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Monetization of Environmental Externalities (Emissions) from Bioenergy

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Abstract. Bioenergy from agriculture is today in the heart of sustainable development, integrating its key components: environment and climate change, energy economics and energy supply, agriculture, rural and social development. Each bioenergy production route presents externalities that must be assessed in order to compare one bioenergy route to another (bio)energy route. The lack of primary and reliable data on externalities is, nevertheless, an important non-technological barrier to the implementation of the best (bio)energy routes. In this article, we want to monetize one environmental externality from bioenergy: emissions (GHG: CO_2, CH_4, N_2O, O_3; CO, NO_x, SO_2, metal, and PM). We have to monetize emissions on the basis of their effects on health, global warming, and soil and water quality. Emissions will be quantified through Life Cycle Analysis (LCA) and ECOINVENT database. Impacts on health will be monetized on the basis of mortality (number of life expectancy years lost multiplied by Value Of Life Year (VOLY)) and morbidity (number of ill persons multiplied by Cost Of Illness (COI)). Impacts on global warming will be monetized by Benefits Transfers from the Stern Review and its critics. Finally, impacts on soil and water quality will be monetized by Averting Behaviour or Defensive Expenses methods. Monetization results will be gathered, weighted, and incorporated in states and firms' decision-making tools. They would enhance capacity of policy makers and managers to chose the best (bio)energy routes.

Keywords: Sustainable development, externality, monetization, bioenergy, emissions

1. Introduction

Bioenergy from agriculture is today in the heart of sustainable development, integrating its key components: environment and climate change, energy economics and energy supply, agriculture, rural and social development. Fighting against climate change imposes the mitigation of greenhouse gases. Considerable efforts have to be pursued, especially in the field of energy production and use.

Each bioenergy production route[2] presents positive and/or negative environmental and socio-economic impacts[3] or externalities[4]. These externalities must be assessed in order to compare one bioenergy route to another (bio)energy route. The lack of primary and reliable data on

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[2] For example: rapeseed, soybean, grass, cereals, sugar beet, maize, miscanthus, potato, hemp, flax, animal by-products…
[3] Emissions, global warming, soil and water quality, health, employment and income, rural development, land-use competition, energy security, public expenses…
[4] "*An externality is present whenever the well-being of a consumer or the production possibilities of a firm are directly affected by the actions of another agent in the economy.*" (Mas-Colell *et al,* 1995). Externalities are goods which have positive or negative interest for economic agents but that are not sold on market. As externalities are market imperfections, they can prevent Pareto efficient allocation of resources (Varian, 1994).

externalities is, nevertheless, an important non-technological barrier to the implementation of the best (bio) energy.

We focus on the monetization of one environmental externality from bioenergy: the emissions. This monetization would allow integration of emissions impacts in states and firms' decision-making tools and would enhance capacity of policy makers to chose the best (bio)energy routes[5].

Section 2 describes the internal costs and externalities evaluation models and the monetization methods we have found in our literature review. It also underlines the (in)adequacy of existing works to our environmental externalities monetization goal. Section 3 develops our methodology to quantify and monetize environmental (emissions) externalities. Section 4 gives some details on work progress.

2. Existing models and methods

2.1. Internal costs evaluation models

A large part of the literature is interested by internal costs of production of bioenergy. Internal costs evaluation models assess economic viability of bioenergy projects or routes (Van Beeck, 1999). Most of them are very specific: use of Geographic Information System (GIS), focus on crop, pre-feasibility… Other models, such as PRIMES, CETM, GREEN, GTAP (-E) (Truong *et al*, 2007), MARKAL-MACRO, MESSAGE-MACRO (Bahn *et al*), LEAP, use a General Equilibrium Model (GEM) to evaluate internal costs (Weisbrod *et al*, 1996; Breuss *et al*, 1998; ECN, 2004; ECN, 2005; Ignaciuk, 2006). These models can also assess some economic externalities (or some environmental political decisions costs), but their priority is on internal costs evaluation.

2.2. Externalities evaluation models

Some models (BEAM, BIOSEM, ELVIRE, SAFIRE, PLANET, RECAP, etc) consider externalities (Stirling, 1997; Madlener *et al*, 2000; Domac *et al*, 2000; Hektor, 2002; O'Doherty *et al*, 2007) but, most of the time, they focus on few socio-economic externalities and on local initiatives. Some externalities evaluation models are based on multipliers and sometimes on Input-Output matrix; they evaluate employment and income externalities of bioenergy (BIOSEM, ABM, INPUT-OUTPUT models). A model as ExternE mostly evaluates environmental externalities of bioenergy. Some other models (ELVIRE, SAFIRE, PLANET) try to take into account socio-economic and environmental externalities but they evaluate only few externalities. The CASES project gathers different models to evaluate a greater number of socio-economic and environmental externalities.

