AN ASSESSMENT OF THE EXTERNALITIES OF BIOMASS FOR ELECTRICITY PRODUCTION IN SPAIN

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ABSTRACT

This paper presents a methodology for the quantification of the socioeconomic and environmental externalities of the biomass fuel cycle. It is based on the one developed by the ExternE Project of the European Commission, and extended and modified by CIEMAT for a better adaptation to biomass energy systems. The methodology has been applied to a biomass power plant, fueled by *Cynara cardunculus*, in Southern Spain. The externalities addressed have been macroeconomic effects, employment, CO_2 fixation, erosion, non-point source pollution, and health effects caused by atmospheric pollution. Results, although still uncertain, suggest that the net external costs of biomass energy are lower than that of conventional energy sources, what, if taken into account, would make biomass more competitive than it is now.

KEYWORDS

Biomass, electricity production, externalities, assessment

INTRODUCTION AND OBJECTIVES

Biomass has the greatest potential, among renewable energies, to supply a large amount of energy, in the short and medium term, in the European Union. Its energy may be used for transport, heat or electricity, and so it is expected to be the largest contributor to the EU objective of achieving 15% of its primary energy requirements with renewable energies by year 2010.

However, there are still several barriers for a widespread implementation of biomass energy. One of the major ones is its cost. Currently, private costs for bioelectricity are higher than for other energy options, so there is no incentive for its production. But it has to be reminded that energy options should not be considered only on a private, financial basis. Choosing one option or another may have consequences on many aspects of society and the environment, which should be taken into account if we want to achieve the higher benefits for society.

These consequences on society or the environment, which are not accounted for, are termed *externalities*. They are produced whenever production processes, or consumers' utility, are affected by variables not controlled by themselves, but by other economic agents. The effects may be positive (external benefits) or negative (external cost). Externalities represent costs or benefits not assigned to their responsibles, and thus not taken into account by the market.

This produces a market failure, as the price, which is the market assignment tool, does not account for all costs and benefits lied to the production process. This, in turn, produces an inefficient assignment of resources. If, for example, an external benefit exists, the price will be higher than its optimum, and thus the quantity produced will be lower than the optimum. In order to correct this failure, externalities have to be incorporated to the cost analysis, or *internalized*. However, prior to this internalization, they must be quantified and expressed in the same terms as prices, that is, in monetary units.

This is the objective of the present study, to quantify the positive or negative externalities that biomass may produce on society and the environment, so that they may be included in its price, and thus be reflected in economic decisions. It is expected that the consideration of externalities will make biomass more competitive with conventional energy sources, and thus promote its wider introduction.

METHODOLOGY

The methodology proposed in this paper for the assessement of the externalities of biomass is based on the ExternE one (EC, 1995), developed within the DGXII of the European Commission. This is a bottom-up methodology, that is, it considers the effect of an additional facility, with a marginal approach. It is site- and technology-specific, and its main characteristics are its transparency, comprehensiveness, and consistency.

Transparency is needed to counterbalance the high degree of uncertainty underlying in the analysis. For each of the stages of the assessment, the starting point, the assumptions used, and the estimation methods have to be clearly defined and explained, so that all the uncertainties and caveats are revealed easily. This also allows for sensitivity analisys to be carried out.

Consistency is assured by using the same assumptions and methods for the same impacts, independently of the activity producing them. This is required to allow for a rightful comparison between different energy options, and to remove the uncertainty produced by the estimation method.

Finally, comprehensiveness means considering all possible impacts, from all fuel cycle stages, in spite of them being negligible. This is essential to compare different options on the same basis. All these characteristics must be present along the stages of the assessment, which are described below.

First, the spatial and temporal boundaries of the assessment have to be defined, considering the comprehensiveness of the methodology previously noted, but also the accurateness of the assessment. Once defined the boundaries, both the location and the activities falling within them have to be fully characterized, since they will determine the impacts of the fuel cycle. These impacts, and their relationship with the activities causing them, are usually shown in an accounting framework.

Not all the impacts identified have to be quantified, because some of them may be negligible, and others may be impossible to quantify. Therefore, the most significant impacts are selected, based on expert judgement or previous results. The quantification of the impacts is done using the *damage function* approach. This is a series of logical steps, which trace the impact from the activity that creates it to the damage it produces, independently for each activity and damage considered. This damage function may be represented by an impact pathway, of which a simplified example is shown in fig.1.

