

MONETIZATION OF ENVIRONMENTAL AND SOCIO-  
ECONOMIC EXTERNALITIES 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 positive and/or negative externalities: GreenHouse Gases and other emissions, soil and water quality, agrochemicals, biodiversity, land-use change, health, local prosperity and well-being, property rights and working conditions... 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 externalities is, nevertheless, an important non-technological barrier to the implementation of the best (bio)energy routes. In this paper, we want to monetize environmental and socio-economic externalities from bioenergy. When monetization of externalities is not possible, another quantitative or a qualitative assessment is proposed. Monetization and other assessment 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.

Key words: sustainable development, bioenergy, externalities, monetization

## 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 [1] presents positive and/or negative environmental and socio-economic impacts or externalities [2]. 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 externalities is, nevertheless, an important non-technological barrier to the implementation of the best (bio)energy.

In this report, we describe the relevant externalities and indicators for the TEXBIAG [3] project. These externalities must fit the biomass and bioenergy sustainability criteria. Retained externalities and indicators are derived from our literature review and from our assessment of sustainability criteria initiatives and certification systems.

If there is a consensus, among initiatives and certification systems, on a list of externalities (or criteria) to take into account, there is little information on indicators to measure these externalities. Several indicators and their methodologies still need to be described accurately. Our proposition is to take part in this exploratory process.

Some of the retained externalities are already measurable by well-defined indicators:

- GreenHouse Gases (GHG) emissions,
- Carbon stocks,
- Air quality.

They can be quantified and, probably, monetized on the basis of their impacts on health, global warming and soil and water quality. We give to these externalities a *green light*.

Some other externalities still need well-defined indicators to be measured:

- Land-use change,
- Health (to monetize emissions impacts),
- Soil quality,
- Water quality,
- Agrochemicals,
- Biodiversity,
- Genetically Modified Organism (GMO),
- Local prosperity.

We give an *orange light* to these externalities and we propose to organise brainstorming sessions, with three or four experts. Experts will have to define indicators to measure these externalities. Their indicators definitions will then be validated by, for example, a *Delphi* method. On the basis of these brainstorming sessions, we will know if it is possible and relevant to monetize these externalities.

Finally, some externalities cannot get better indicator than a *go/no go* or a traffic lights *colour*:

- Working conditions,
- Property rights,
- Local well-being.

We give a *red light* to these externalities and develop qualitative indicators that can be used by policy makers and managers to assess them.

Two last externalities seem interesting to study but their impact assessment is beyond the scope of the TEXBIAG project:

- Competition with food,
- Energy security.

Both get a *red light*. Nevertheless, we give some information on them at the end of this paper.

Monetized indicators will be introduced in System Perturbation Analysis (SPA) from VUB to enhance policy makers' choice of the best bioenergy routes. Monetized and non-monetized indicators will be introduced in tables which will contain all monetized, quantitative and qualitative information (Adams *et al*, 2006) on each bioenergy route retained (one table by bioenergy route). These tables will allow policy makers and managers to take into account all dimensions [4] of sustainable development in their choice of the best bioenergy routes to support.

Section 2 focuses on the sustainability criteria developed by sustainability criteria initiatives and certification systems. In Section 3, we describe the indicators developed or to be developed by TEXBIAG project for the externalities retained. Section 4 concludes.

#### Externalities considered by sustainability criteria initiatives and certification systems

The aim of this paper is to define a list of externalities (and their indicators) that fits TEXBIAG partners and Belgian Federal Public Service (FPS) – Health, Food Chain Safety and Environment requirements. TEXBIAG partners need externalities that can be monetized and then introduced in decision-making tools to support bioenergy. FPS needs sustainability criteria to develop a certification system of bioenergy or biomass.

Sustainability criteria initiatives and certification systems on biomass and /or bioenergy already exist. Some are relevant for TEXBIAG externalities selection. We consider a panel of initiatives led by different stakeholders (consultants, government representatives, distributors, social and/or environmental NGOs...) on different agricultural products (soy, palm oil, fruits and vegetables, coffee, wood...).

Table 1 presents the relevant sustainability criteria initiatives and certification systems, their acronyms, and the sources where can be found a complete table of their criteria.

These initiatives and certification systems take different sustainability criteria into account. Table 2 briefly presents the list of sustainability criteria retained by initiatives and certification systems.