2.3. Externalities monetization methods

Once bioenergy externalities are identified and quantified, they must be monetized. By definition, there is rarely a market to put a monetary value on externalities. Thus the Willingness To Pay (WTP) of individuals to avoid an externality or their Willingness To Accept (WTA)[6] an externality if compensated for is used to monetize externalities.

This monetization is based on different techniques according to the type of externality (Pearce *et al*, 2006; Atkinson *et al*, 2007; De Palma *et al*, 2007; Jenkins *et al*, 2007). If the externality affects a good used, its use can be actual, planned or possible. If the externality affects a good

[5] This project is tied to the TEXBIAG project: "*Decision Making Tools to Support the Development of Bioenergy in Agriculture*". This project is sponsored by the BELgian Science POlicy and led by Walloon Agricultural Research Center, University of Namur, Vrije Universiteit Brussel and Katholieke Universiteit Leuven.

[6] WTA is often greater than WTP. WTP is more often used in literature.

not or passively used, its value can be of existence[7], altruistic[8] or bequest[9]. For used goods, revealed preferences methods are suitable, for non used goods, stated preferences methods must be adopted.

Revealed preferences methods are based on existing substitute market. The principal revealed preferences methods are Travel Cost Method, Hedonic Price, Averting Behavior and Cost Of Illness. Stated preferences methods are based on hypothetical market created by researchers. Contingent Valuation, Choice Modeling (or Choice Experiment) and Deliberative Monetary Valuation are the principal stated preferences methods. For all types of externalities, WTP or WTA can be assessed indirectly by Benefits Transfers. Benefits Transfers are the adaptation of existing studies and databases to research context.

2.4. (In)adequacy of internal costs and externalities evaluation models and monetization methods to our aim

From our extensive study of the literature, it appears that a large part of it is mostly interested by internal costs of bioenergy production and by the comparison of (bio)energy economic viability and cost-effectiveness. Some environmental externalities are sometimes taken into account (especially emissions) to prove the advantage of bioenergy use. Some socio-economic externalities are also considered (especially direct employment) but, most of the time, at local level (case study of a local initiative).

From this literature review, it also appears that externalities are sometimes quantified (tons of CO_2 emitted, number of jobs created…) but rarely monetized (cost of one ton of CO_2, benefits from job creation…). Nevertheless, several methods to monetize externalities exist.

Among the large number of models which evaluate bioenergy externalities and internal costs, few are relevant for monetizing environmental externalities from bioenergy: ECOINVENT can be used as a database to quantify emissions, and information can be found in ExternE and CASES projects. There are several reasons of the inadequacy of existing works to our bioenergy externalities monetization goals.

First, lots of models evaluate internal costs of bioenergy while we have to assess externalities from bioenergy. Second, lots of models assess impacts on local or regional level or for isolated initiatives while we need to assess bioenergy externalities on a (inter)national level. Third, few bioenergy externalities are evaluated by different models while we want to study more environmental externalities in an integrated model. Fourth, bioenergy externalities are only quantified by existing models while we also want to monetize these externalities.

Existing models can be useful as a tool-box to assess different bioenergy externalities, but we need to construct our own integrated model to monetize environmental (emissions) externalities from bioenergy at a (inter)national level.

Monetization methods are more relevant for us and we can use several of them to assess environmental externalities from bioenergy. For example, we can use Cost Of Illness to assess the impacts of emissions on health, Averting behavior or defensive expenses to assess the impacts of emissions on soil and water quality, and Benefits transfers to monetize the impacts of emissions on global warming.

3. Monetization of emissions

[7] For example, the value of threaten species.
[8] The value for the others.
[9] The value for the future generations.

In this project, we want to monetize emissions[10]: GreenHouse Gases (GHG) emissions (CO_2[11], CH_4[12], N_2O[13], O_3[14]), other emissions (CO[15], NO_x[16], SO_2[17], metal), and particles (PM[18]). We must take into account emissions during the whole life cycle of a product, from production down to waste management[19]. To quantify emissions from each bioenergy route, we will use Life-Cycle Analysis (LCA) and ECOINVENT database.

If we don't adapt an existing database on cost by ton of emission, we have to monetize[20] emissions on the basis of their effects on health, global warming, and soil and water quality. We don't investigate impacts on material, landscape, noise, odor, visibility, biodiversity… In literature, monetization of these impacts is negligible when compared to impacts on health and global warming.

Monetization of health, global warming, and soil and water quality externalities from emissions will be gathered and weighted to obtain emissions externality assessment.

