# SSD

SCIENCE FOR A SUSTAINABLE DEVELOPMENT

## "DECISION-MAKING TOOLS TO SUPPORT THE DEVELOPMENT OF BIOENERGY FROM AGRICULTURE"

## «TEXBIAG»

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SCIENCE FOR A SUSTAINABLE DEVELOPMENT
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FINAL REPORT

# DECISION-MAKING TOOLS TO SUPPORT THE DEVELOPMENT OF BIOENERGY FROM AGRICULTURE

## "TEXBIAG"

**SD/EN/05**


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## SUMMARY


### CONTEXT

Bioenergy from agriculture is today at 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 in our atmosphere. Considerable efforts have to be pursued, especially in the field of energy production and use.
Concerning energy supply, the limitation of fossil fuels import is a crucial matter: beside the rational use of energy, the contribution of renewable sources, including biomass, for energy production is of considerable importance. It is worth to note that, in addition to the limitation of fossil fuels import, implementing renewable energy sources offers other attractive economic advantages, such as jobs creation, technology development, technology export, etc.

Sustainable agriculture leads to important questions about the diversification of agricultural productions and sources of incomes for farmers, the use of rural and arable lands for food and non-food crops, the contribution of agriculture to climate change fighting and renewable energy supply.
The lack of primary and reliable data on bioenergy externalities from agriculture and the lack of decision-making tools are important non-technological barriers to the development of bioenergy from agriculture on a large scale, and, consequently, to the achievement of the national and regional objectives of sustainable development in greenhouse gases mitigation, secure and diversified energy supply, rural development and employment and agriculture future. Furthermore, the recent worldwide controversies about transport biofuels, food shortages and increasing prices have demonstrated the need for sustainability criteria applied to biofuels and bioenergy.

### OBJECTIVES

In this sustainable development context, the objective of the TEXBIAG project is to lead to an actual and significant contribution of bioenergy from agriculture to the mitigation of greenhouse gases emission, to a secure and diversified energy supply, to farmers' incomes and rural development.

To reach this final objective, it is necessary to grasp the modifications that will affect land-use on the one hand, and the energy utilizations and conversions of biomass on the other hand. To support this, it is also imperative to develop a comprehensive and reliable knowledge of the environmental and socio-economic impacts (externalities) of bioenergy from agriculture, which condition its long term development.
To achieve this goal, the TEXBIAG project provides three tools:

1. A database of primary quantitative data related to environmental and socio-economic impacts of bioenergy from agriculture integrating biomass logistics;
2. A mathematical model monetizing bioenergy externalities from agriculture;

3. A prediction tool assessing the impacts of political decisions made in the framework of the development of bioenergy from agriculture on different economic sectors (energy, agriculture, industry, and environment).

## CONCLUSIONS

Considering priority chains and available sources and experts for data collection, data adaptation focused on the 4 four main energy crops for biofuels production in Belgium:

- Maize (grain maize in Flanders, silage maize in Wallonia);
- Wheat;
- Rapeseed;
- Sugar beet.

Different scenarios have been considered for each crop, according to farm size, soil characteristics and/or fertilizers application.
Detailed results and calculations are available in Deliverable D1 – Database of environmental and socio-economic impacts of bioenergy from agriculture.

Applying qualitative and/or quantitative indicators and monetization possibilities to cultivation pathways enables producing comparisons between studied biomasses.
The following impacts are included in the externalities assessment model:

- Quantification of GHG emissions for the cultivation step
- Qualitative impact on water quality
- Quantification of acidification and eutrophication potentials
- Qualitative impact on soil quality
- Impact of deposition of pollutants on biodiversity
- Job creation relating to cultivation
- Qualitative assessment of socio-economic impacts
- Monetization of impacts

The externalities assessment model underlines the sensitivity of results towards cultivation pathways and the choice between work processes options.
The main conclusion drawn from these figures and calculations is that even if default values exist for bioenergy production routes and are commonly accepted, it should remain possible to propose data adapted to the local context.
The database and models developed by this project can be of great support to this process, allowing the user, whether a policy-related decision-maker or a producer, to compare options between several bioenergy routes and their cultivation pathways.

## CONTRIBUTION OF THE PROJECT IN A CONTEXT OF SCIENTIFIC SUPPORT TO A SUSTAINABLE DEVELOPMENT POLICY

TEXBIAG must be seen as a contribution to the impact assessment of bioenergy in general, with focus on the cultivation step, which is one of the biggest, if not the biggest, contributing step to the overall impact of a given bioenergy chain. Impact criteria are under continuous development at national and European levels to allow producers bioenergy to demonstrate to potential consumers the quality of their products (through the observance of standards) along the process-chain. TEXBIAG contributes to a clear and harmonized methodology at European scale, regarding emissions assessment all along the fuels life cycle, as well as the verification of these emissions at the suppliers' side.

Among the three tools developed by TEXBIAG the database of environmental and socio-economic impacts gathers a considerable amount of data adapted to the local context. Focussing on the cultivation step, several crop management scenarios were selected matching realistic situations according to farm size, soil characteristics and fertilisation preferences.

The externalities assessment model assembles quantitative, qualitative and monetization results for the cultivation step of considered routes. It enables the comparison of these routes according to an extended set of sustainability criteria and allows the user to decide whether a category of impact weighs more than another in a particular situation.

The policy prediction tool (SPA2) finally is made available, and allows the following:

- To define an arbitrary 'system' by assembling streams and components (e.g. Belgium)
- To study the substitution of components within the considered system
- To feed in data from arbitrary sources, with or without data modifications, and in combination with local data
- To determine the impacts of any substitution, with any assumption about impact methodology

Additional specific advantages of SPA2 are:

- Flexibility in mixing different types of data sources
- Unlimited streams going in and out of process units
- No allocation assumptions needed inside the system

The impact balances must allow policy makers to take decisions, and the combined tool allows to assess/compare the decisions taken by them.

**KEYWORDS**

Bioenergy, biomass, agriculture, sustainable development, decision-making tools, externalities, environmental impacts, socio-economic impacts, policy prediction.

# CHAPTER 1 INTRODUCTION

## 1.1. CONTEXT

Bioenergy from agriculture is today at 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 in our atmosphere. Considerable efforts have to be pursued, especially in the field of energy production and use.
Concerning energy supply, the limitation of fossil fuels import is a crucial matter: beside the rational use of energy, the contribution of renewable sources, including biomass, for energy production is of considerable importance. It is worth to note that, in addition to the limitation of fossil fuels import, implementing renewable energy sources offers other attractive economic advantages, such as jobs creation, technology development, technology export, etc.

Sustainable agriculture leads to important questions about the diversification of agricultural productions and sources of incomes for farmers, the use of rural and arable lands for food and non-food crops, the contribution of agriculture to climate change fighting and renewable energy supply.
The lack of primary and reliable data on bioenergy externalities from agriculture and the lack of decision-making tools are important non-technological barriers to the development of bioenergy from agriculture on a large scale, and, consequently, to the achievement of the national and regional objectives of sustainable development in greenhouse gases mitigation, secure and diversified energy supply, rural development and employment and agriculture future. Furthermore, the recent worldwide controversies about transport biofuels, food shortages and increasing prices have demonstrated the need for sustainability criteria applied to biofuels and bioenergy.

Research on sustainability criteria and certification systems in Europe has started in several institutions and through European and international initiatives (the Dutch Cramer Commission, the United Kingdom (UK) Renewable Transport Fuels Obligation, the German Biofuels Sustainability Ordinance, the Roundtable on Sustainable Palm Oil, the Roundtable on Sustainable Biofuels, etc.).
These regulatory and voluntary initiatives have fed the debates around the new EU Directive on the promotion of renewable energy sources. Sustainability requirements are included in this new Directive as well as in the revised Fuel Quality Directive. Even if this Renewable Energy Directive (RED) overrules pre-existing national initiatives, national standards and voluntary schemes can support its implementation and cover aspects lacking in the Directive.

## 1.2. OBJECTIVES OF THE PROJECT

In this sustainable development context, the objective of the TEXBIAG project is to lead to an actual and significant contribution of bioenergy from agriculture to the mitigation of greenhouse gases emission, to a secure and diversified energy supply, to farmers' incomes and rural development.

To reach this final objective, it is necessary to grasp the modifications that will affect land-use on the one hand, and the energy utilizations and conversions of biomass on the other hand. To support this, it is also imperative to develop a comprehensive and reliable knowledge of the environmental and socio-economic impacts (externalities) of bioenergy from agriculture, which condition its long term development.
To achieve this goal, the TEXBIAG project provides three tools:

1. A database of primary quantitative data related to environmental and socio-economic impacts of bioenergy from agriculture integrating biomass logistics;
2. A mathematical model monetizing bioenergy externalities from agriculture;
3. A prediction tool assessing the impacts of political decisions made in the framework of the development of bioenergy from agriculture on different economic sectors (energy, agriculture, industry, and environment).

# CHAPTER 2 METHODOLOGY AND RESULTS

## 2.1. DATABASE OF ENVIRONMENTAL AND SOCIO-ECONOMIC IMPACTS OF BIOENERGY CHAINS

### 2.1.1. Priority bioenergy chains selection

Considering the numerous existing bioenergy chains, an enquiry was consequently conducted, asking Belgian stakeholders which bioenergy chains they would consider the most relevant for the Belgian market.

The enquiry was based on bioenergy chains selected by the most advanced European sustainability initiatives: the Cramer Commission for the Netherlands, the Biofuel Quota Law for Germany, the Renewable Transport Fuels Obligation (RTFO) for United Kingdom and the RES Directive of the European Commission.

A list of more than 200 stakeholders was established, including e.g. private companies from biomass production, conversion and distribution, public authorities, research institutions, consultants. Results were cross-checked with consortium partners and Follow-up Committee members and can be considered as representative.

As a result of this enquiry Table I ranks bioenergy chains relevant for the Belgian market to be studied in priority by the TEXBIAG project.

*Table I - Bioenergy chains relevant for the Belgian market, ranked according to their importance*

| Resource type | Production | Resource | Conversion technology | |
|---|---|---|---|---|
| ***High importance*** | | | | |
| Agriculture | Belgium | Rapeseed | (Pure plant oil) | Biodiesel |
| Agriculture | Belgium | Wheat | Ethanol | ETBE |
| Agriculture | Belgium | Sugar beet | Ethanol | ETBE |
| Forest | Belgium or import | Wood pellets | 100% biomass power plant | |
| | | | Co-firing in coal power plant | |
| | | | CHP | |
| Forest | Belgium or import | Wood chips | Co-firing in coal power plant | |
| | | | CHP | |
| Forest | Belgium or import | Wood dust | Co-firing in coal power plant | |
| | | | CHP | |
| Residues, by-products & wastes | Belgium | Landfill gas | Biogas | Power/CHP |
| Residues, by-products & wastes | Belgium | Sewage sludge | Biogas | Power/CHP |
| Residues, by-products & wastes | Belgium | Manure | Biogas | Power/CHP |
| Residues, by-products & wastes | Belgium | Biogenic fraction of MSW | Biogas | Power/CHP |
| ***Medium importance*** | | | | |

| | | | | |
|---|---|---|---|---|
| Agriculture | Belgium | Maize | Ethanol | ETBE |
| | | | Biogas | Power/CHP or biofuel |
| Agriculture | Import | Soybean | (Pure plant oil) | Biodiesel |
| Agriculture | Import | Palm oil | (Pure plant oil) | Biodiesel |
| Agriculture | Import | Sunflower | (Pure plant oil) | Biodiesel |
| Agriculture | Import | Sugarcane | Ethanol | ETBE |
| Agriculture | Import | Jatropha oil | (Pure plant oil) | Biodiesel |
| Residues, by-products & wastes | Belgium | Tallow | Biodiesel | |
| Residues, by-products & wastes | Belgium | Used cooking oils & fats | Biodiesel | |
| Residues, by-products & wastes | Belgium | Agrofood residues | Co-firing in coal power plant | |
| Residues, by-products & wastes | Belgium or import | Glycerine | Methanol | |
| ***Lower importance*** | | | | |
| Agriculture | Belgium | Miscanthus, SRC, Switch grass | Lignocellulosic ethanol | |
| Main crop or residues | Belgium | Woody & non-woody biomass | Gasification | Methanol |
| | | | | Fischer-Tropsch |
| | | | | DME |

### 2.1.2. Available and missing data

Next step consisted in cross-checking priority bioenergy chains with available datasets in the primary data source: the EcoInvent database. This exercise demonstrates that the majority of the chains are included in this database, except a few ones, as detailed in Table II.

Most biofuel chains are included in the database. The main missing data concern power production in large power plants, which is a major biomass application in Belgium, either for co-firing in coal power plants or for 100% biomass plants, such as "les Awirs" (Liège). Data on biogas production from wastes are also missing.