From our literature review, we can see that Cramer Commission and RTFO initiatives cover the greatest number of sustainability criteria and describe them with lots of details (and methodologies). Moreover the Cramer Commission initiative seems to guide European Union work on sustainability criteria. Thus, Cramer Commission and RTFO, which are commissioned by public authorities and developed by consultants in collaboration with stakeholders (industries, NGOs...), should also inspire our own selection of externalities.

Section 3 describes how TEXBIAG project defines externalities retained, and how it develops (or expects to develop) indicators for measuring these externalities quantitatively and / or qualitatively. These indicators should be:

- Operational at reasonable cost,
- Checkable regularly at reasonable cost,
- Relevant for all types of produced or imported energy,
- Compatible with international measures (a special attention must be paid to WTO acceptance if these externalities are considered as compulsory (Biomass Technology Group, 2008)).

#### Externalities considered by TEXBIAG project

For each environmental or socio-economic externality retained, TEXBIAG project proposes, below, quantitative (quantification, monetization) and/or qualitative (reporting, quotation) indicators. A traffic lights *color* (*green, orange or red*) is attached to each externality considered according to the present state of development of its quantitative indicators and monetization methodology.

#### *Environmental externalities*

##### *Global warming*

*GreenHouse Gases.* For each bioenergy route selected, TEXBIAG project will study:

- CO<sub>2</sub> [5],
- CH<sub>4</sub> [6],
- N<sub>2</sub>O [7],
- and O<sub>3</sub> [8] emissions.

GHG emissions will be quantified from feedstock production down to waste management by Life-Cycle Analysis (LCA) through ECOINVENT database.

Calculation methodology is derived from Fuel Quality and Renewable European Directives (EC, 2007; EC, 2008 [9]) [10]. Emissions during cultivation, transport, processing, distribution and end-use steps are considered. Method for accounting co-products is allocation by energy. When values are missing, default values (conservative) are available.

$$E = eec + el + ep + etd + eu - eccs - eccr - eee$$

where

- E = total emissions,
- eec = emissions from extraction or cultivation of raw material,
- el = annualised emissions from carbon stock change caused by land-use change,
- ep = emissions from processing,
- etd = emissions from transport and distribution,
- eu = emissions from use,
- eccs = emission savings from carbon capture and sequestration,
- eccr = emission savings from carbon capture and replacement,
- eee = emission savings from excess electricity from cogeneration.

Quantification will give us net emissions (gCO<sub>2</sub>eq [11]/MJ [12]).

Direct land-use change impacts on GHG emissions are considered. If bioenergy crop replaces another crop, direct land-use change impacts on GHG emissions are taken into account one time (one-shot). If bioenergy crop is cultivated on land that wasn't cultivated before (forests, grasslands, wetlands...), we have a change in carbon stocks that must be assessed during a number of years (20 years).

Calculation of annualised emissions from carbon stock change:

$$(CSR - CSA) \times MWCO_2 / MWC \times 1/20 \times 1/P$$

where

- CSR = Carbon stock reference (January 2008, ton carbon/ha),
- CSA = Carbon stock when raw material was taken (ton carbon/ha),
- MWCO<sub>2</sub> = 44.010 (Molecular Weight of CO<sub>2</sub>),
- MWC = 12.011 (Molecular Weight of C),
- P = yield/hectare

Emissions from bioenergy will then be compared to emissions from fossil energy references. GHG emission savings targets can also be defined on the basis of the European Directives (a minimum requirement of 35 % emission savings from fossil fuel comparator). Emissions can also be compared between bioenergy routes.

Quantified emissions can then be monetized on the basis of their impacts on health, global warming, and soil and water quality [13].

To monetize emissions impacts on health, we can calculate the incremental health cost due to emissions [14]. 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 (COPD)...),
- Cancers,
- Cardiac problems,
- Hypertension,
- Allergies,
- Children's problems,

- 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 is the more difficult part of the evaluation.

Health externality can be assessed on the basis of the sum of all individuals' Willingness To Pay (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 [15] doesn't facilitate the evaluation of WTP to avoid health externality. There is also a disjunction between large part of payments [16] 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 [17] risk from emissions, we can multiply the number of life expectancy years lost due to premature deaths by a Value Of Life Year (VOLY) [18].

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 admissions,
- Emergency room visits,
- Treatments (medicine),
- Symptom days,
- Restricted activity days.

We can 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 can be obtained by Benefits Transfers [19] and experts' advices.

