



THE ECONOMIC AND SOCIAL RESEARCH INSTITUTE

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

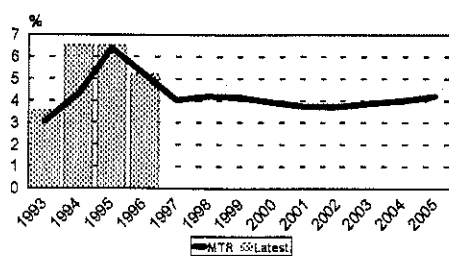
In discussing the future outlook of the energy sector in Ireland it is necessary to make some forecasts of the likely evolution of energy demand over the remainder of this decade. The most significant determinant of energy demand is likely to be the level of economic growth. As shown in Figure 1 simulations 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

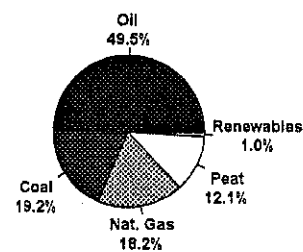
GDP at Constant Market Prices



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 CO₂ per capita is currently above the EU average (see Fitz Gerald and McCoy, 1992).

Table 2: Tonnes of CO₂ per Tonne of Oil Equivalent

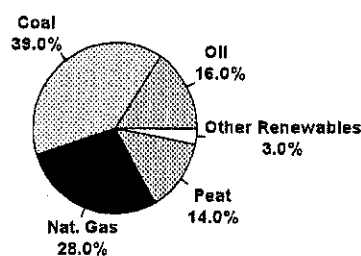
Peat	4.34
Coal	3.7
Oil	3.01
Gas	2.07

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 CO₂ 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 CO₂ 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 CO₂. 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 CO₂ is released on combustion, it is reabsorbed during the production process. Thus biomass appears to be an attractive option in meeting EU protocols on CO₂ 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 zero¹. 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 provides³ 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

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

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 it 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.

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

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

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

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

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).

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

$$R_a + R_b = R \quad (5)$$

$$R_a = f_3(p_a, p_l, p_r, p_k, p_m) \quad (6)$$

$$R_b = f_4(p_b, p_l, p_r, p_k, p_m) \quad (7)$$

$$p_r = f_5(p_a, p_b, p_l, p_k, p_m, R) \quad (8)$$

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

$$Q_b^s = f_6(p_a, p_b, p_l, p_k, p_m, R) \quad (9)$$

$$\frac{\delta Q_b^s}{\delta p_a} < 0, \frac{\delta Q_b^s}{\delta p_b} > 0, \frac{\delta Q_b^s}{\delta p_l} < 0, \frac{\delta Q_b^s}{\delta p_k} < 0, \frac{\delta Q_b^s}{\delta p_m} < 0, \frac{\delta Q_b^s}{\delta R} > 0 \quad (10)$$

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

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.

$$Q_a^d = g_1(p_a) \quad (12)$$

$$p_a = g_2(Q_a^s) \quad (13)$$

$$\text{for the EU } \frac{\delta g_2}{\delta Q_a^s} \leq 0, \text{ for Ireland } \frac{\delta g_2}{\delta Q_a^s} = 0 \quad (14)$$

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.

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

$$\frac{\delta \Pi_a^i}{\delta R^i} = P_{Ra}^i \quad (16)$$

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

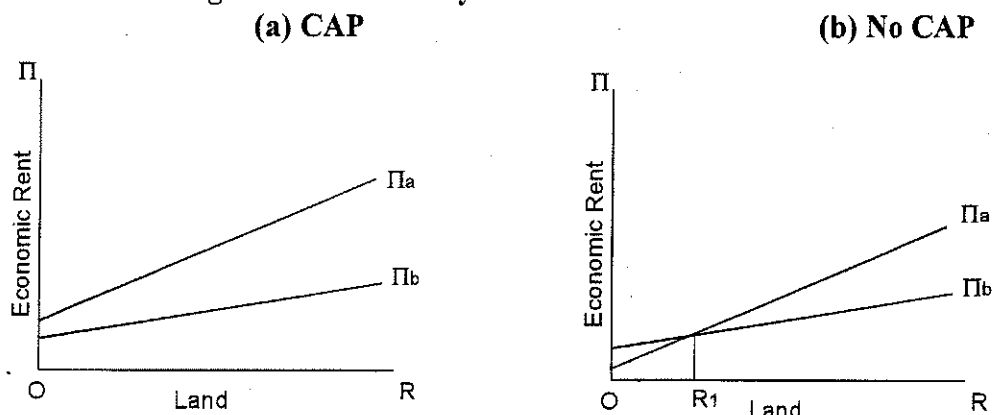
$$\frac{\delta \Pi_b^i}{\delta R^i} = P_{Rb}^i \quad (18)$$

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



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 R₁ 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

$$Q_b^d = g_3(p_b, Y) \quad (19)$$

$$\frac{\delta g_3}{\delta p_b} < 0 \quad (20)$$

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 implies¹³ 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.