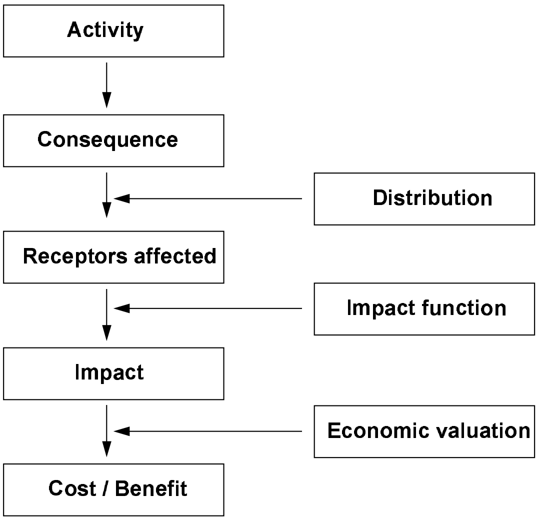

Fig.1. Impact pathway

First, the consequences derived from each activity, such as erosion, or atmospheric emissions, have to be determined. These consequences will then be distributed along time and space, within the boundaries previously defined. That way, the receptors affected are identified. The impacts on these receptors are quantified by means of impact functions. These may be sometimes relatively simple, although they are usually quite complex, such as dose-response functions, or complex models. The main problems in this stage arise from the lack of adequate impact functions in some cases, and from the interactions existing between different impacts.

The last stage for the quantification of externalities is the economic valuation of costs and benefits. Since prices reflect marginal utility, externalities have to be valued in the same term. Hence, their economic valuation is based on the willingness to pay (WTP) for, or to accept, a welfare change. This measure is easier to obtain when there is a market for the affected goods. However, this is not the common case, so other alternative valuation methods, such as contingent valuation, have to be used. The major obstacle for using these methods is that the transferability of the values obtained is very limited. In addition, there are no WTP values for impacts such as soil erosion or employment, so other estimates have to be used.

In addition to all the uncertainty sources cited along the stages of the assessment, there is another of great importance, due to the consideration of long-term effects, which is the choice of discount rate. There are not yet clear indications for this choice in literature. All these uncertainties should be dealt with using conventional statistical techniques. Unfortunately, this is not possible in most cases, so it has to be assessed by sensitivity analysis or expert judgement.

RESULTS

The externalities addressed in the study have been macroeconomic effects, employment, CO_2 fixation, erosion, non-point source pollution, and health effects of atmospheric pollution. The methodology has been applied to a 20 MW fludized bed combustion power plant, sited near Seville, in Southern Spain. The fuel used is *Cynara cardunculus*, grown in 9,300 ha of set-aside lands. It has to be reminded that what have been estimated are gross externalities, that is, that caused by the implementation of this biomass power plant. In order to obtain the net externality, the externalities of the alternatives have to be estimated and then compared. To ease this comparison, monetary values are referred to the electricity production of the power plant, as shown in table 1, in which values obtained are expressed in mECU per kWh.

Macroeconomic Effects

The implementation of a power plant produces effects in the rest of the economy, because of the increase in demand of goods and services created by the expenditure in the project. These effects have been assessed by means of an input-output model. Introducing in the model the expenditure generated by the plant construction and operation, and by fuel production, both in intermediate inputs and in labour, what amounts to an annual average figure between 2,709 and 5,995 kECU (depending on the discount rate chosen), the increases in gross domestic product (GDP) and government tax revenues have been estimated. For GDP, the results range between 1,324 and 2,729 kECU per year, and for tax revenues the results are 391 to 806 kECU per year. These values should not be added, as GDP may include some of the tax revenues.

Employment

Both direct and indirect employment effects of the biomass power plant have been assessed, along all the fuel cycle. Direct employment has been estimated from similar projects or direct calculations, amounting to around 81 jobs. Indirect employment is that created by the new flow of expenditure generated by the project, and so it has been assessed using the same input-output model as for the other macroeconomic effects. It has been estimated to range between 19 and 39 jobs. The economic valuation of employment has been attempted by calculating government savings in unemployment subsidies, both in agriculture (which features a special regime in Spain) and in the rest of the economy. The government savings would be some 365 to 1,222 kECU per year. It is assumed that this approach provides a lower limit for the value of employment, since it is considered that job creation has a higher value for society than that reflected by unemployment subsidies.