In order to assess accurately emissions impacts on health, we propose to lead a brainstorming session with three or four experts to define indicators and methodologies.

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 can use Benefits Transfers method. A great number of studies (CASES, 2007; Kuik *et al*, 2007) try to assess GHG cost, in particular, CO<sub>2</sub> cost. The cost by ton of CO<sub>2</sub> 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.

To monetize emissions externalities, we can 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.

GHG externality gets a *green* light but some parts of its monetization deserve more information (for example, brainstorming session on health impacts of GHG emissions).

*Carbon stocks.* For each selected bioenergy route, the role of bioenergy production as carbon sinks and sources will be considered in GHG emissions quantification. Direct land-use change will be taken into account.

Carbon sinks, above (vegetation) and below (soil) ground, must be maintained. Conversion of wetlands, forests...is not allowed because GHG released during the conversion of these areas cannot be compensated by bioenergy GHG savings in a reasonable period. Evidence of carbon sinks conservation compared to a reference date (to be defined) must be reported.

Carbon stocks externality gets a *green* light as necessary information to assess it is present in GHG and land-use change externalities.

*Land-use change.* For each selected bioenergy route, TEXBIAG project proposes to study the impacts of land-use change.

Land-use change has direct and indirect impacts. Direct impacts arise when a crop is replaced, on a specific parcel, by a bioenergy crop. Indirect impacts arise because what is no more produced on this parcel must be produced elsewhere at the expense of other land.

Land-use change has different impacts on emissions (Searchinger *et al*, 2008), biodiversity (Riedacker, 2007), competition with other land-uses, and so on. Here, we focus on direct and indirect impacts of land-use change on GHG emissions.

Direct land-use change impacts are taken into account in GHG emissions calculation. Indirect land-use change impacts must be studied and reported at national level.

Direct impacts of land-use change on GHG emissions are considered in GHG calculation method. It's important to note that impacts of land-use change on GHG emissions are linked to the mass plant and to the soil. If the mass plant change can be assessed, the change in Soil Organic Carbon (SOC) is more difficult to evaluate. It is a slow process which depends on numerous factors.

Indirect impacts of land-use change must be reported by governments and compared to a reference date (to be defined).

A brainstorming session, with three or four experts, seems necessary to ensure the adequate definition of the indicators to measure land-use change externality. For this reason, we give an *orange* light to land-use change externality.

### *Environment quality*

Environment quality externalities depend on Good Agricultural Practices (GAP). These GAP are described by cross-compliance rules (EC, 2003) of Common Agricultural Policy (CAP). These rules only apply to European farmers but we are looking for a common set of sustainability criteria for biomass and bioenergy produced in European Union (EU) or imported from outside EU. Nevertheless, we can recommend a qualitative assessment of agricultural practices to produce biomass and bioenergy within or outside EU.

*Air quality.* For each selected bioenergy route, TEXBIAG project will study:

- CO [20],
- NO<sub>x</sub> [21],
- SO<sub>2</sub> [22],
- metal emissions,
- and PM [23].

Other emissions can also be considered:

- NMVOC [24],
- PAH [25],
- and Benzene.

These emissions will be quantified from feedstock production down to waste management by LCA through ECOINVENT database.

Quantification will give us net emissions (g/MJ) that will be compared to emissions from fossil energy references.

Moreover, emissions quantified will be monetized on the basis of their impacts on health and soil and water quality.

Evidence of compliance with relevant laws and regulations, and reporting of GAP can be complementary to the quantitative assessment.

Prioritization of good practices and quotation for compliance (for example, according to the number of regulations respected or to the number of priority good practices applied) could be developed.

As methodologies for quantification and monetization of emissions are already well defined for GHG externality, we give a *green* light to air quality externality. Nevertheless, the prioritization of good practices and the quotation for compliance that can be developed through other externalities brainstorming sessions (for example, soil quality, water quality...) could be relevant for air quality externality too.

*Soil quality.* For each selected bioenergy route, TEXBIAG project will study agricultural practices impacts (negative or positive) on soil structure and fertility. Agricultural practices must:

- Control erosion,
- Avoid steep slope cultivation,
- Prevent salination,
- Preserve nutrient balance and organic matter (for example, pH),
- Promote crop rotation,
- Manage residues removal,
- Reduce burning use,
- Manage waste treatment,
- ...