3.1. Health impacts

To monetize emissions impacts on health, we must calculate the incremental health cost due to emissions[21]. The choice of illnesses to consider is difficult as specific illnesses are rarely linked with certainty to specific pollutants. However we can focus on respiratory problems (asthma, Chronic Obstructive Pulmonary Disease…), cancers, cardiac problems, hypertension, allergies, children's problems, and symptoms not severe.

The link between one ton of emission and the number of life expectancy years lost and/or the number of ill persons will be the more difficult part of the evaluation.

Health externality is assessed on the basis of the sum of all individuals' WTP to avoid it. Individuals are ready to pay to see their health risk from emissions reduced but also to see their relatives' and the whole society's health risk reduced. As there is no real market for health, we cannot use market price. The multiplicity of health service payers[22] doesn't facilitate the evaluation of WTP to avoid health externality. There is also a disjunction between large part of payments[23] and medical goods or services received. Payments are global and made by groups and purchases of medical goods or services are illness specific and made by individuals.

To evaluate WTP to reduce mortality[24] risk from emissions, we will multiply the number of life expectancy years lost due to premature deaths by a Value Of Life Year (VOLY) [25].

To evaluate WTP to reduce morbidity risk from emissions, the best way is to multiply the number of ill persons by their Cost Of Illness (COI). COI is composed by all direct, medical or not, and indirect costs tied to a specific disease from diagnosis to cure or death: hospital

[10] "*Primary pollutants are pollutants present in the state that they were emitted, whilst secondary pollutants are not emitted as such, but formed in the atmosphere through chemical reactions between one or more pollutants.*" (Holland *et al*, 2002, p. 3).
[11] Carbon dioxide
[12] Methane
[13] Nitrous oxide
[14] Ozone
[15] Oxide of carbon
[16] Oxides of nitrogen
[17] Sulphur dioxide
[18] Particulate Matter of different sizes
[19] For example, we must take into account emissions from transport of production to distribution sites, from end-use of production and from waste management.
[20] We only consider monetization of impacts. Identification of emissions, calculation of dispersion, and identification of population exposed (exposure-response functions) are considered as given.
[21] "*(…) medical cost avoided due to pollution prevention or costs incurred due to a lack of pollution control*." (ABT ASSOCIATES, 2003, p. 3).
[22] Patients, public administration, mutual and private insurances, etc.
[23] Taxes, insurance provision, etc.
[24] "*(…) people dying earlier than they would in the absence of air pollution.*" (Holland *et al*, 2002, p. 3).
[25] Other possibilities are the Value Of Statistical Life (VOSL) and the human capital approach.

admissions, emergency room visits, treatments (medicine), symptom days, and restricted activity days.

We will find data on number of life expectancy years lost and on number of ill persons in medical mortality and morbidity databases. VOLY and cost of standard treatments will be obtained by Benefits Transfers[26] and experts' advices.

3.2. Global warming impacts

To monetize emissions externalities, we also need to take into account emissions impacts on global warming. GHG have impacts on global warming which itself has worldwide impacts: mortality, morbidity, sea level, energy demand, migrations, agricultural and economic impacts...

As assessing costs of global warming is beyond the scope of this project, we will use Benefits Transfers method. A great number of studies (CASES, 2007, pp. 34-52; Kuik *et al*, 2007) try to assess GHG cost, in particular, CO_2 cost. The cost by ton of CO_2 emitted varies a lot between studies. We can find information on global warming costs in the *Stern review* (Stern, 2006) and in its numerous critics.

3.3. Soil and water quality impacts

To monetize emissions externalities, we finally consider emissions impacts on soil and water quality. We need to identify and quantify the link between soil and water quality and emissions due to agricultural practices used in bioenergy conversion routes. Some modelling of the link between soil and water quality and bioenergy emissions will be available this summer. To monetize the emissions impacts on soil and water quality, we can use soil and water treatment costs, and health and environmental costs due to acidification, eutrophication...

Conclusion

This project is still in progress. Bioenergy conversion routes are selected and detailed by project partners. For each bioenergy route retained, the quantification of emissions based on ECOINVENT database has begun. We have now to define monetary values by ton of emissions. These monetary values will be based on emissions impacts on health, global warming and soil and water quality. Monetization results will be gathered, weighted, and incorporated in states and firms' decision-making tools[27]. They would enhance capacity of policy makers and managers to chose the best (bio)energy routes.

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[26] Another possibility is the Contingent Valuation.

[27] Integration of environmental impacts has a cost for firms but can also have potential benefits: goodwill, brand value, increased performance, market share and sales, customers' trust, labels, certifications, awards, subsidies, decreased taxes and fines, workers' motivation, etc. There are different ways to integrate emissions impacts in firms' decision-making tools but Full Cost Accounting seems to be the most relevant method (Criardo *et al*, 2007).

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