to oil and gas; using biomass from municipal waste; the development of renewable energy sources, such as windmills and biomass. We have selected five of these possibilities for inclusion in Table 11 to illustrate how a schedule of the cost of carbon abatement can be developed.

For windmills we have considered the case where they replace electricity which would have been generated from gas and peat. We also assume that the transmission system could not absorb more than 5% of its electricity from windmills because of the problem dispatching them.[23] For biomass we also make the comparison with electricity generated from gas and peat. In practice, because of the technology, the most feasible option for a new biomass venture would be to use it to substitute for peat in a new station, or possibly an existing station. As peat is used in preference to other fuels in electricity generation to provide security of supply and regional employment and as biomass would also meet these requirements this seems a reasonable assumption on substitution possibilities. As a result, we assume in Table 11 that biomass expands to provide the same share of electricity as is currently met from peat.

The results in Table 11 show a clear hierarchy between the different methods of carbon abatement examined here. Energy saving and a carbon tax (with the revenue used to cut labour taxes) should be the first priority in reducing carbon emissions; then a switching of fuels from peat to gas; thereafter windmills should be used in so far as the grid can absorb their output. Of the methods considered here biomass from wood is likely to be the most expensive means of reducing carbon emissions.

Financing Biomass Production

In the long-run if biomass is to have a role as a fuel source for electricity generation it must be because it is the most efficient fuel, taking account of all costs, including environmental costs. The correct approach would be for the state to use taxes to adjust the prices of other fuels to reflect the environmental costs which they impose. If the newly adjusted prices made biomass economic then a market would develop. If the cost of biomass remained prohibitive in spite of a correct apportionment of environmental costs it would, correctly, be replaced by other technologies.

Given the state of our knowledge at present, the uncertainties about environmental costs, technological change and future energy prices it may be desirable to undertake a pilot project to study the potential for biomass to meet our energy needs. If this is the

demand side management.

[23] Electricity supplies from windmills are dependent on the wind blowing and are, as a result, not reliable

case it is clear that public funds will be needed to provide sufficient incentive to all those involved to participate. However, as discussed in Honohan *et al.*, 1995, the cost to society of providing public assistance is likely to be greater than the direct cost of assistance provided. They suggest that the shadow price of government subsidies is approximately 1.5 times the absolute cost of the public expenditure. This means that the cost of bridging the gap between the price of biomass based electricity and the price of the next most expensive alternative will be substantially greater than suggested by the data in Table 7.

The discussion above has highlighted the importance of risk and uncertainty in determining the behaviour of crucial agents in biomass production - farmers, contractors and electricity generators. If biomass production carried no risk to any of the agents then the appropriate discount factor to use in calculating the costs would be at the lower end of the range examined. As illustrated in Table 8, this would have a significant effect on the cost of biomass production and on the subsidy which must be provided to make it viable.

There are a number of different ways of providing a subsidy to biomass which will have different incentive effects for the agents affected. There is a choice of who the subsidy is paid to. If the subsidy were paid to the electricity generator then it would raise the price which that industry could pay for the biomass. It would have the advantage that the generator would have every incentive to get value for money from the producers. However, it would be difficult for the generator to provide suitable contracts which reduce the risks facing growers. In addition, by subsidising use of biomass in generation, while leaving the price paid by the wood products industries unchanged, there would be a redirection of wood from what might be its best use from the point of view of the economy.[24] It is only if there were clear evidence that wood biomass used in generating electricity had superior environmental effects to using it in wood products industries that subsidising the end users (generators) would be appropriate.

In subsidising growers it is important that the right balance be struck between incentives to maximise output and a reduction in the riskiness of the process from the point of view of the grower. If all the subsidy were paid as an establishment grant to get farmers or contractors to shift to biomass it might well achieve the desired initial shift as the up front payment would minimise the risk of loss to the grower. However, it would leave little incentive for the grower to tend the biomass over the life of the investment resulting in poor productivity and yields.

On the other hand, if all the subsidy were paid as a fixed amount per tonne of dry matter delivered at the farm-gate it would still leave the grower with considerable uncertainty as to the future income. In using a high rate of discount of such benefits the grower will need a higher subsidy than when a direct payment is made at the time of establishment. However, once they have embarked on growing biomass they will have every incentive to work to ensure the maximum output from the land.

A variant of the fixed subsidy per tonne of dry matter delivered would be to guarantee a price per tonne with a variable subsidy paid by the state. This would minimise the risk to the grower while still leaving an incentive to maximise output (yield). However,

[24] The current situation where the state grant aids wood processing industries is discriminatory in the other direction. It would be better if no subsidy was paid to such firms directly as they benefit in any event from the subsidisation of timber production.

it would leave little incentive for the grower to fight for a good price and there might also be problems in ensuring the quality of the dry matter delivered. In this case there would be a serious danger that the growers weak incentive to bargain over price could result in inefficient behaviour by users of the wood biomass so that the state would not only carry all the risk of the venture, but also possibly end up providing an unnecessary subsidy to generators or other users of the biomass.

Probably the best compromise is the provision of an establishment grant which covers the initial costs of moving into biomass followed by a fixed real subsidy per dry tonne delivered over the lifetime of the investment. This would ensure that the growers were insured against any absolute loss on the investment while still having an incentive to maximise yield from the land. Growers would still face a risk that devoting land to biomass would produce a lower income over the project life time than other possible land uses.