Some impacts on soil quality can be quantified and monetized:

- Health and economic impacts (yield) from acidification, eutrophication,
- Cost of treatment to restore soil quality (for example, organic or mineral fertilizers cost),
- Cost of pollution control,
- ...

Evidence of compliance with relevant laws and regulations, and reporting of GAP can be complementary to the quantitative assessment.

Prioritization of good practices and quotation for compliance could be developed.

A brainstorming session, with three or four experts, is necessary to define quantitative indicators, monetization methodology, good practices prioritization and/or compliance quotation for soil quality externality. Thus we give an *orange* light to this externality.

*Water quality.* For each selected bioenergy route, TEXBIAG project will study agricultural practices impacts (negative or positive) on ground and surface water quantity and quality. Agricultural practices must:

- Prevent depletion,
- Prevent use from non-sustainable resources,
- Promote efficient use (irrigation),
- Manage treatment and reuse,
- Prevent and correct contamination,
- Manage waste,
- Protect natural courses and wetlands,
- ...

Water quantity needed by each bioenergy route must be reported.

Some impacts on water quality can be monetized:

- Health and economic impacts from acidification, eutrophication,
- Cost of making water drinkable (for example, contamination categories can be tied to specific treatment cost classes),
- Financial penalties for surface and non-exploited ground water that is not cleaned,
- ...

Evidence of compliance with relevant laws and regulations, and reporting of GAP can be complementary to the quantitative assessment.

Prioritization of good practices and quotation for compliance could be developed.

As a brainstorming session is necessary to define quantitative indicators, monetization methodology, good practices prioritization and/or compliance quotation for water quality externality, we give an *orange* light to this externality.

*Agrochemicals.* For each selected bioenergy route, TEXBIAG project will study agrochemicals [26], fertilizers and pesticides used by agricultural practices:

- Agrochemicals use must be responsible,
- Agrochemicals cannot be banned by (inter)national laws, conventions and regulations (World Health Organization (WHO) type 1A or 1B, Amsterdam convention, Stockholm convention on pesticides),
- Workers in charge of agrochemicals must be trained and adequately equipped,
- Agrochemicals must be stored and disposed adequately,
- Crop rotation and ICP must be promoted,
- Biological alternatives and IPM must be promoted,
- ...

Agrochemicals, fertilizers and pesticides used by each bioenergy route will be quantified by LCA through ECOINVENT database.

Some agrochemicals impacts can be monetized:

- Impacts on health,
- Impacts on soil and water quality,
- Cost of agrochemicals,
- ...

Evidence of compliance with relevant laws and regulations (no use of banned agrochemicals), and reporting of GAP can be complementary to the quantitative assessment.

Prioritization of good practices and quotation for compliance could be developed.

A brainstorming session is necessary to define quantitative indicators, monetization methodology, good practices prioritization, and/or compliance quotation for agrochemicals externality. Thus we give an *orange* light to this externality.

### *Biodiversity*

*Biodiversity.* For each selected bioenergy route, TEXBIAG project will study impacts (negative or positive) of agricultural practices on biodiversity. Agricultural practices must:

- Conserve and restore high conservation value, protected and / or vulnerable areas,
- Preserve rare, threatened and / or endangered species (and their habitats),
- Avoid deforestation,
- Avoid burning use,
- Promote native crop species,
- Preserve landscape,
- ...

Moreover, some areas must be excluded from cultivation (EC, 2008):

- Forests undisturbed by significant human activity (no intervention or sufficiently long ago),
- Areas designated by relevant law or authority for nature protection purposes,
- Areas for the protection of rare, threatened or endangered ecosystems or species recognised by international agreements or included in lists drawn up by intergovernmental or international non-governmental organisations,
- Grasslands with high biodiversity (species-rich, not fertilised, not degraded).

Biodiversity externality can be assessed by, for example, Potentially Disappeared Fraction of species (PDF) and compared to a reference date (to be defined).

Biodiversity externality can also be monetized by, for example, Benefits transfers from Contingent valuations (Rehdanz, 2007).

Evidence of compliance with relevant rules (EU), conventions (CBD, CITES), and treaties can be complementary to the quantitative assessment.

Quotation for this compliance could be developed (for example, according to the number of conventions, or articles of conventions, respected).

Biodiversity externality gets an *orange* light as a brainstorming session, with three or four experts, is necessary to define its quantitative indicators, monetization methodology and/or compliance quotation.

*Genetically Modified Organism.* As highly discussed topic, GMO use cannot be put aside from our discussion of sustainability criteria for bioenergy.