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.

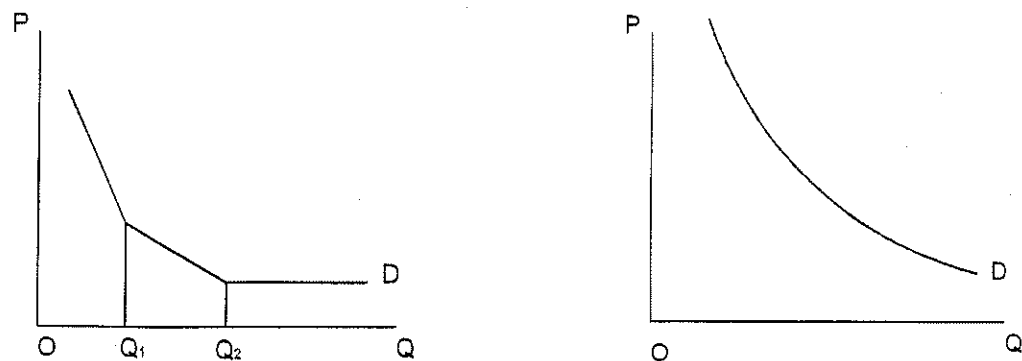
The potential for trade in timber products will restrict the sensitivity of the price to local supply conditions. On the assumption of price-taking behaviour in Ireland the demand curve should be downward sloping but fairly flat; at an EU level it could be expected to have a steeper slope.

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

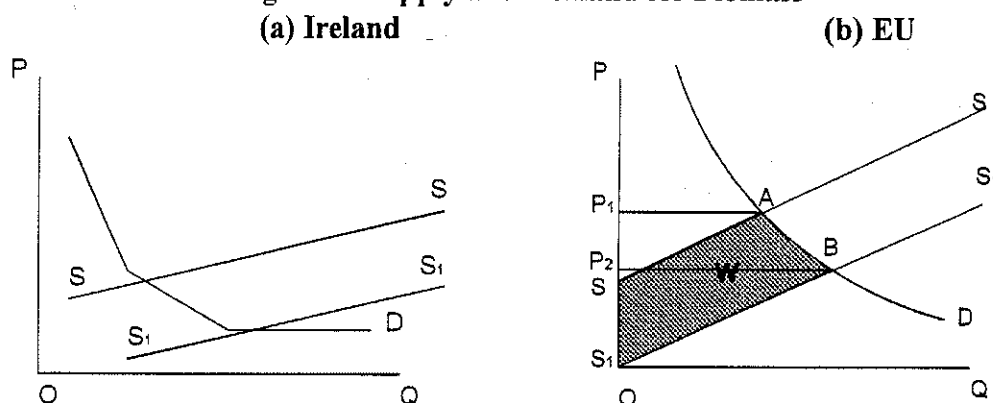


As shown in Figure 5, the demand for biomass in Ireland is probably made up of a series of different demand curves reflecting the alternative uses of biomass, both energy and non-energy. The higher value non-energy demand, which is currently observed for forestry products, may show a normal downward 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



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 CO₂ 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.

$$C = \frac{1}{\alpha} Q_b \quad (22)$$

$$p_b^d = g_4(\alpha C, E) \quad (23)$$

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

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.

$$S = (p_b^s - p_b^d)\alpha C \quad (25)$$

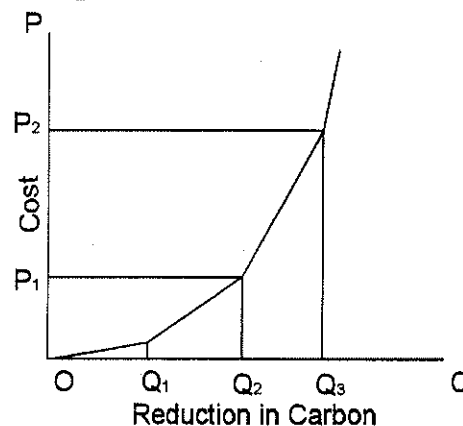
$$\frac{S}{C} = (p_b^s - p_b^d)\alpha \quad (26)$$

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

	<i>Cattle Rearing</i>	<i>Cattle Other</i>	<i>Tillage</i>
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 use¹⁵ 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.

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*

	<i>Cattle Rearing</i>	<i>Cattle Other</i>	<i>Tillage</i>	<i>Biomass (willow)</i>
Labour availability	0.046	0.043	0.026	
Labour needed	0.015	0.018	0.023	0.01 to 0.02

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.