At present there are substantial subsidies paid to encourage a shift in land use from agriculture to forestry. It would be very important that the subsidies paid for biomass should be comparable to those paid for forestry. While this may be difficult to achieve, given their different maturity profiles, failure to do so could lead to a distortion in resource use in the economy. As discussed above, unless there are strong environmental reasons to the contrary, wood biomass should be used by whatever industry, wood processing or electricity generation, can pay the highest price.

If the subsidy is paid to the producer it would have to be explicit whereas if paid by the generator it could be bundled into a higher price for electricity. The benefits of transparency strengthen the argument in favour of payment to producers but the issue of who should pay the subsidy arises? The justification for paying a subsidy for biomass production arises initially from the need to increase our understanding of the technology. In the long run it is the potential environmental benefits which may arise from it which will drive any future development. In the short-term if a pilot project is to be initiated in the absence of carbon taxes it will require a subsidy. As discussed above, any subsidy should be harmonised with the subsidies paid for forestry. There is a strong argument for the funding of these subsidies by the European Community as one of the beneficial side effects of developing biomass will be some reduction in the cost of the CAP either to EU tax payers or EU consumers.[25] This is already reflected in the assistance given by the EU to developing forestry.

6. Conclusions

The results of this study suggest that for the foreseeable future generating electricity from biomass is likely to be a very expensive option. In this study we have considered the wider costs and social benefits which could arise from the development of wood biomass and these do not alter our conclusions. Even if full account is taken of the potential environmental benefits from such a shift in fuel it still seems an expensive way to meet the desired environmental objective. If policy is concerned with halting the process of global warming in a reasonable time frame there are a range of other measures which should be undertaken first which will produce a reduction in carbon emissions at much less cost than the development of biomass.

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25 See Callaway and McCarl, 1994, for evidence on the potential savings to the US government from a shift in land use from agriculture to forestry or biomass.

In the long run these other measures may not prove sufficient to meet the necessary environmental objectives and, as a result, it may be desirable to develop the technology of biomass and explore the many obstacles which prevent it becoming an economically viable technology in case it is needed at a future date. If this is the case it may be desirable to carry out further research to improve our understanding of the economic and technical problems involved in achieving viability (see Convery and Dripchak, 1983). At present two fruitful areas for research may be the development of high yielding types of wood biomass and the contractual and legal problems involved in developing a market in a relatively new product. The development of market supports which will minimise the risk to the parties involved, farmers, contractors, and generators, while maintaining the correct incentives for all those involved, needs further study.

In undertaking a pilot project care should be taken that the incentives provided do not distort the market for other forms of wood produced by the forestry sector. If any additional wood biomass produced can be used more profitably in wood processing industries then it should not be redirected to electricity generation.

Given all the uncertainties involved, the best approach to developing a pilot scheme would be to centre the project around the new peat fired generating station which is to be built in the Midlands. The technology of the generation process will allow wood biomass to be substituted for peat at relatively little expense. As a result, it would not be necessary to risk a very substantial investment in a purpose designed generator.

Whether or not such a scheme will prove a success depends on the reaction of landowners. A number of studies in the past have stressed the problems posed by the perceived riskiness of the project in attracting participants. Convery and Dripchak, 1983, suggested that farmers needed a guaranteed income to attract them. They also stressed the fact that farmers are quite old and may have a more limited time horizon than other market participants poses a problem. To minimise these problems of risk and uncertainty while maintaining sufficient incentives to maximise output will require careful design of any incentive package. Hannan and Commins, 1993, stress a range of additional issues which also need to be considered in designing a policy framework which will result in a satisfactory shift in land use.

Honohan *et al.*, 1995, suggest that the economic cost of public funds is substantially greater than the accounting cost. Thus the economic cost of the subsidy which would be necessary to encourage the growing of biomass would probably be around 1.5 times the direct outlay by the state. To obtain maximum benefit it is important that this subsidy be structured to maintain an incentive for growers to maximise the yield from the land while at the same time limiting the risks which they face. However, in designing such a subsidy scheme it is important that it should be consistent with the incentives currently available to encourage the development of forestry. If the subsidy to biomass were greater than that to forestry it could well be self-defeating as the wood products industry would still be in a position to bid for the wood biomass when it becomes available. Any attempt to lock farmers into providing biomass purely for electricity generation should be avoided as such contracts would, in all probability, prove impossible to enforce.

Even if any scheme to subsidise biomass is co-ordinated with current schemes for forestry the impact of a policy to encourage biomass production involving increased subsidies will be to reduce the value of existing forests. By increasing supply there would be some tendency for prices to fall. The major gainers could be the existing wood products industries which could see an increase in the supply of their inputs and a fall in prices.

Even if the end result of this experiment is that the biomass is bought by the wood products industry it may still be successful in promoting research into plant varieties and in developing an active market in biomass. As the danger of capital loss on generation plant is minimised by the proposed piggy-backing on the peat generator, the costs of such an outturn would be relatively small. If it is still desired to test the viability of using biomass in the peat boiler it should probably be sufficient to pay market prices to buy limited quantities of biomass for testing.

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