*Table II - Data availability in EcoInvent*

| | Automotive power | Electricity | Heat/CHP |
|---|---|---|---|
| **Local** | ▪ Biodiesel from rapeseed<br>▪ Ethanol/ETBE from wheat<br>▪ Ethanol/ETBE from sugarbeet<br>▪ Ethanol/ETBE from maize<br>▪ Biodiesel from used cooking oils & fats<br>▪ Lignocellulosic ethanol from grass<br>▪ Methanol from gasification<br>▪ DME from gasification<br>▪ (Biodiesel from tallow)<br>▪ (Methanol from glycerine) | ▪ Wood residues in large power plants (co-firing and 100% biomass) | ▪ Wood chips<br>▪ Biogas from grass<br>▪ Biogas from wastes |
| **Import** | ▪ Biodiesel from soybean<br>▪ Biodiesel from palm oil<br>▪ Ethanol/ETBE from maize US<br>▪ Ethanol/ETBE from sugar cane<br>▪ (Biodiesel from jatropha) | | |

*green = available, red = not available*

TEXBIAG seeks to gather primary data related to environmental and socio-economic impacts of bioenergy. Available datasets in the EcoInvent database need therefore to be adapted to the Belgian context. This is done through experts' consultation.

Figure 1 gives a range of GHG emissions associated with production steps for ethanol and biodiesel (gathered from default values included in the RES Directive). This illustrates that the majority of GHG emissions are tied to the cultivation and conversion processes.

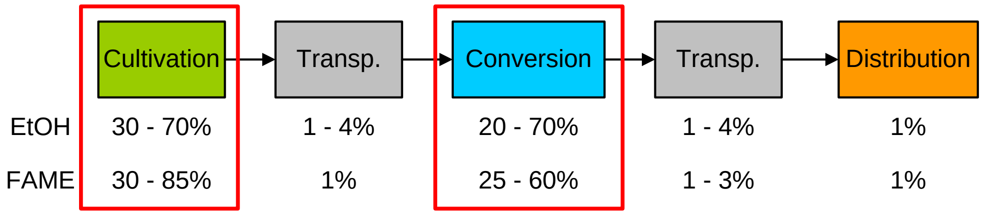



*Figure 1 – Distribution of GHG emissions for ethanol (EtOH) and biodiesel (FAME) chains per step (retrieved from EC, 2009)*

The adaptation of EcoInvent data in the Belgian context needs therefore to be firstly focused on agricultural practices and conversion processes. Whether the latter are not anticipated to vary a lot from average Swiss or European processes, agricultural practices are often, if not always, specific to local conditions.

### 2.1.3. Agricultural practices adaptation

As summarised in Figure 2, the cultivation of any crop takes several inputs and outputs. EcoInvent data relating to crop cultivation are detailed in the Ecoinvent report No.15 "Life Cycle Inventories of Swiss and European Agricultural Production Systems" (Nemecek & Kägi, 2007).

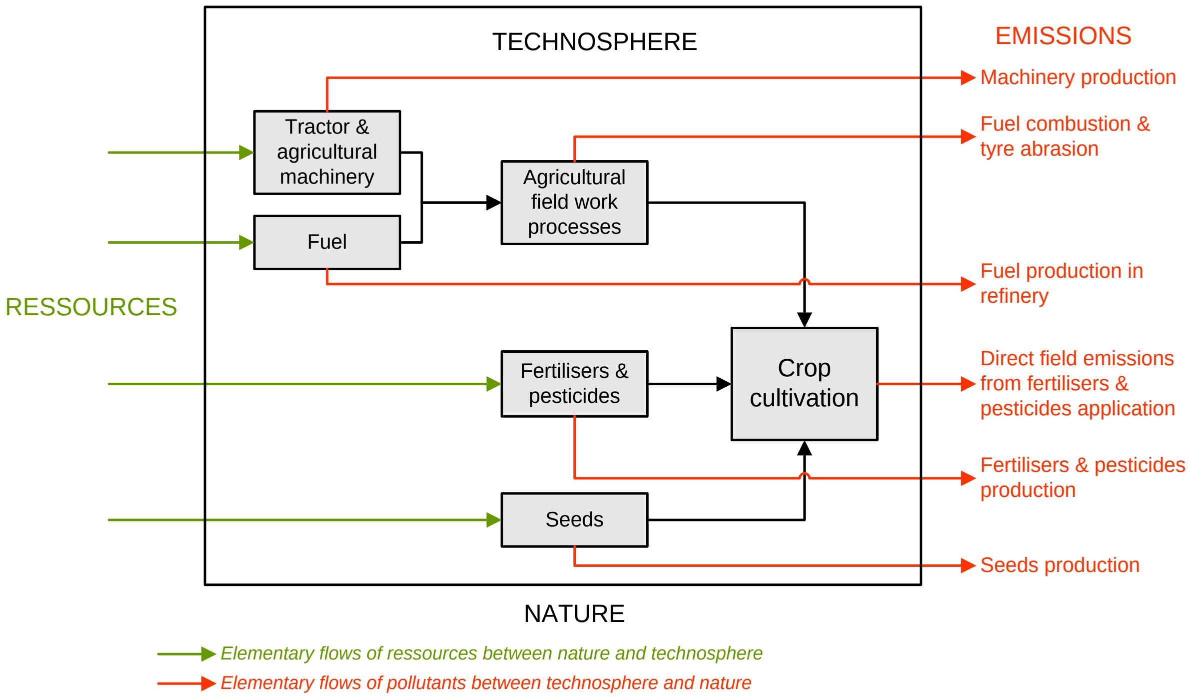



*Figure 2 – Examples of elementary flows considered in crop cultivation in EcoInvent*

### → Agricultural work processes

Firstly, it is worth noting that EcoInvent assumes that fields and meadows are not irrigated, as it is the most frequent practice in Switzerland and Europe, and tallies with the data source used (Nemecek & Kägi, 2007). This statement is also valid for Belgium.

Agricultural work processes include operations such as land preparation (tillage), mineral and organic fertilisers application, plant protection products application, sowing, harvesting, transport from field to farm, etc.

In Nemecek & Kägi (2007), the following data are displayed for each agricultural work processes:

- machinery description;
- fuel consumption;
- emissions per hour (HC, $NO_x$, CO), calculated from emission models based on engine speed and power;
- other emissions ($CO_2$, $SO_2$, $CH_4$, $N_2O$, etc.) are calculated according to fuel consumption, thanks to emission factors.

Machinery description and fuel consumption have been cross-checked with Belgian experts and related emissions adapted accordingly (detailed results and calculations are available in Deliverable D1 – Database of environmental and socio-economic impacts of bioenergy from agriculture).

### → Agrochemicals production

Life cycle inventory data for the production of mineral fertilisers included in EcoInvent represent the European average.

They were compiled from different sources, requiring different procedures and assumptions, as detailed in Nemecek & Kägi (2007). For these reasons they are not questioned in the TEXBIAG project.

Based on the target-organism group, pesticides of agricultural importance can be broadly categorised as:

- Herbicides (for weed control);
- Insecticides (for insect control);
- Fungicides (for fungal pathogen control);
- Others (such as nematicides, bactericides, rodenticides).

Most modern synthetic organic pesticides are manufactured entirely from intermediates derived from fossil fuels.

It is very difficult to obtain current, accurate and specific data on pesticide production. The reasons for this is that detailed information on the production processes is available to the pesticide industry, but not to the public. Nevertheless LCA studies of agricultural production have shown the impact of pesticide production to be fairly small, usually below 5% (Nemecek & Kägi, 2007). The toxic impact of the substance applied in the field, however, can be very significant.

Even though LCI data for pesticides in EcoInvent refer to the situation in the USA, manufacturing processes, which are patent-based, would not differ greatly in Europe.

For these reasons, pesticides manufacturing processes are not adjusted by TEXBIAG. The active ingredients and applied amounts are compared and emissions modified consequently (see below).

Life cycle inventories for seeds are modelled according to 5 steps:

- seed production;
- transport to seed-processing centre;
- processing of the seed;
- seed storage;
- transport to final user or regional storehouse.

The seed of most crops are used in relatively small quantities. Life cycle assessment studies have shown that the environmental burdens of agricultural crops due to seed lie below 5% for most crops (Nemecek & Kägi, 2007). For this reason, seed manufacturing are not adapted by TEXBIAG. Only the quantity of seed required for the cultivation of a given crop is adapted and related emissions adapted accordingly (see below).

### 2.1.4. Direct field emissions from fertilisers and pesticides application

As shown here above, the major adjustment to make regarding agricultural practices in EcoInvent relates to the direct field emissions due to fertilisers and pesticides application during cultivation.

The models used in EcoInvent to estimate emissions due to fertilisers and pesticides application are detailed in Nemecek & Kägi (2007) and related sources.

An Excel spreadsheet gathering formulae and calculations was used in order to adapt emissions according to amounts of fertilisers and pesticides used in Belgian cultivation pathways (detailed results and calculations are available in Deliverable D1 – Database of environmental and socio-economic impacts of bioenergy from agriculture).

Direct field emissions considered are the following:

- Emissions of ammonia ($NH_3$) to the air:
  - Causes eutrophication and acidification;
  - From slurry and liquid manure spreading;
  - From liquid sewage sludge;
  - From solid manure (from cattle & pigs) spreading;
  - From mineral fertilisers (%N emitted in form of $NH_3$);
- Nitrate ($NO_3^-$) leaching to ground water:
  - Causes eutrophication when comes to surface → $N_2O$ emissions;
  - Model considers:
    - N mineralisation from the soil organic matter per month;
    - N uptake by vegetation per month;
    - N input from the spreading of fertiliser;
    - Soil depth and type;
    - Crop rotation;
    - Soil cultivation intensity.
- Emissions of phosphorus to water:
  - Causes eutrophication;
  - 3 sources:
    - Leaching to ground-water;
    - Run-off to surface water (rivers);
    - Erosion of soil particles to rivers;
- Emissions of nitrous oxide ($N_2O$) to the air:
  - Intermediate product of the denitrification process ($NO_3^-$ to $N_2$);
  - Also a by-product of the nitrification process ($NH_4$ to $NO_3^-$);
  - Model considers:
    - Available N in fertilisers;
    - N in crop residues;
    - N from biological N fixation (estimated by the quantity of N contained in the shoots of legumes);
    - Losses of N in the form of $NH_3$;
    - Losses of N in the form of $NO_3^-$;
- Emissions of nitrogen oxides $NO_x$ to the air;
  - Produced in parallel of $N_2O$ in denitrification process;
- Nutrient inputs in agricultural soils: not inventoried because it is assumed that fertilisers cover the needs of the plants;
- Release of fossil $CO_2$ after urea application: during urea production process, $CO_2$ is used, which is released to the atmosphere after urea application and transformation in the soil;
- Emissions of heavy metals (HM) to agricultural soil, surface water and ground water:
  - Cadmium (Cd), Chromium (Cr), Copper (Cu), Lead (Pb), Mercury (Hg), Nickel (Ni) & Zinc (Zn);

- Sources:
  - Seeds;
  - Plant protection products (mineral fertilisers, farmyard manure & pesticides[1]);
- 3 types:
  - Leaching of HM to ground water;
  - Emissions of HM into surface water through erosion of particles;
  - Emissions of HM to agricultural soil (can be positive or negative).

### 2.1.5. Data adaptation for Belgian bioenergy routes

Considering priority chains (see section 2.1.1) and available sources and experts for data collection, data adaptation focused on the 4 four main energy crops for biofuels production in Belgium:

- Maize (grain maize in Flanders, silage maize in Wallonia);
- Wheat;
- Rapeseed;
- Sugar beet.

Different scenarios have been considered for each crop, according to farm size, soil characteristics and/or fertilizers application.
Soil characteristics influence among others nitrogen mineralisation rate from the soil organic matter. Selected cases are:

- low mineralisation rate: 90 kg $NO_3^-$/ha.year
- medium mineralisation rate: 150 kg $NO_3^-$/ha.year
- high mineralisation rate: 250 kg $NO_3^-$/ha.year

Selected scenarios are the following:

- Grain maize (Flanders):
  1. Big holding, without P & K fertilisation, on soil with a low mineralisation rate
  2. Big holding, without P & K fertilisation, on soil with a medium mineralisation rate
  3. Big holding, with P & K fertilisation, on soil with a low mineralisation rate
  4. Big holding, with P & K fertilisation, on soil with a medium mineralisation rate
  5. Smallholding, with N, P & K fertilisation, on soil with a low mineralisation rate
  6. Smallholding, with N, P & K fertilisation, on soil with a medium mineralisation rate
- Silage maize (Wallonia):
  1. Big holding, without P & K fertilisation, on soil with a low mineralisation rate
  2. Big holding, without P & K fertilisation, on soil with a high mineralisation rate
  3. Big holding, with P & K fertilisation, on soil with a low mineralisation rate
  4. Big holding, with P & K fertilisation, on soil with a high mineralisation rate
  5. Smallholding, with N, P & K fertilisation, on soil with a low mineralisation rate
  6. Smallholding, with N, P & K fertilisation, on soil with a high mineralisation rate
- Wheat:
  1. Without P & K fertilisation, on soil with a low mineralisation rate

[1] However, heavy metal inputs from pesticides are confirmed to be negligible, compared to other sources, such as atmospheric deposition, manure and sewage sludge applications (Nicholson *et al*., 2003).