For each bioenergy route selected, TEXBIAG project proposes that GMO use be reported.

Evidence of compliance with relevant laws and regulations on GMO should also be required. Quotation for this compliance could be developed.

It seems difficult to monetize GMO externality. However, we expect to lead a brainstorming session on this topic (or to tie GMO discussion with another externality brainstorming) in order to gather additional information and define compliance quotation. Presently, we give an *orange* light to GMO externality.

### *Socio-economic externalities*

It's important to note here that taking into account some socio-economic externalities, as taking into account biodiversity externality, can be incompatible with WTO rules if this integration of externalities is compulsory (in a certification scheme, for example).

### *Local prosperity*

For each bioenergy route selected, TEXBIAG project proposes to study active contribution to local prosperity through economic performance indicators:

- Employment creation (for local staff),
- Rural value added,
- Local expenses,
- ...

We do not assess the socio-economic sustainability of a particular batch of biomass or bioenergy from a specific plant. We assess the socio-economic sustainability of a bioenergy route. This prevents a direct implementation of indicators from Global Reporting Initiative (GRI, 2006).

Employment can be direct, indirect or induced. Direct employment is due to the activity of, for example, a new or a bigger bioenergy production plant. Indirect employment is due to increased activity for the suppliers of the bioenergy production plant, and for the suppliers of these suppliers, and so on. Induced employment is due to increased spending made by people who get an income from bioenergy production plant, from bioenergy production plant's suppliers, or from suppliers of suppliers... There are also displacement effects: bioenergy adoption creates activity (for example, in agricultural sector) but also destructs or displaces activity (for example, in fossil energy sector...). To take this phenomenon into account, net employment creation must be calculated.

The part of employment creation opens to local population should be considered (Domac *et al.*, 2005).

Net employment creation can be monetized.

Rural value added and local expenses could be assessed through LCA, if we can identify which part of the cultivation and the processing of biomass or bioenergy influences local population: origin of raw material, furniture, infrastructure...

Local prosperity externality gets an *orange* light as a brainstorming session, with three or four experts, is necessary to define accurately its quantitative indicators and monetization methodology.

### *Working conditions*

For each selected bioenergy route, TEXBIAG project will study working conditions. Working conditions to respect are:

- Legal (sub)contracts,
- Legal national minimum or relevant industry standard wage (paid regularly and in convenient form),
- Maximum working hours,
- Health and safety (information on hazards, potable water, clean sanitary, clean place to eat, protective equipment, preventive measures, accidents records, medical care, clean and safe accommodation if applicable...),
- Training,
- Information on workers' rights,
- Freedom of association and collective bargaining right (ILO conventions 87 [27] and 98 [28]),
- No discrimination (ILO conventions 100 [29] and 111 [30]),
- No child labour, or only on family farm and without interfering with education (ILO conventions 138 [31] and 182 [32]),
- No forced labour (ILO conventions 29 [33] and 105 [34]),
- ...

Compliance with local and national laws and regulations; and with Human rights and ILO conventions [35] (ILO, 1998) should be reported. Quotation for this compliance could be developed.

It seems difficult to monetize working conditions externality but we expect to define compliance quotation (for example, according to the number of conventions respected). We give a *red* light to working conditions externality.

### *Property rights*

For each selected bioenergy route, TEXBIAG project proposes to study rights that must be clearly defined, documented and legally established; and for which systems to resolve conflicts exist:

- Property rights,
- Land-tenure rights,
- Customary rights,
- Rights of use,
- ...

Evidence of compliance with relevant local and national laws and regulations must be reported. Quotation for this compliance could be developed.

It is irrelevant to monetize property rights externality but we expect to define compliance quotation. We give a *red* light to property rights externality.

### *Local well-being*

For each bioenergy route selected, TEXBIAG project proposes to study the contribution to the well-being of local population. Indicators of local population well-being can be:

- Fair and transparent deals between growers and millers, and smallholders and local businesses,
- Information in adequate form for all stakeholders,
- Discussion possibilities,
- Free consent of local people,
- System to deal with complaints,
- Compensations
- ...

Evidence of compliance with ILO conventions 107 [36] and 169 [37], and evidence of initiatives which contribute to local well-being should be reported. Quotation of these compliance and initiatives could be developed.