CO_2 Fixation

This may be the most controversial effect to value, because of the uncertainty of the global warming process itself, and of the effects it may produce. In the present study, CO_2 emissions and absorptions for the whole biomass fuel cycle have been accounted, resulting in a net CO_2 absorption, of 13,116 tons of CO_2 per year, because of the carbon fixation by the energy crop. The valuation of this absorption has been made using literature values for the damages caused per ton of CO_2 emitted, ranging from 2.18 to 15.45 ECUper ton (Dorland et al, 1995). This results in benefits of 29 to 203 kECU per year. In addition to the uncertainties cited above, a major caveat is the assumption that the negative impact of emissions will equal the positive impact of the absorption.

Erosion

Soil losses due to the energy crop cultivation have been assessed using the EPIC model, developed by the US Dept. of Agriculture, resulting in 1.12 t/ha per year, or 10,427 tons per year for the whole area. Damages are caused when the soil is then carried by water, into watercourses and reservoirs, altering water flow and storage capacity. However, the valuation of these effects is quite difficult, because of the complexity of the processes involved. As a first approximation, the cost of sediment removal from reservoirs has been used to estimate the damages caused by erosion, amounting to 80 to 178 kECU per year.

Non-point Source Pollution

Using the same EPIC model mentioned above, the amount of fertilizers and pesticides lost by leaching and runoff into groundwaters has been estimated to be around 18,073 kgNO_3 and 2,366 kgP per year. Unfortunately, as for erosion impacts, very little information exists on the quantitative impacts that these products may cause in the environment, and so only a valuation for the impact of nitrates in groundwaters has been carried out. This valuation is based in a study by Silvander (1991) who obtained the willingness to pay to reduce nitrate concentration in groundwaters. The resulting figure is 12 to 119 kECU per year. However, it is expected that this value will be lower for Spain, because of the lower public concern for nitrate pollution.

Health Effects

The health effects considered have been those caused by atmospheric pollutants, such as particulate matter (PM), SO_2, NO_x, and ozone. However, no dispersion models are available for ozone or NO_x, and SO_2 emissions are negligible. Thus, the effects assessed have been only those of PM, and of these only from the emissions from the generation stage, as mobile-source emissions are much smaller, and their dispersion modeling very complex. PM concentrations have been estimated with ISC and WTM models included in EcoSense software, developed by IER. For the quantification and valuation of the impacts, the dose-response functions and monetary values proposed by the ExternE Project (EC, 1995) have been used, producing values from 290 to 683 kECU per year.

These results are summarized in table 1. Effects are shown with their corresponding sign, positive for benefits and negative for costs. It is important to note that these results are still subtotals, as other important impacts, such as those on biodiversity, recreation, or road networks have to be assessed.

Table 1. Impacts and externalities of the biomass fuel cycle.

	Physical impact per year	Monetary valuation (mECU/kWh)
GDP (+)	1,324-2,729 kECU	8.83-18.19
Tax revenues (+)	391-806 kECU	2.61-5.37
Employment (+)	100-120 jobs	2.43-8.15
CO_2 fixation (+)	13,116 t CO_2	0.05-1.15
Erosion (-)	10,427 t soil	0.54-1.19
Non-point source pollution (-)	18,073 kg NO_3	0.08-0.80
Health effects (-)	various types	1.93-4.55

CONCLUSIONS

This paper has presented a methodology for the quantification of externalities of biomass energy systems, as a first step towards their internalization. The methodology, developed by the ExternE Project of the European Commission, and adapted by CIEMAT, offers several advantages, which have been explained. The results of its application for a biomass power plant in Spain have been shown.

These results, which are gross externalities, have to be added to the private costs to produce the total cost of electricity production with biomass. In order to compare with the possible alternatives, the external costs of those should also be added.

When a rough comparison is attempted, preliminary results suggest that biomass energy net external costs may be lower than those of conventional energy sources. If coal is taken as an example, it may be seen that negative impacts of biomass, except for non-point source pollution, are lower, while positive impacts are higher. In the case of global warming and erosion, the difference between biomass and coal externalities may account for more than the difference in their production prices.

Therefore, we may conclude that, in spite of the great uncertainty underlying the assessment of externalities, it seems that the total cost of producing electricity from biomass is lower than that of electricity from fossil fuels, mostly because of the environmental benefits and the employment created. This costs competitiveness should promote a larger implementation of biomass energy.

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