2. Without P & K fertilisation, on soil with a high mineralisation rate
3. With P & K fertilisation, on soil with a low mineralisation rate
4. With P & K fertilisation, on soil with a high mineralisation rate

- Rapeseed:
  1. Without P & K fertilisation, on soil with a low mineralisation rate
  2. Without P & K fertilisation, on soil with a high mineralisation rate
  3. With P & K fertilisation, on soil with a low mineralisation rate
  4. With P & K fertilisation, on soil with a high mineralisation rate
- Sugar beet:
  1. On soil with a low mineralisation rate
  2. On soil with a high mineralisation rate

Detailed results and calculations are available in Deliverable D1 – Database of environmental and socio-economic impacts of bioenergy from agriculture.

### 2.2. ENVIRONMENTAL AND SOCIO-ECONOMIC EXTERNALITIES ASSESSMENT

Many bioenergy sustainability initiatives got down to the establishment of a list of environmental and possibly socio-economic sustainability criteria for biomass and bioenergy. From an extensive study of these initiatives (see Deliverable D26) it is possible to draw a list of themes or principles for which there is a consensus.
Relevant sustainability criteria for biomass and bioenergy can be classified in 3 categories: (1) environmental criteria, such as GHG emissions saving, carbon stocks conservation, environment quality preservation, etc.; (2) socio-economic criteria, such as food security, workers' rights respect, land property rights respect, etc.; and (3) macro-level issues, mainly related to indirect land-use changes (LUC), which can have disastrous consequences on GHG emissions, biodiversity losses, socio-economic impacts, etc.

#### 2.2.1. Environmental sustainability criteria and indicators

One of the universally claimed benefits of bioenergy use is the reduced GHG emissions. Nonetheless it is now recognised that bioenergy does not at all times lead to a reduction of GHG emissions compared to fossil energy. The most consensual environmental sustainability criterion therefore considers a GHG emission reduction potential of bioenergy, in comparison with a fossil fuel equivalent. For instance this minimum GHG saving must be at least 35% for the RED (CE, 2009).
In addition to GHG reduction potential, above- and below-ground carbon stocks conservation is also perceived as a crucial environmental sustainability criterion. Existing indicators mainly relate to payback time, that is to say the period necessary to recover the carbon stock at a reference date.
Beside carbon-related criteria, biodiversity protection and high conservative value areas conservation are also decisive. Several conventions support the verification of these criteria, such as the Convention on Biological Diversity or the Convention on International Trade in Endangered Species (CITES) of Wild Fauna and Flora.
Other widely recommended environmental sustainability criteria relate to the conservation of air, water and soil quality and the sound use of pesticides. Various quantitative or qualitative indicators for environment quality conservation are attached to these sustainability criteria.

### 2.2.2. Socio-economic sustainability criteria and indicators

Beside its potential impacts on the environment, bioenergy also affects social and economic conditions. In front of rising critics regarding adverse effects of the increased use of bioenergy, and biofuels in particular, the urge for ensuring socio-economic sustainability is more than ever felt.

However implementing mandatory socio-economic criteria can also create conflicts with the World Trade Organization (WTO). This explains why the European Commission chose not to include socio-economic sustainability criteria in the new RES Directive and to focus on environmental principles only (GHG emissions reduction, biodiversity and agricultural practices).

Nevertheless socio-economic impacts on local well-being, working conditions, land property rights or local prosperity are included in several sustainability initiatives (Cramer Commission, RTFO, RSPO, RSB and many others). Qualitative indicators and existing (inter)national conventions support the implementation of sustainability criteria related to socio-economic conditions. Examples of these conventions include the Global Reporting Initiative (GRI), the Universal Declaration of Human Rights and conventions of the International Labour Organisation (ILO).

Considering the strained debates on whether or not socio-economic sustainability should be incorporated in the new RES Directive, the European Commission offered to report from 2012 on third countries and Member States that are a significant source of (raw material for) biofuels consumed within the Community (EC, 2009). Those reports will assess if EU biofuel policy has an impact on social sustainability in the Community and in third countries, on the availability of foodstuffs at affordable prices and on the respect of land use rights. Moreover reports will state whether the country has ratified and implemented conventions of the International Labour Organisation (on forced labour, freedom of association, equal remuneration, employment discrimination, child labour, etc.) or the Carthagena protocol on biosafety. The Commission shall, if appropriate, propose corrective action; in particular if evidence shows that biofuel production has a significant impact on food prices.

### 2.2.3. Macro-level issues – indirect effects

Indirect effects of bioenergy are mainly related to indirect land-use changes. Indirect land-use change occurs when pressure on agriculture due to the displacement of previous activity or use of the biomass induces land-use changes on other lands in order to maintain previous level of (e.g., food) production (Gnansounou *et al.*, 2008). This is also called "leakage" or "displacement effect".

Indirect land-use changes may induce several deplorable effects, such as greenhouse gas emissions (through deforestation for instance), biodiversity losses, competition with food, local energy supply, medicine and building materials, or prosperity and economic effects.

It seems not possible at the present state of knowledge to accurately assess the effects of indirect land-use changes due to bioenergy production. Several challenges exist to accurately quantify emissions resulting from indirect land-use at a global scale. A global trade and economic model with country by country and crop by crop data would be needed (Johnson & Roman, 2008). All the available studies at the moment use general/partial equilibrium models. However, at present, only rough estimations based on hypothetical cases are available. No model has been developed or used to down-scale indirect effects lower than the national level and neither to predict the spatial relocation of displaced activities (Gnansounou *et al.*, 2008).

Since indirect effects of bioenergy are impossible to assess at the company level and therefore cannot be translated as it is into sustainability criteria, many sustainability initiatives, such as RED (EC, 2009), Cramer Commission (Cramer *et al*., 2007), UK RFTO (RFA, 2008), suggest entrusting Governments with the monitoring of indirect land-use changes and leakage effects.

### 2.2.4. Externalities monetization methods

There is rarely a market to monetize impacts of soil quality on biodiversity. The Willingness To Pay (WTP) of individuals to avoid these impacts or their Willingness To Accept (WTA) them if compensated for can thus be used to monetize impacts or externalities.
Monetization is based on different techniques according to the type of impact or externality (Pearce *et al*., 2006, Atkinson *et al*., 2007, De Palma & Zaouli, 2007, Jenkins *et al*., 2007). If the externality affects a good:

- Used, its use can be actual, planned, or possible;
- Not or passively used, its value can be of existence (for example, the value of threaten species), altruistic (the value for the others), or bequest (the value for the future generations).

For used goods, revealed preferences methods are suitable, for non-used goods, stated preferences methods must be adopted. Another method is the Benefits transfers.

**→ Revealed preferences methods**

Revealed preferences methods are based on existing or substitute market. If a market exists for the externality, its monetization is the market price. If there is no market for the externality, a substitute market is used. Methods with substitute markets can be e.g. the travel cost method, the hedonic price method, the averting behaviour method or the cost of illness method.
The Travel cost method monetizes an externality, a natural site quality for example, on the basis of expenses made by people to go to this site (transport, time opportunity cost, frequency, accommodation, etc.).
The hedonic price method monetizes an externality by observing related good market (Secchi, 2007). For example, the value of noise can be assessed by the impact it has on house price. Problems are multicollinearity (houses near roads are affected by noise and pollution) and potential lack of information on externalities when buying on related market.
To monetize an externality, the Averting behaviour or defensive expenses method assesses all the expenses people are ready to make to prevent this externality (for example, the cost of double-glazing to prevent road noise).
Cost Of Illness (COI) is a type of Averting behaviour method applied to health externalities (ABT, 2003). It represents all the costs, from diagnosis to cure or death, tied to morbidity due to an externality.

**→ Stated preferences methods**

Stated preferences methods are based on hypothetical markets (Fankhauser, 1994, Freeman, 1996, Gallagher *et al*., 2003, Colombo *et al*., 2006, Groothuis *et al*., 2007).
To monetize externalities, Contingent valuation method uses questionnaires to create a hypothetic market and evaluate consumers' behaviour (Welsch, 2003, Dziegielewska *et al*., 2005). This method is close to marketing and has its advantages and limits (expensive, time-consuming, questionable reliability…).

Choice modelling (or Choice experiment method) is another stated preferences method (Rambonilaza, et al., 2007), quite similar to Contingent valuation method; it takes into account the different attributes of an externality to monetize it.
Another alternative is the Deliberative monetary valuation. This method uses participatory deliberation to monetize environmental changes (Bovea & Vidal, 2004, Spash, 2007).

**→ Benefits transfers**

For all types of externalities, instead of assessing own WTP or WTA, which is quite time-consuming and expensive, Benefits transfers can be used Smith et al., 2002, Bergstrom & Taylor, 2007). Benefits transfers are the adaptation of existing studies and databases to own context. They must be used carefully because of important transfer limits: quality and accuracy of other studies, differences in coverage and unit, differences between contexts (population characteristics, importance of externalities assessed…), data age, etc.

**→ Monetization methods – conclusion**

In the TEXBIAG framework, bioenergy externalities monetary value can be estimated through:

- Market price,
- Hedonic price,
- Contingent valuation,
- Benefits transfers,

but also through:

- Avoided damage costs,
- Replacement costs,
- Restoration costs,
- Alternative or substitute costs.

### 2.2.5. Externalities interactions – qualitative model

The most relevant bioenergy externalities have been selected and indicators for their assessment are being defined.
Since bioenergy externalities are not stand-alone impacts, selected externalities are being articulated (see Figure 3) into a qualitative model in order to identify cause-effect relationships, feedback, induced and non-linear effects between them. Systems dynamics and indicators are being used to describe and assess these potential links.
The qualitative model defines links between externalities, studied separately, and characterizes these relations into positive (correlation), negative (inverse) or indeterminate.

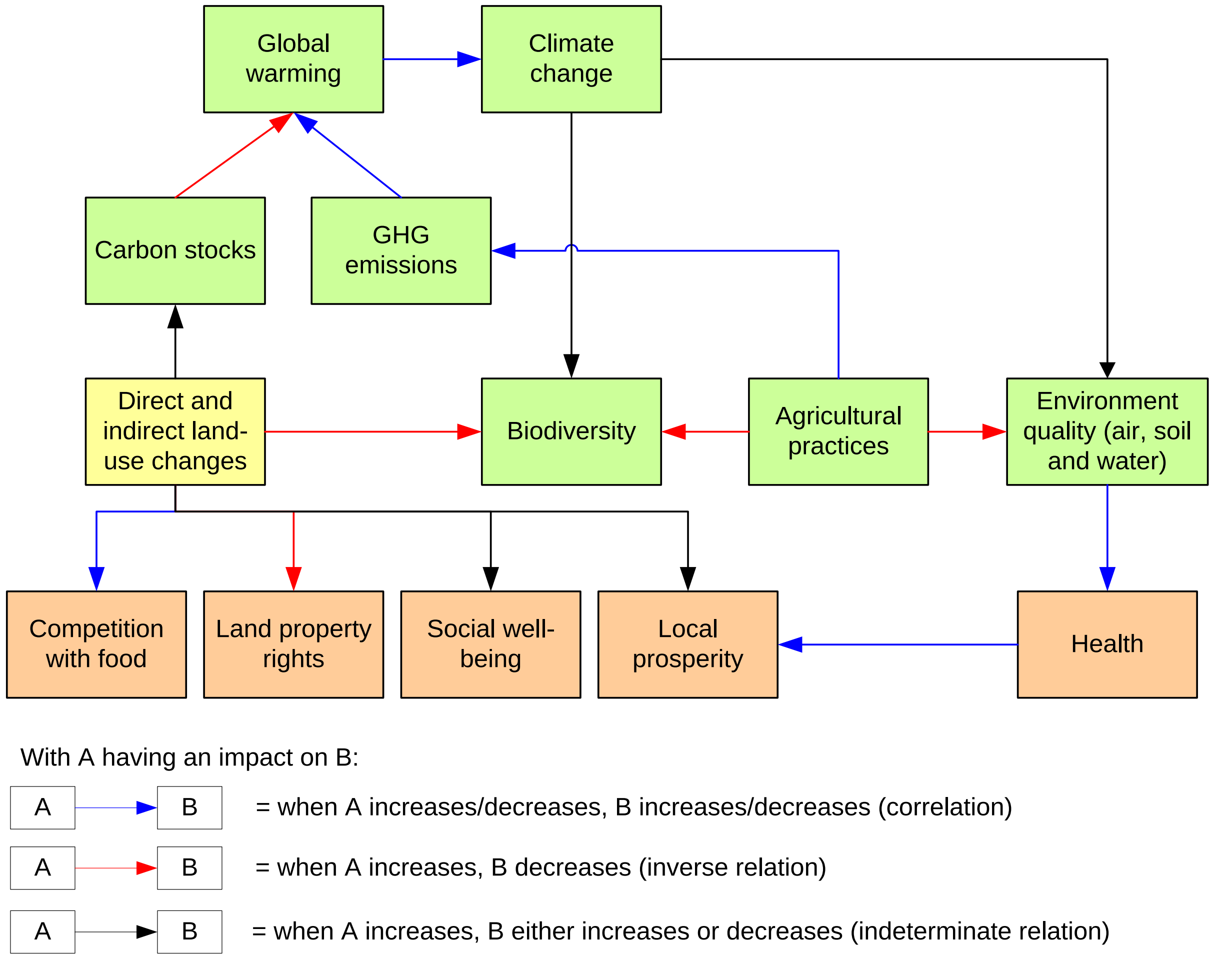



*Figure 3 - Major bioenergy externalities and their relations*

From this modelling, it appears that many interactions between bioenergy externalities are not straightforward.