It is not relevant to monetize local well-being externality but we expect to define initiatives quotation. We could also think about local well-being indicators during the brainstorming on local prosperity externality. We give a *red* light to local well-being externality.

### *Competition with food*

Impacts of increasing biomass demand for energy use on food markets are difficult to measure. Lots of studies exist but give very different estimations of these impacts [38]: from zero impact to dramatic influence on markets. It's also important to note that, even if increasing biomass demand for energy use has impacts, these impacts are not necessarily negative (higher food price also represents higher income for local farmers).

Nevertheless, food supply must be sufficient to ensure food security. Food (and feed) price must maintain the right of local population to food. Food must be available (quantity) and affordable (price).

Available arable land, degraded land, fallow... should be preferred for bioenergy cultivation to prevent this competition in land-use.

Land, food, feed, livestock availability and prices are interconnected. Assessment of impacts due to bioenergy cultivation needs a model of land, food, feed and livestock markets on international level; this is beyond the scope of TEXBIAG project. A general monitoring of relevant prices evolution, and of local food importations and exportations, seems however relevant to identify any crucial impact of bioenergy cultivation.

Land availability, evolution of land price, food availability (production, importations, exportations) and food, feed, and livestock prices evolution should be monitored.

Due to the absence of consensus on bioenergy impacts on international food markets, and to the impossibility to study this topic within TEXBIAG project, we give a *red* light to competition with food externality.

### *Energy security*

Evaluation of bioenergy impacts on energy security needs a model at European level [39] (Arnold *et al*, 2007abc; Behrens *et al*, 2007), and is thus beyond the scope of TEXBIAG project.

Nevertheless, for each bioenergy route selected, TEXBIAG project proposes to report some information:

- Importations,
- Fossil energy importations replaced by this bioenergy route,
- Exportations,
- By-products importations and exportations,
- Storing possibilities.

For imported bioenergy or biomass, the number of potential countries of origin and the security of their furniture can be assessed.

Due to the impossibility to study this topic within TEXBIAG project, we give a *red* light to energy security externality.

## Conclusion

Table 3 describes the environmental and socio-economic externalities retained in TEXBIAG project, and their quantitative and qualitative indicators. The traffic lights *colour* they get according to the present development of their indicators and monetization methodologies is also given. Brainstorming sessions will enhance the definition of more accurate quantitative indicators.

We can fulfil this table for each bioenergy route selected. It will help policy makers and managers to choose the best bioenergy routes according to sustainability criteria or externalities. At first glance, tables can assist policy makers and managers to put aside bioenergy routes that get a *no go* (or a more nuanced information as traffic lights *colour*) on qualitative assessment. Then, for the remaining bioenergy routes, monetization of some externalities can be introduced in decision-making tools. For policy makers, monetization can be introduced in SPA. And for managers, monetization can be introduced in a socio-environmental management system.

Finally, if the methodology we are developing for TEXBIAG project is fruitful, we could adapt and apply it to other activity sectors.

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## Footnotes

1. For example: rapeseed, soybean, grass, cereals, sugar beet, maize, miscanthus, potato, hemp, flax, animal by-products...
2. “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).
3. 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.
4. Policy makers can give different weights to different dimensions (criteria, externalities) of sustainable development.
5. Carbon dioxide
6. Methane
7. Nitrous oxide
8. Ozone
9. Annex VII
10. Methodologies are also described in Perrin *et al* (2008) and in Vanstappen *et al* (2008).
11. Correspondences between CO<sub>2</sub> and other GHG are available.
12. Efficiency of processing (from raw material to energy) is taken into account.
13. We don’t investigate impacts on material, landscape, noise, odor, visibility... In literature, monetization of these impacts is negligible when compared to impacts on health and global warming.
14. “(...) medical cost avoided due to pollution prevention or costs incurred due to a lack of pollution control.” (ABT ASSOCIATES, 2003, p. 3)
15. Patients, public administration, mutual and private insurances, etc.
16. Taxes, insurance provision, etc.
17. “(...) people dying earlier than they would in the absence of air pollution.” (Holland *et al*, 2002, p. 3)
18. Other possibilities are the Value Of Statistical Life (VOSL) and the human capital approach.
19. Another possibility is the Contingent Valuation
20. Oxide of carbon
21. Oxides of nitrogen
22. Sulphur dioxide
23. Particulate Matter of different sizes
24. Non Methane Volatile Organic Compounds
25. Polycyclic Aromatic Hydrocarbons
26. Agrochemicals, fertilizers and pesticides are called “agrochemicals” here.
27. ILO (1948)
28. ILO (1949)
29. ILO (1951)
30. ILO (1958)
31. ILO (1973)
32. ILO (1999)
33. ILO (1930)
34. ILO (1957a)
35. There are other ILO conventions that should be respected. As sustainability criteria initiatives and certification systems, we propose here a minimum package of conventions to respect.

36. ILO (1957b)
37. ILO (1989)
38. According to date, macro, meso or micro level, and to products considered
39. With a PRIMES or a POLES model
40. GreenHouse Gases
41. If the criteria is selected : +, if the criteria is described : ++, and if some methodology is given :  
+++ , if criteria is lacking: 0
42. Under development
43. Monitoring by Government
44. Genetically Modified Organism
45. Participation, respect...
46. Monitoring by Government

Table 1

*Sustainability criteria initiatives and certification systems*

<b>Initiatives</b>	<b>Acronyms</b>	<b>Sources</b>
Cramer Commission		SenterNovem, 2005; Cramer <i>et al</i> , 2006
Renewable Transport Fuel Obligation	RTFO	Tipper <i>et al</i> , 2006 ; Dehue <i>et al</i> , 2007
Round table on Sustainable Palm Oil	RSPO	Denruyter, 2007; WWF Germany, 2007
Basel Criteria for Responsible Soy Production		Proforest, 2004; RTRS, 2006; Cert ID, 2006
Utz Codes of Conduct		Utz Certified, 2007
Eurep or Global Good Agricultural Practices	EurepGAP- GlobalGAP	GLOBALG.A.P.(EUREPGAP), 2007; ACCS, 2007
International Federation of Organic Agriculture Movements	IFOAM	IFOAM, 2002
Sustainable Agricultural Network / Rainforest Alliance	SAN/RA	Smeets <i>et al</i> , 2006; SAN/RA, 2008
Forest Stewardship Council	FSC	Forest Stewardship Council, 2002; Stupak, 2007
Pan-European Forest Council	PEFC	PEFC, 1998; Stupak, 2007
American Tree Farm System	ATFS	Fritsche <i>et al</i> , 2006
Sustainable Forestry Initiative Standard	SFIS	Fritsche <i>et al</i> , 2006
EUropean Green Electricity NETWORK	Eugene	Van Dam <i>et al</i> , 2006; Fritsche <i>et al</i> , 2006
Green Gold Label program	GGL	Van Dam <i>et al</i> , 2006; Fritsche <i>et al</i> , 2006
Öko-institut		Fritsche <i>et al</i> , 2006



Table 3

*Qualitative and quantitative indicators for environmental and socio-economic externalities*