Many of them are time or space dependent. Agricultural practices vary a lot from one region to another; indirect effects are far from being understood and assessed correctly, long-term effects of climate change are still unknown, etc.

The qualitative model is iteratively refined through interactions with experts in workshops and brainstorming sessions. Since a lot of research efforts are still ongoing on many of these parameters (climate change, biodiversity, indirect effects, etc.) it is also important to keep an eye on scientific releases in order to improve this model.

### 2.2.6. Indicators for externalities assessment – summary

Qualitative and/or quantitative indicators enabling the assessment of the above-mentioned environmental and socio-economic externalities are described in Deliverables 6 and 6'.

The table below summarizes studied externalities, potential qualitative and/or quantitative indicators and monetization possibilities. In case no monetization is possible a qualitative assessment using a "traffic light" code is used. This aims at drawing attention on potential risks for a given externality.

*Table III - Summary of indicators and monetization possibilities for the assessment of bioenergy externalities*

<table>
<tr><th>Externalities</th><th colspan="2">Sustainability criteria</th><th colspan="3">Indicators</th></tr>
<tr><td rowspan="7">Environmental externalities</td><td colspan="2">GHG emissions - Global warming – Climate change</td><td>Q</td><td>€</td><td></td></tr>
<tr><td rowspan="3">Environment quality</td><td>Air quality</td><td>Q</td><td>€</td><td>🟩🟧🟥</td></tr>
<tr><td>Soil quality</td><td>Q</td><td>€</td><td>🟩🟧🟥</td></tr>
<tr><td>Water quality</td><td>Q</td><td>€</td><td>🟩🟧🟥</td></tr>
<tr><td rowspan="2">Biodiversity</td><td>Biodiversity</td><td>Q</td><td>€</td><td></td></tr>
<tr><td>GMO</td><td></td><td></td><td>🟩🟧🟥</td></tr>
<tr><td rowspan="6">Socio-economic externalities</td><td colspan="2">Local prosperity</td><td>Q</td><td></td><td></td></tr>
<tr><td colspan="2">Working conditions</td><td></td><td></td><td>🟩🟧🟥</td></tr>
<tr><td colspan="2">Property rights</td><td></td><td></td><td>🟩🟧🟥</td></tr>
<tr><td colspan="2">Local well-being</td><td></td><td></td><td>🟩🟧🟥</td></tr>
<tr><td colspan="2">Competition with food</td><td></td><td></td><td>🟩🟧🟥</td></tr>
<tr><td colspan="2">Energy security</td><td></td><td></td><td>🟩🟧🟥</td></tr>
<tr><td>Macro-level externalities</td><td colspan="2">Indirect land-use change</td><td>?</td><td>?</td><td></td></tr>
</table>

*Q : Quantitative indicator(s)*

€ : *Monetization possible*

🟩🟧🟥 : *Traffic lights to assess potential risk*

Monetized and non-monetized indicators are displayed in tables with all monetized, quantitative and qualitative information on each bioenergy route selected (one table per bioenergy route). These tables allow policy makers to take into account all dimensions of sustainable development in their choice of the best bioenergy routes to support.

### 2.2.7. Externalities assessment of selected bioenergy routes – results

Applying qualitative and/or quantitative indicators and monetization possibilities to cultivation pathways enables producing interesting comparisons between studied biomasses. Selected results are discussed below.

It is worth noting that calculations focus on elements that were adapted to the Belgian context: that is to say, direct field emissions due to phytoproducts adaptation and agricultural work processes (tractors and machinery consumption and emissions). Even tough also consequent, impacts of phytoproducts and seed manufacturing, machinery production and fuel refining are not included in the results displayed here after, except for wheat and rapeseed in the calculations run by SPA (see section 2.3).

The following impacts are considered in subsequent sections:

- Quantification of GHG emissions for the cultivation step
- Qualitative impact on water quality
- Quantification of acidification and eutrophication potentials
- Qualitative impact on soil quality
- Impact of deposition of pollutants on biodiversity
- Job creation relating to cultivation
- Qualitative assessment of socio-economic impacts
- Monetization of impacts

### 2.2.8. Quantification of GHG emissions for the cultivation step

Simply balancing $CO_2$ absorbed by crop growth with GHG emissions for the cultivation of this crop not surprisingly shows negative GHG emissions. However it is crucial here to mention that these calculations do not include GHG emissions relating to land-use change.

Furthermore, only the cultivation step is considered here. More complete calculations are made through SPA software in the policy prediction tool (see section 2.3).

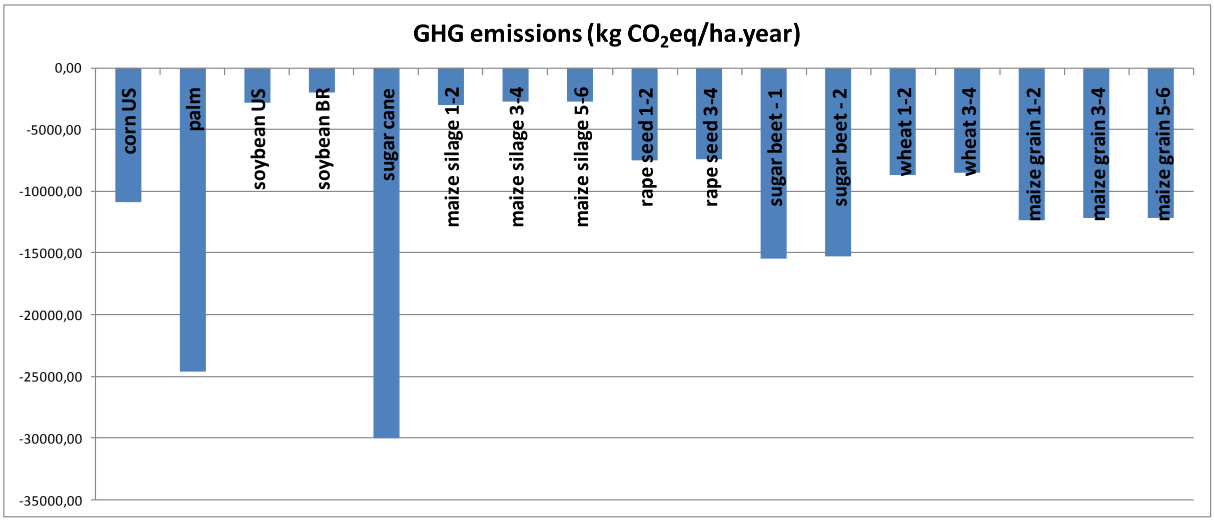



*Figure 4 – GHG emissions associated with the cultivation step*

### 2.2.9. Qualitative impact on water quality

Some substances emitted on field during cultivation affect water quality. Beside the quantification of acidification and eutrophication potentials (see below), the model combines several factors to provide a qualitative assessment (traffic lights) of crop cultivation on water quality:

- nitrate leaching risks according to previous crop, soil type and climate conditions (assessed for local crops only);
- nitrate, phosphorus and phosphate emissions to rivers and ground-water;
- irrigation (impact on water stocks).

Figure 5 compares emissions impacting water quality for considered crops and scenarios (locally produced and imported).

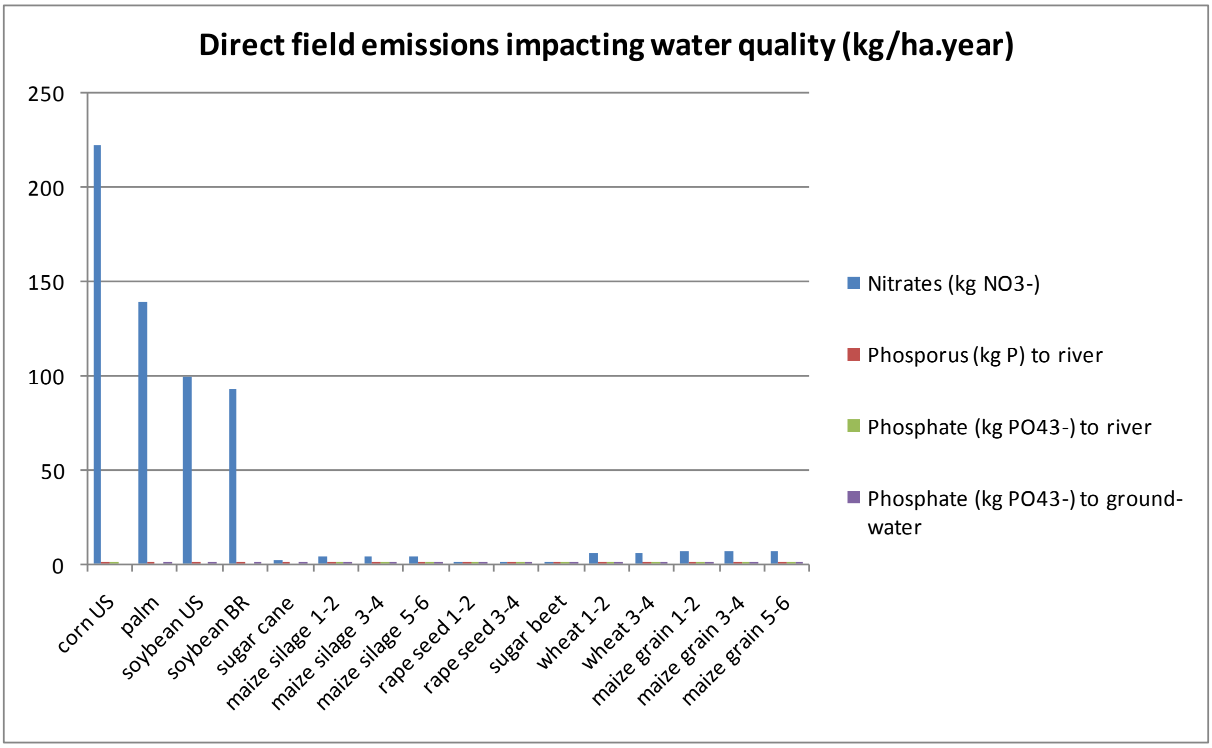



*Figure 5 – Direct field emissions having an impact on water quality*

For reasons of clarity, nitrate emissions can be withdrawn from the graph in order to visualize more clearly other emissions.

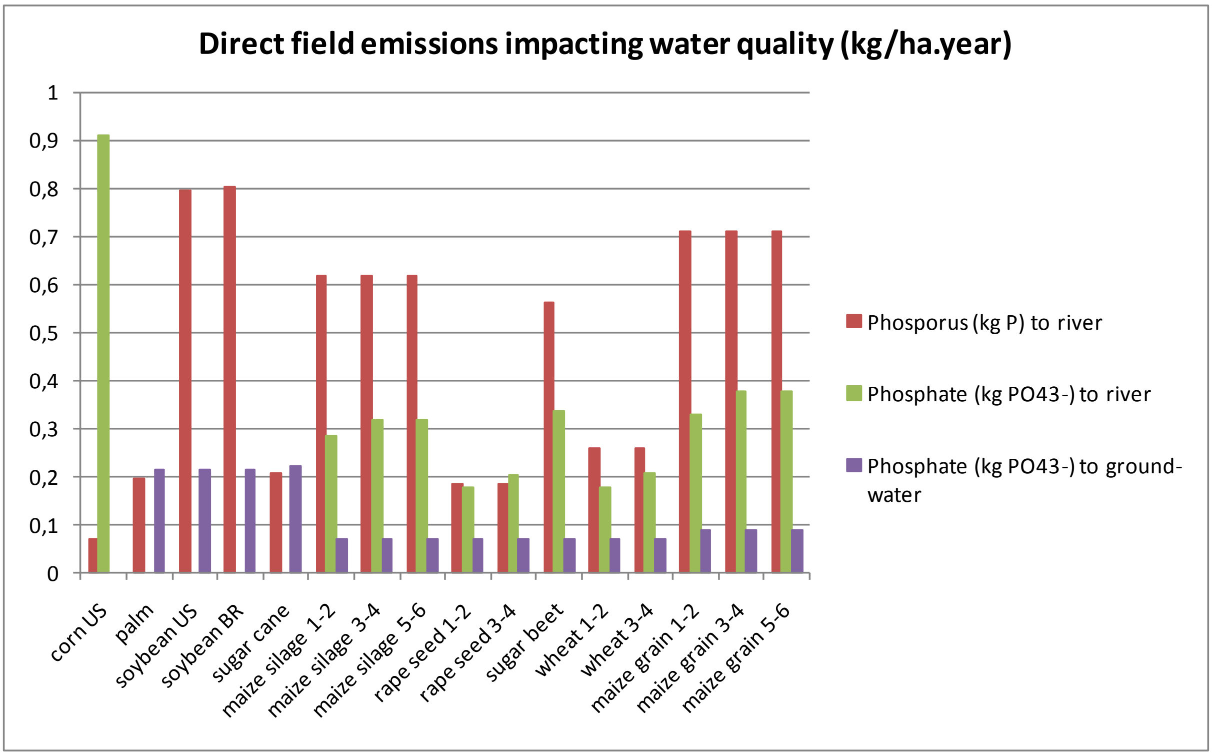



*Figure 6 - Direct field emissions having an impact on water quality (except nitrate emissions)*

A first look at these graphs shows that imported crops have a worse impact on water quality due to nitrate leaching to ground-water. Furthermore imported crops are sometimes irrigated (such as corn in the USA), impacting water stocks.

The inclusion of nitrate leaching risk for locally produced scenarios enables assigning traffic lights regarding water quality as presented below.

| WATER QUALITY | | |
|---|---|---|
| **Bioenergy route** | **Cultivation** | **Comment** |
| Grain maize |  | If maize follows other crop (part of rotation) |
| |  | If maize monoculture |
| Silage maize |  | Nitrate, phosphorus/phosphate emissions to river and ground-water |
| Rapeseed |  | Low nitrate & phosphorus/phosphate emissions |
| Sugar beet |  | Low nitrate & phosphorus/phosphate emissions |
| Wheat |  | Nitrate emissions important + potential risk of leaching |
| Corn US |  | High nitrate & phosphate emissions to river |
| Palm |  | Nitrate emissions important + potential risk of leaching on degraded soil |
| Soybean |  | Phosphorus & nitrate emissions |
| Sugarcane |  | Low nitrate & phosphorus/phosphate emissions |

*Figure 7 – Summary of qualitative assessment of impact on water quality*

### 2.2.10. Quantification of acidification and eutrophication potentials

Acidification potential is expressed in kg $SO_2$eq. Substances taking part to acidification are sulphur dioxide (1 kg $SO_2$eq), nitrogen oxides (1 kg $NO_x$ = 0.7 kg $SO_2$eq), ammonia (1 kg $NH_3$ = 1.88 kg $SO_2$eq) and hydrogen chloride (1 kg HCl = 0.88 kg $SO_2$eq).
Eutrophication potential is expressed in kg $PO_4^{3-}$eq. Substances taking part to eutrophication are nitrogen oxides (1 kg $NO_x$ = 0.13 kg $PO_4^{3-}$eq), ammonia (1 kg $NH_3$ = 0.35 kg $PO_4^{3-}$eq), phosphorus (1 kg P = 3.06 kg $PO_4^{3-}$eq) and phosphate (1 kg $PO_4^{3-}$eq) (Tchouate, 2003).

Results for acidication and eutrophication potentials are displayed in the figures below.

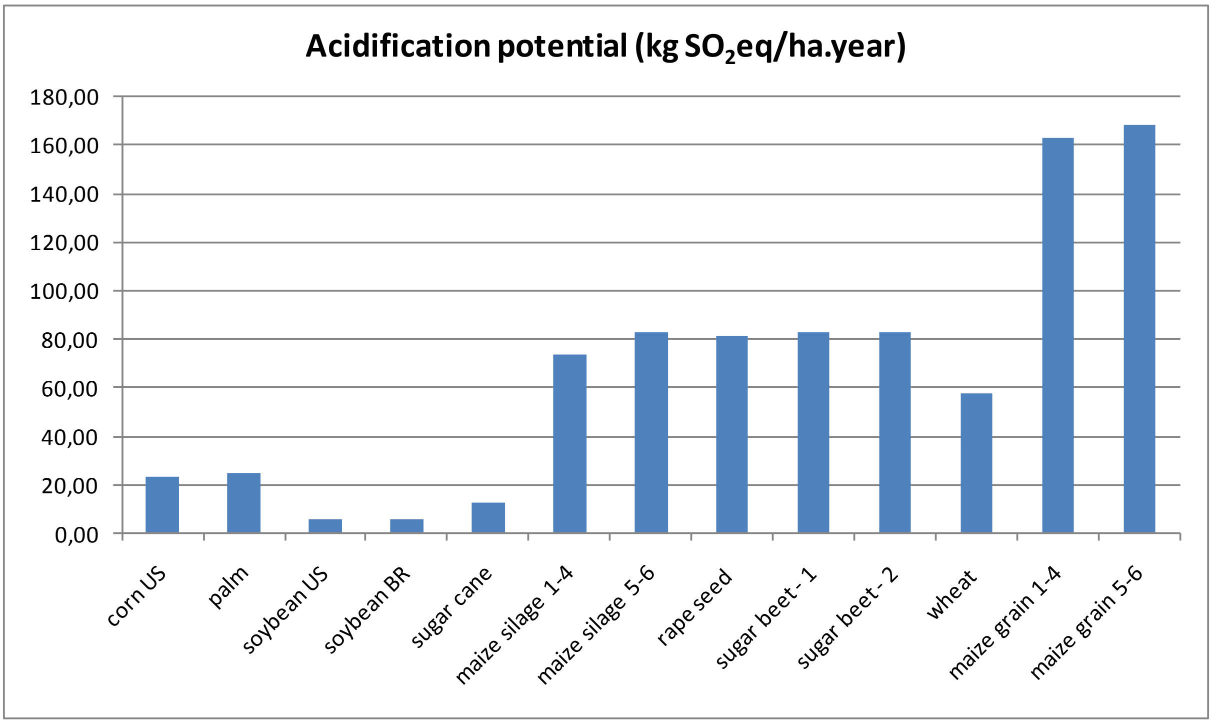



*Figure 8 –Acidification potentials for 1 ha of crop*

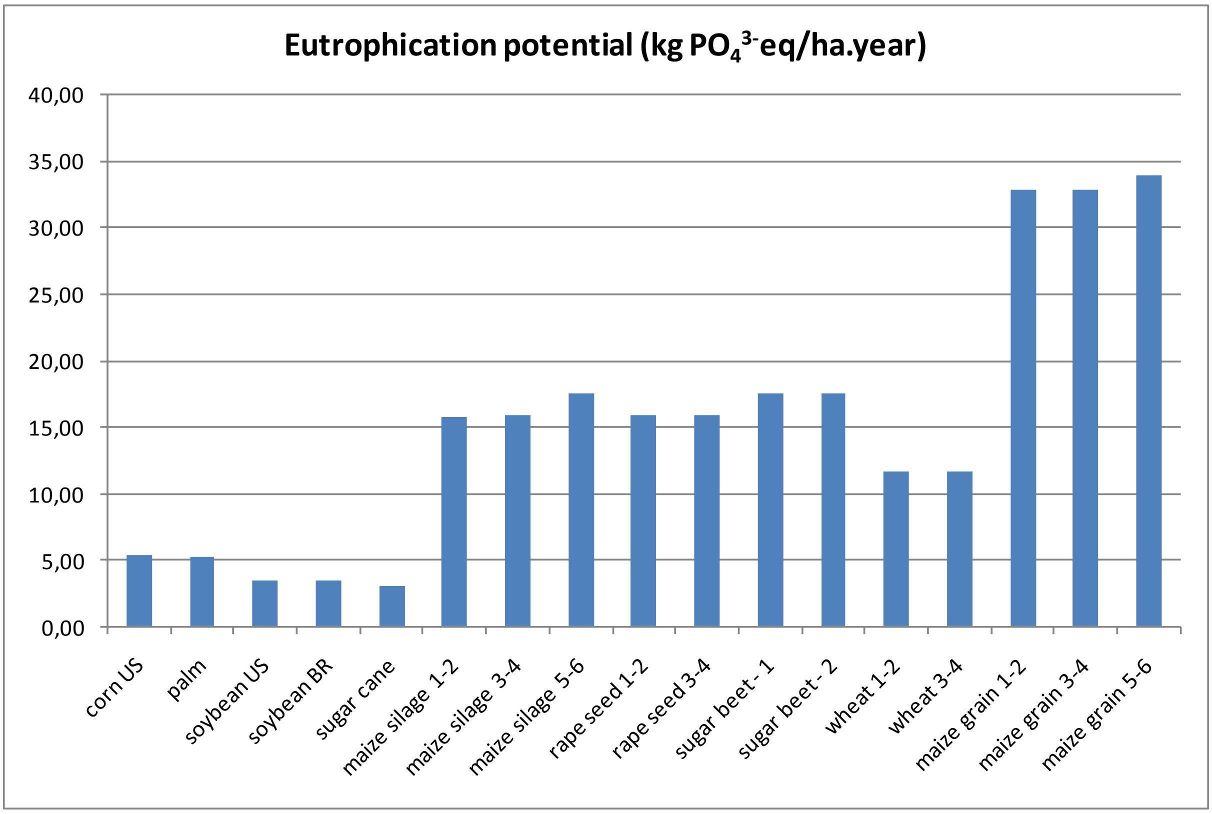



*Figure 9 – Eutrophication potential for 1 ha of crop*

Both graphs show better results in terms of acidification and eutrophication for imported crops. Among locally produced crops, grain maize has the worst effect, while other crops (silage maize, rapeseed, sugar beet and wheat) have similar results.

### 2.2.11. Qualitative impact on soil quality

Two factors are combined in order to assess raw material cultivation impacting soil quality: the risk of soil compaction and the impact on soil organic carbon.
Results were produced for locally produced biomass only and are summarised in the table below.

*Table IV – Qualitative assessment of impact on soil quality, through soil compaction and impact on soil organic carbon*

| | | SOIL COMPACTION | |
|---|---|---|---|
| **Bioenergy route** | **Risk** | **Rotation** | **Work processes** |
| Grain maize | 🔴 | if maize monoculture or follows potatoes | |
| | 🟡 | if follows maize or sugar beet, chicory | No tillage, leguminous green manure and by-products not buried |
| | 🟢 | if follows maize or sugar beet, chicory | Tillage, leguminous green manure and by-products buried |
| Silage maize | 🔴 | if maize monoculture or follows potatoes | |
| | 🟡 | if follows maize or sugar beet, chicory | No tillage, leguminous green manure and by-products not buried |
| | 🟢 | if follows maize or sugar beet, chicory | Tillage, leguminous green manure and by-products buried |
| Rapeseed | 🟢 | | |
| Sugar beet | 🟡 | | No tillage, leguminous green manure and by-products not buried |
| | 🟢 | | Tillage, leguminous green manure and by-products buried |
| Wheat | 🔴 | if follows potatoes, endives or carrots | Tillage, leguminous green manure and by-products buried |
| | 🟡 | if follows maize or sugar beet | Tillage, leguminous green manure and by-products buried |
| | 🟢 | if follows lineseed or rapeseed | Tillage, leguminous green manure and by-products buried |
| | 🔴 | if maize monoculture | Tillage, leguminous green manure and by-products buried |
| **Bioenergy route** | **Risk** | **SOIL ORGANIC CARBON** | |
| ALL | 🔴 | Tillage, leguminous green manure not buried but by-prod burried | |
| | 🟡 | No tillage, leguminous green manure & by-products not burried | |
| | 🟢 | Tillage, leguminous green manure and by-products buried | |

This table demonstrates the sensitivity of results regarding cultivation options. Even tough a simpler option, crop cultivation should not be considered as isolated and impact should take into account crop rotation and the place of the considered crop in this rotation. Work processes also impact soil quality and should be accounted for in any studied scenario.
Furthermore these qualitative assessments cannot consider the influence of weather conditions on soil structure, varying from one year to another.

### 2.2.12. Impact of deposition of pollutants on biodiversity

The impact of deposition of pollutants on biodiversity is expressed in dPDF/m².a according to a model developed to assess the impacts of airborne emissions of acidifying substances ($SO_x$, $NO_x$, and $NH_3$) on natural ecosystems in the Netherlands (Goedkoop & Spriensma 2001).
Results are shown below.