	Qualitative indicators	Quantitative indicators	Traffic lights colour
<b>Environmental externalities</b>			
Global warming			
<i>GHG</i>		<ul style="list-style-type: none"> <li>➤ Net emissions (gCO<sub>2</sub>eq/MJ) of CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O and O<sub>3</sub></li> <li>➤ Minimum requirement of 35% emission savings from fossil energy references</li> <li>➤ Monetization (cost by gCO<sub>2</sub>eq) of impacts on health, global warming and soil and water quality</li> </ul>	Green
<i>Carbon stocks</i>	<ul style="list-style-type: none"> <li>➤ Evidence of no conversion of wetlands and forests</li> <li>➤ Evidence of conservation compared to a reference date</li> </ul>	<ul style="list-style-type: none"> <li>➤ Considered in GHG emissions calculation</li> </ul>	Green
<i>Land-use change</i>	<ul style="list-style-type: none"> <li>➤ Reporting of indirect impacts on national level, comparison to a reference date</li> </ul>	<ul style="list-style-type: none"> <li>➤ Direct impacts considered in GHG emissions calculation</li> </ul>	Orange
Environment quality			
<i>Air quality</i>	<ul style="list-style-type: none"> <li>➤ Evidence of compliance with GAP</li> <li>➤ Evidence of compliance with relevant laws and regulations</li> <li>➤ Prioritization of practices and quotation of compliance</li> </ul>	<ul style="list-style-type: none"> <li>➤ Net emissions (g/MJ) of CO, NO<sub>x</sub>, SO<sub>2</sub>, metal, PM (NMVOC, PAH, benzene)</li> <li>➤ Comparison to fossil energy references</li> <li>➤ Monetization (cost by g) of impacts on health and soil and water quality</li> </ul>	Green
<i>Soil quality</i>	<ul style="list-style-type: none"> <li>➤ Evidence of compliance with GAP</li> <li>➤ Evidence of compliance with relevant laws and regulations</li> <li>➤ Prioritization of practices and quotation of compliance</li> </ul>	<ul style="list-style-type: none"> <li>➤ Monetization of health and economic impacts (yield) from acidification, eutrophication</li> <li>➤ Cost of treatment to restore soil quality</li> <li>➤ Cost of pollution control</li> </ul>	Orange
<i>Water quality</i>	<ul style="list-style-type: none"> <li>➤ Evidence of compliance with GAP</li> <li>➤ Evidence of compliance with relevant laws and regulations</li> <li>➤ Prioritization of practices and quotation of compliance</li> </ul>	<ul style="list-style-type: none"> <li>➤ Water quantity needed</li> <li>➤ Monetization of health and economic impacts from acidification, eutrophication</li> <li>➤ Cost of making water drinkable (contamination categories and cost classes)</li> <li>➤ Financial penalties for surface and non-exploited ground water not cleaned</li> </ul>	Orange
<i>Agrochemicals</i>	<ul style="list-style-type: none"> <li>➤ Evidence of compliance with GAP</li> <li>➤ Evidence of compliance with relevant laws, conventions and regulations (WHO types, Amsterdam convention, Stockholm convention on pesticides...)</li> <li>➤ Prioritization of practices and quotation of compliance</li> </ul>	<ul style="list-style-type: none"> <li>➤ Quantity of agrochemicals, fertilizers and pesticides used</li> <li>➤ Monetization of impacts on health</li> <li>➤ Monetization of impacts on soil and water quality</li> <li>➤ Cost of agrochemicals</li> </ul>	Orange
Biodiversity			
<i>Biodiversity</i>	<ul style="list-style-type: none"> <li>➤ Evidence of compliance with relevant rules (EU), conventions</li> </ul>	<ul style="list-style-type: none"> <li>➤ Potentially Disappeared Fraction of species and comparison to</li> </ul>	Orange

	<ul style="list-style-type: none"> <li>➤ (CBD, CITES) and treaties</li> <li>➤ Quotation of compliance</li> </ul>	<ul style="list-style-type: none"> <li>a reference date</li> <li>➤ Monetization based on Benefits transfers from Contingent valuations</li> </ul>	
<i>GMO</i>	<ul style="list-style-type: none"> <li>➤ Reporting on use</li> <li>➤ Evidence of compliance with relevant laws and regulations</li> <li>➤ Quotation of compliance</li> </ul>		Orange
<b>Socio-economic externalities</b>			
Local prosperity		<ul style="list-style-type: none"> <li>➤ Number of net direct, indirect and induced jobs created (full-time equivalent)</li> <li>➤ Part of jobs created for local staff</li> <li>➤ Monetization of jobs</li> <li>➤ Rural value-added</li> <li>➤ Local expenses</li> </ul>	Orange
Working conditions	<ul style="list-style-type: none"> <li>➤ Evidence of compliance with local and national laws and regulations; with Human rights and ILO conventions (29, 87, 98, 100, 105, 111, 138, 182)</li> <li>➤ Quotation of compliance</li> </ul>		Red
Property rights	<ul style="list-style-type: none"> <li>➤ Evidence of compliance with relevant local and national laws and regulations</li> <li>➤ Quotation of compliance</li> </ul>		Red
Local well-being	<ul style="list-style-type: none"> <li>➤ Evidence of initiatives that contribute to local population well-being</li> <li>➤ Quotation of initiatives</li> </ul>		Red
Competition with food	<ul style="list-style-type: none"> <li>➤ Land availability</li> <li>➤ Land price evolution</li> <li>➤ Food availability (production, importations, exportations)</li> <li>➤ Food prices evolution</li> <li>➤ Feed prices evolution</li> <li>➤ Livestock prices evolution</li> </ul>		Red
Energy security	<ul style="list-style-type: none"> <li>➤ Number of potential countries of origin</li> <li>➤ Security of their furniture</li> </ul>	<ul style="list-style-type: none"> <li>➤ Importations</li> <li>➤ Fossil energy importations replaced by bioenergy route</li> <li>➤ Exportations</li> <li>➤ By-products importations and exportations</li> <li>➤ Storing possibilities</li> </ul>	Red