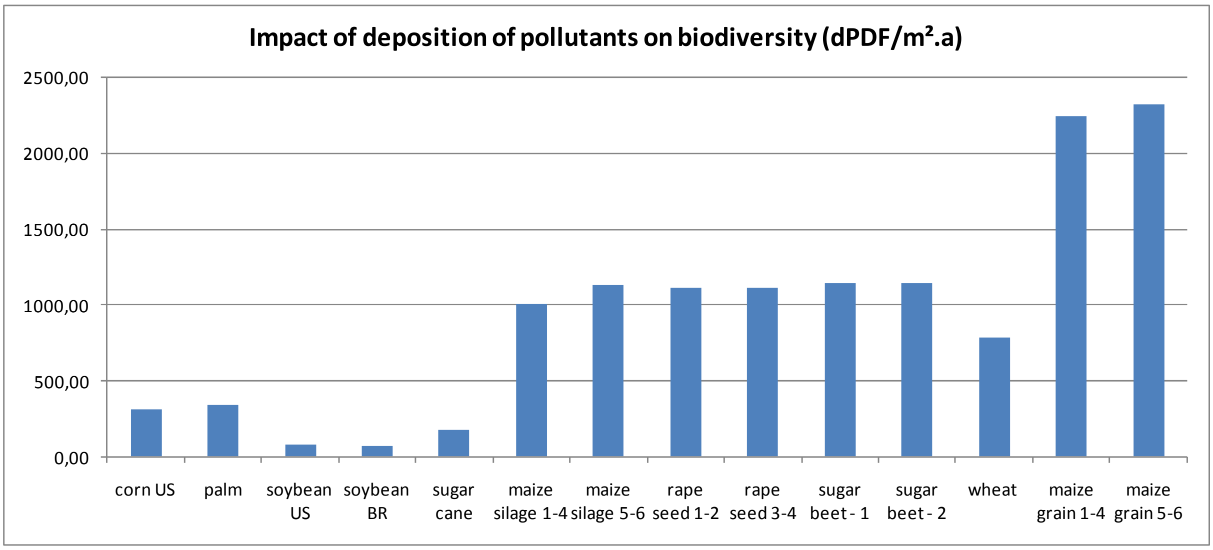



*Figure 10 – Impact of deposition of pollutants on biodiversity*

It is worth noting that this model does not take into account the impact of land-use change, such as deforestation, on biodiversity. If better results are attributed to imported crops, this has to relate to less fertilisers' use.

### 2.2.13. Job creation relating to cultivation and conversion

As described in Deliverable 4, job creation data has been extracted from GEMIS. Results in terms of job creation (direct and indirect jobs) for 1 ha of cultivated land are shown below (figures for corn US and silage maize are not available for part of the chain or for the whole chain and thus are not considered here).

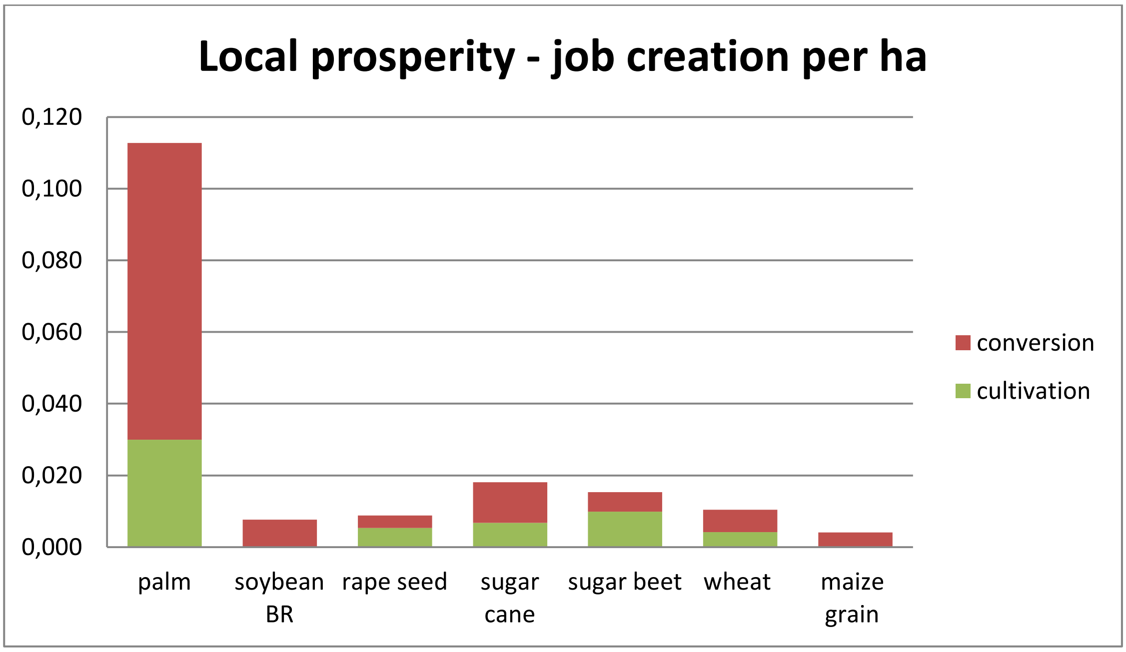



*Figure 11 – Job creation per ha of cultivated land*

Results show the biggest job creation for palm biodiesel. This relates first to the cultivation step that requires considerable man efforts because of the manual harvest. Secondly, results expressed in jobs per ha are also more important for palm because this crop has a significantly higher yield compared to the other.

Results for raw material for biodiesel production show again the advantage of palm methyl ester in terms of job creation per ha.

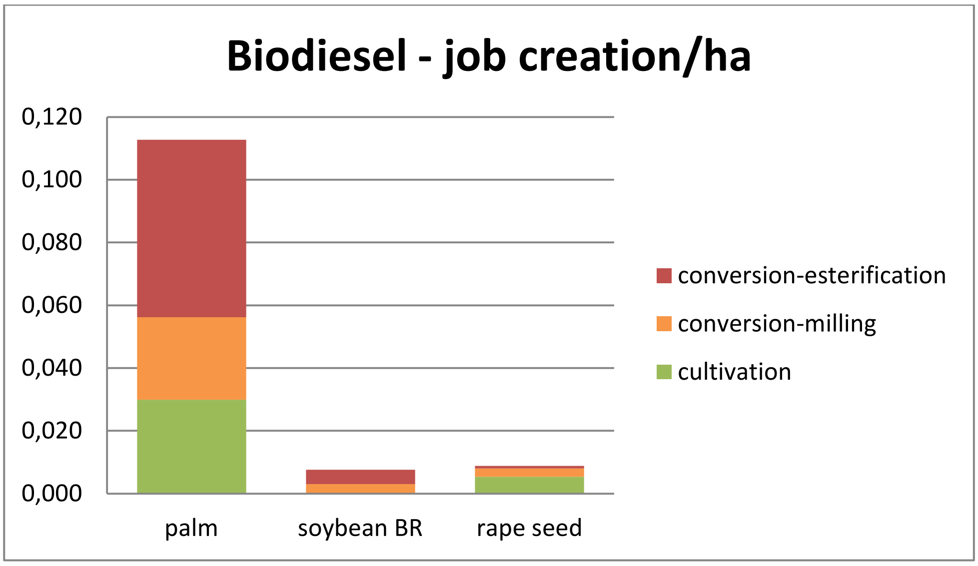



*Figure 12 – Job creation for biodiesel production per ha of cultivated land*

However, while expressed in jobs per energy content (TJ), results are quite different, as illustrated in the figure below. In terms of energy content, both imported biodiesel (palm and soybean) create more jobs than their locally produced equivalent (rapeseed). This is explained by the more important rate of mechanization in local productions (both cultivation and conversion).

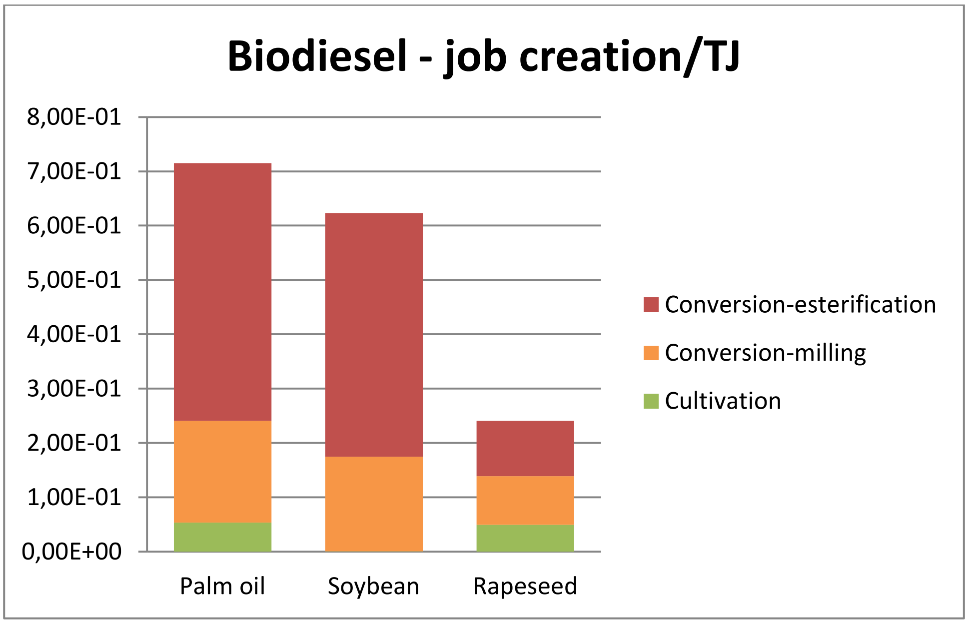



*Figure 13 - Job creation for biodiesel production per TJ*

The same observation is made for ethanol production where sugarcane comes first in terms of job creation per ha but is overtaken by wheat in terms of energy content.

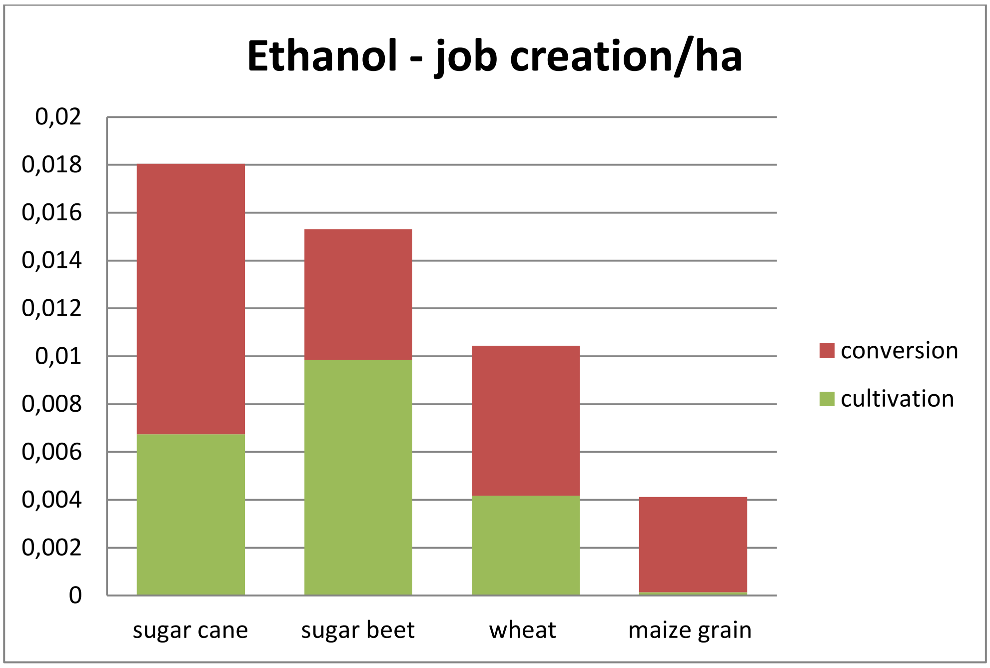



*Figure 14 – Job creation for ethanol production per ha of cultivated land*

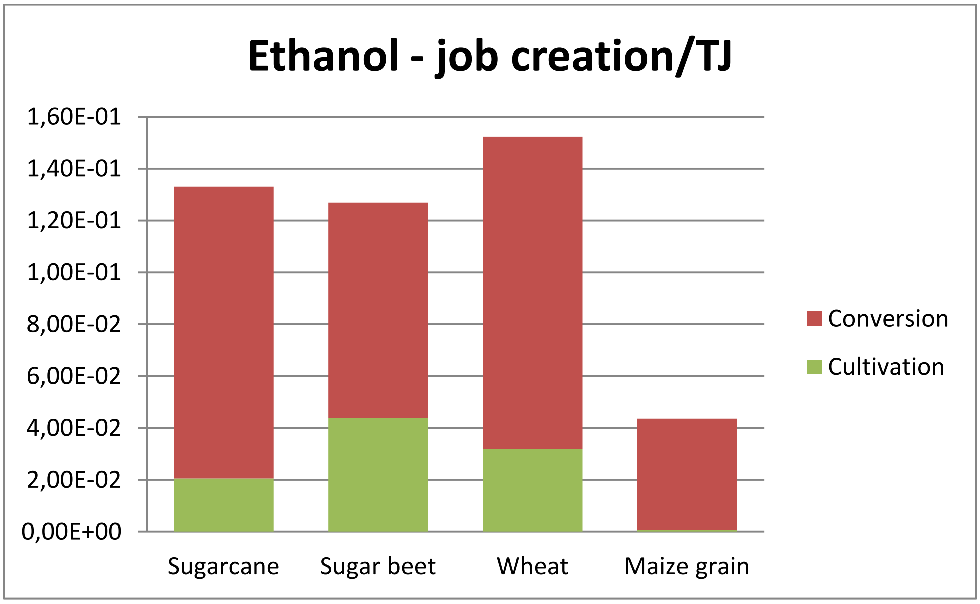



*Figure 15 - Job creation for ethanol production per TJ*

#### 2.2.14. Qualitative assessment of socio-economic impacts

As described in section 2.2.2, socio-economic externalities are assessed qualitatively. Results are gathered in Table V.

Social well-being mainly refers to working conditions. Child labour possibly involved in crop cultivation such as palm, soybean and sugarcane consequently awards them a red light.
Similarly property rights may also be threatened in those 3 bioenergy routes.
Since each studied route involves crops usually used for food production, all bioenergy routes should receive a yellow traffic light regarding those impacts.
Finally energy security was assessed according to Ducroire Credit Insurance.

From this table it appears that soybean cultivated in Brazil and sugarcane are less favourable from a socio-economic point of view.

*Table V – Qualitative assessment of socio-economic externalities*

| **Bioenergy routes** | **Social well-being** | **Property rights** | **Competition with food** | **Energy security** |
|---|---|---|---|---|
| Wheat | 🟢 | 🟢 | 🟡 | 🟢 |
| Rapeseed | 🟢 | 🟢 | 🟡 | 🟢 |
| Grain maize | 🟢 | 🟢 | 🟡 | 🟢 |
| Silage maize | 🟢 | 🟢 | 🟡 | 🟢 |
| Sugar beet | 🟢 | 🟢 | 🟡 | 🟢 |
| Palm | 🔴 | 🟡 | 🟡 | 🟢 |
| Soybean US | 🟢 | 🟢 | 🟡 | 🟡 |
| Soybean BR | 🔴 | 🟡 | 🟡 | 🔴 |
| Sugar cane | 🔴 | 🟡 | 🟡 | 🔴 |
| Corn US | 🟢 | 🟢 | 🟡 | 🟡 |

### 2.2.15. Monetization of impacts

According to methodology summarized in section 2.2.4, a monetary value has been calculated for the following categories of impacts:

- GHG emissions impacts on human health;
- Airborne emissions impacts on human health:
- Heavy metal emissions impacts on human health;
- Airborne emissions impacts on biodiversity.

**→ GHG emissions impacts on human health**

GHG emissions impacts on human health receive the following values:

- $CO_2$ = 8.34E-3 €/kg;
- $CH_4$ = 2.65E-1 €/kg;
- $N_2O$ = 1.27E+1 €/kg.

Results are presented below. The cultivation step, even showing negative GHG emissions (due to $CO_2$ absorption by plant growth), have more varied results in terms of monetization. This is explained by the monetary value that differs from one greenhouse gas to the other. Once again results will be more significant once displayed for the whole bioenergy chain (see end of this section).

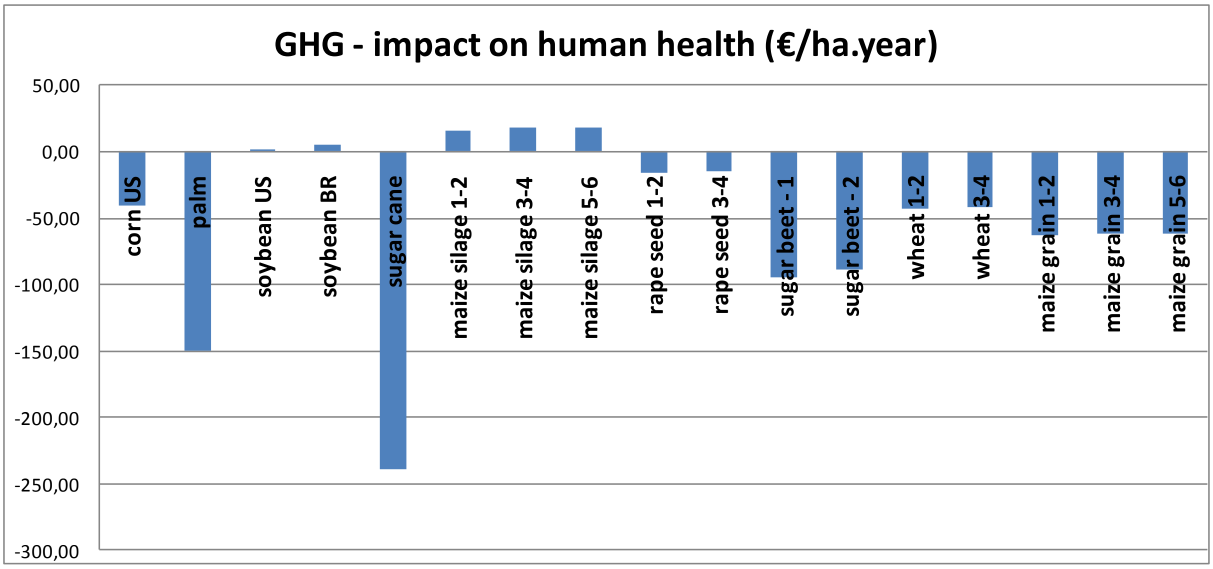



*Figure 16 – Monetary value of GHG emissions impact on human health, for the cultivation step*

### → Airborne emissions impacts on human health

Emissions to air impacting human health are monetized as follows:

- Sulphur dioxide $SO_2$ = 1.21E+1 €/kg;
- Nitrogen oxides $NO_x$ = 8.48 €/kg;
- Ammonia $NH_3$ = 3.18E+1 €/kg;
- Particle matter PM00 = 2.12 €/kg;
- Particle matter PM25 = 2.90E+1 €/kg;
- Non-metal volatile organic compounds NMVOC = 2.80 €/kg.

Results show again an advantage for imported crops, related to less phytoproduct use.

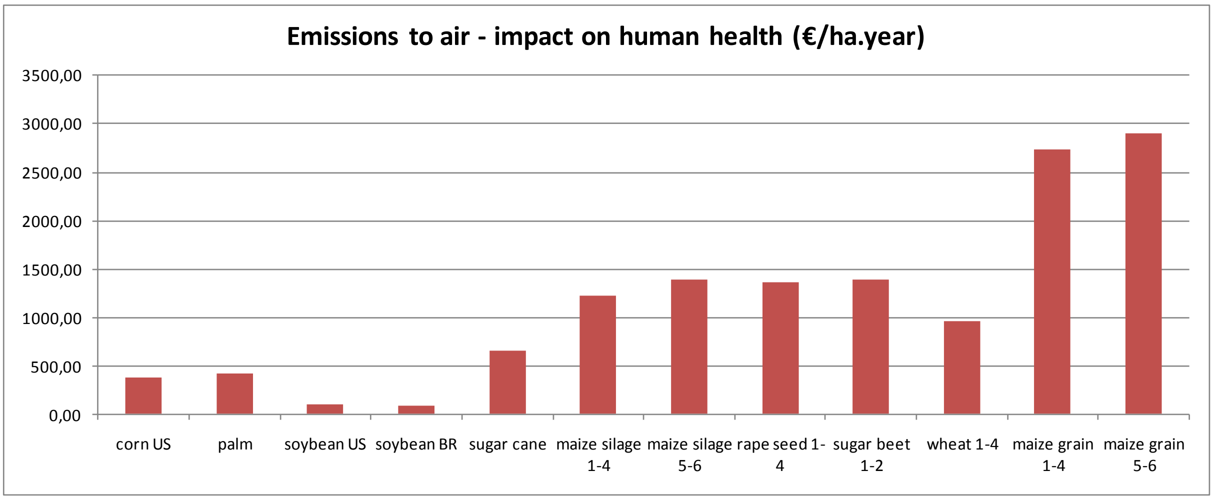



*Figure 17 – Monetary value of airborne emissions impact on human health, for the cultivation step*

→ **Heavy metal emissions impacts on human health;**

Heavy metals emissions impacts on human health are monetized as follows:

- Cadmium Cd = 1.34E+2 €/kg;
- Chromium Cr = 3.47E+1 €/kg;
- Chromium Cr-VI = 1.74E+2 €/kg;
- Lead Pb = 4.27E+2 €/kg;
- Mercury Hg = 1.16E+4 €/kg;
- Nickel Ni = 6.12 €/kg;
- Arsenic As = 8.58E+2 €/kg.

Results displayed in the graph below show important differences between selected scenarios for locally produced crops. This is explained by heavy metal emissions variation between fertilisation schemes.

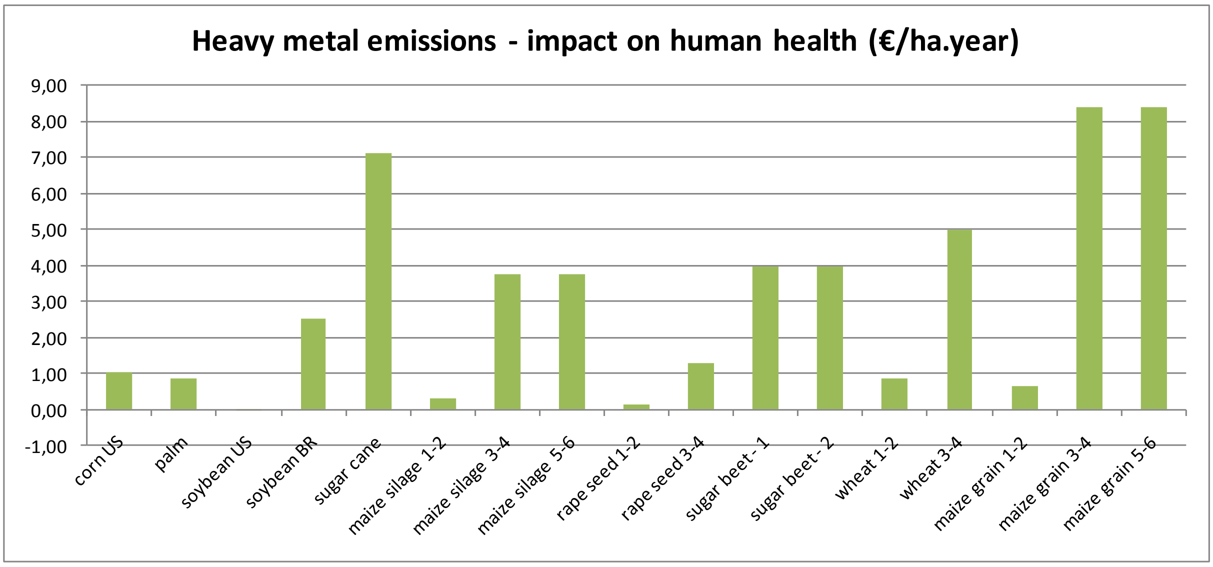



*Figure 18 - Monetary value of heavy metal emissions impact on human health, for the cultivation step*

→ **Airborne emissions impacts on biodiversity**

Emissions to air impacting biodiversity are monetized as follows:

- Sulphur dioxide $SO_2$ = 7.39E-1 €/kg;
- Nitrogen oxides $NO_x$ = 1.69 €/kg;
- Ammonia $NH_3$ = 5.14 €/kg.

Results show again the same trend: advantage for imported crops, related to less phytoproduct use, with the worse score for grain maize.

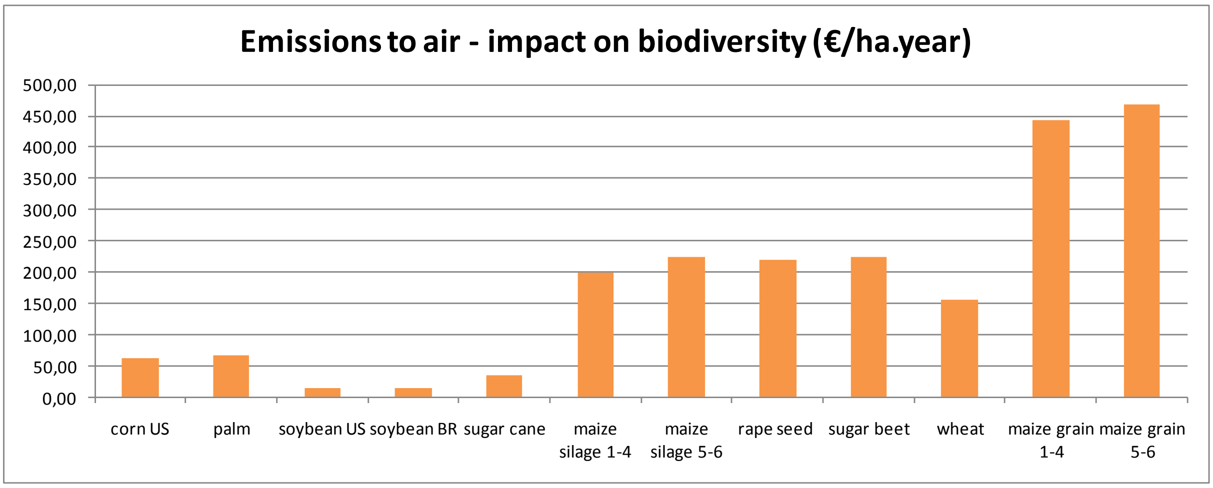



*Figure 19 - Monetary value of airborne emissions impact on biodiversity, for the cultivation step*

→ **Monetization of cultivation and conversion steps for wheat and rapeseed**

Additionally calculations made in section 2.3 allow calculating monetization impacts also for the conversion steps, for wheat and rapeseed.
Results are presented in the graphs below.

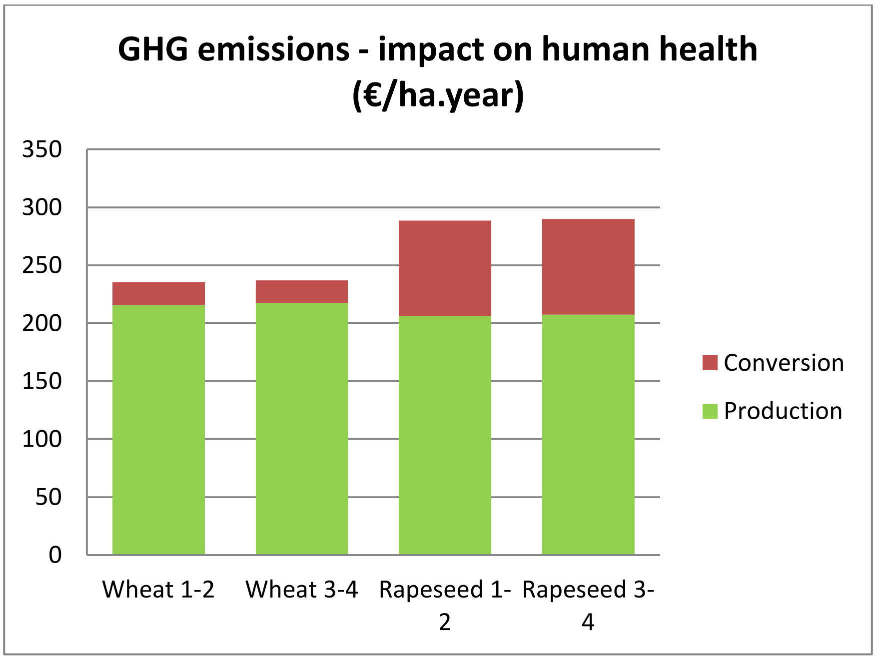



*Figure 20 – Monetization of GHG emissions impact on human health*

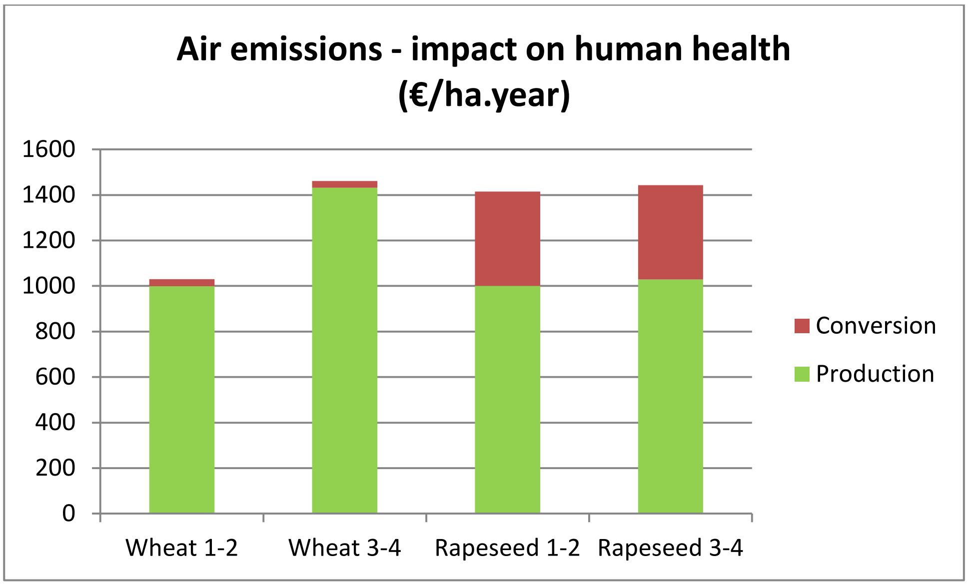



*Figure 21 - Monetization of airborne emissions impact on human health*

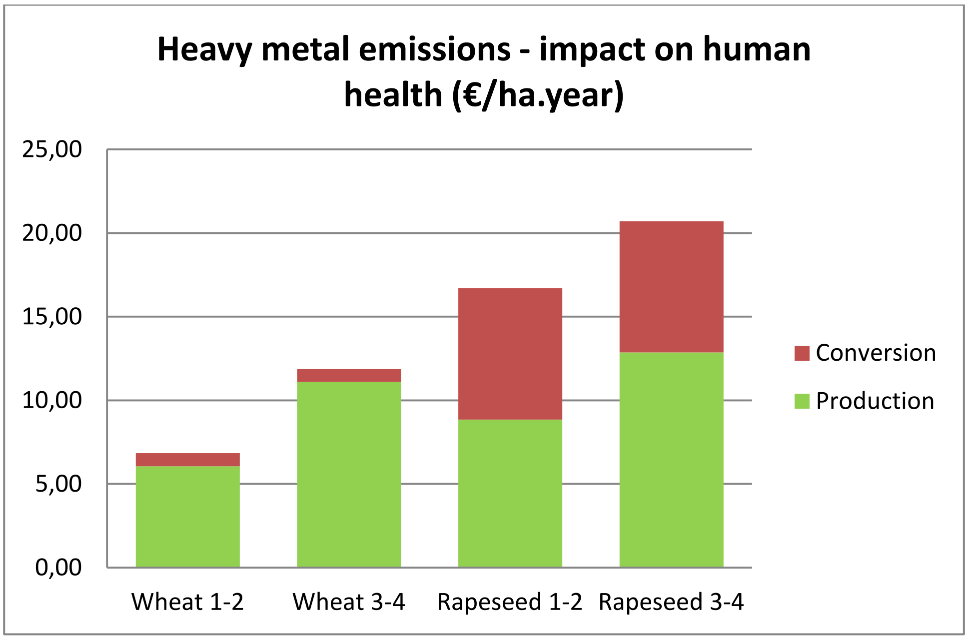



*Figure 22 - Monetization of heavy metal emissions impact on human health*

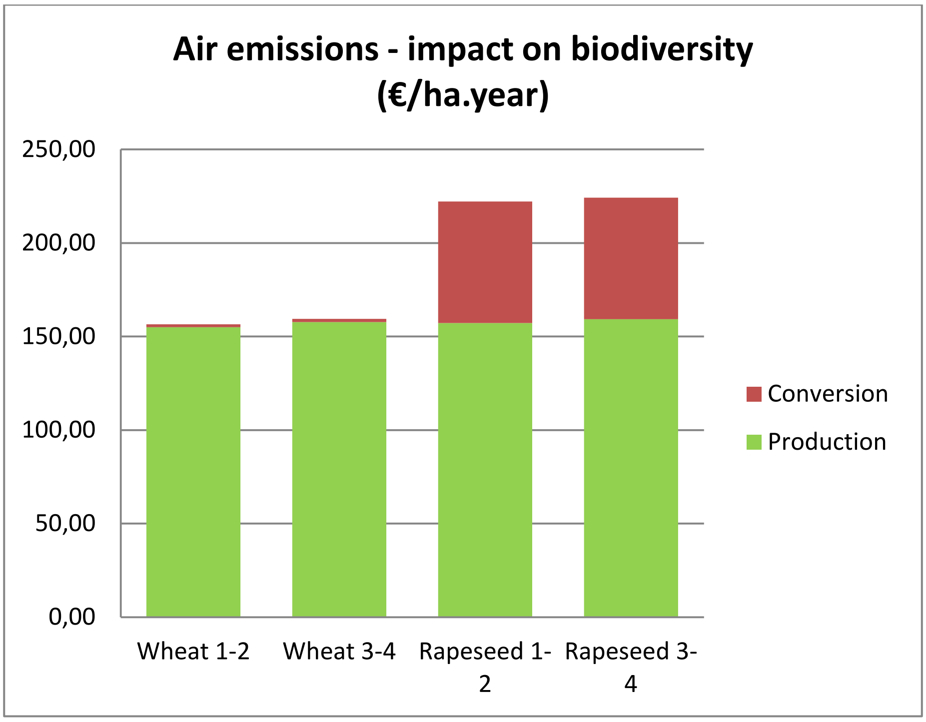



*Figure 23 - Monetization of airborne emissions impact on biodiversity*

All those figures show a greater contribution of the cultivation step compared to the conversion step. Wheat has a global score generally better than rapeseed, especially regarding the impact of the conversion step. The greatest costs are attributable to the impact of airborne emissions on human health.

### 2.2.16. Conclusions

Except in terms of nitrate leaching, imported crops generally show a better environmental result, mainly due to less phytoproducts application. However from the socio-economic side, imported crops are more controversial.

Among locally produced crops it appears that grain maize has a much worse effect on the environment compared to the other considered crops. Now current trends show a transition in Belgium from silage maize towards grain maize. This shift is explained by the increasing inclusion of starch in animal feed rations required by newly developed animal breeds. This means that the environmental impact of grain maize should be accounted for while choosing between silage or grain maize.

The examination of these graphs underlines the sensitivity of results towards cultivation pathways and the choice between work processes options.

The main conclusion drawn from these figures and calculations is that even if default values exist for bioenergy production routes and are commonly accepted, it should remain possible to propose data adapted to the local context.

The database and models developed by this project can be of great support to this process, allowing the user, whether a decision-maker or a producer, to compare options between several bioenergy routes and their cultivation pathways.

## 2.3. SYSTEM PERTURBATION ANALYSIS

### 2.3.1. System Perturbation Analysis methodology

The System Perturbation Analysis methodology (SPA) considers a given system where resources are transformed into products via a set of documented conversion routes as shown in Figure 24. These conversions lead to impacts such as GHG emissions, land requirements and energy use.

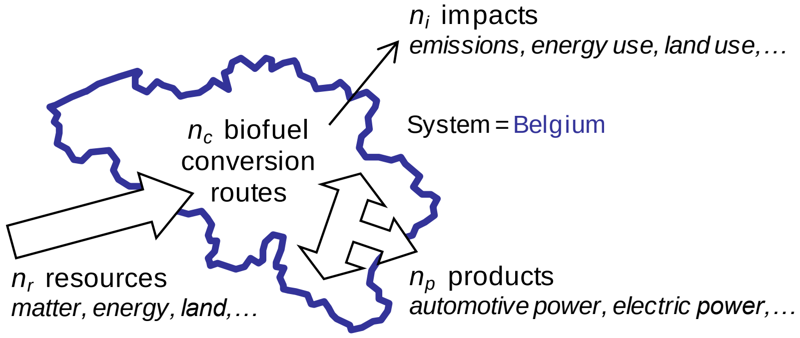



*Figure 24: SPA system with resources, conversion routes, products and impacts*

A single resource can be converted to different products simultaneously (eg. co-products). Besides the major resources, each route consumes so-called utilities, which in their turn can be considered as separate types of resources. The contributions to the different kinds of impacts arise not only from resources and products but also from the utilities and must therefore be calculated in a cautious way, in order to avoid double counting. More detailed information on the SPA methodology and supporting background equations can be in found in a paper about biomass use assessment via SPA (Bram, 2009).

The objective of a system perturbation analysis is to determine the variations of considered impacts on a system (in casu Belgian) when conventional resources are replaced by alternative ones (e.g. 1MJ gasoline replaced by 1 MJ ethanol from wheat). To calculate these impact variations, a single resource is perturbed with a certain magnitude (e.g. import reduction of 1 ton of gasoline per year). The demand side is managed through a boundary condition which keeps all product amounts at constant level. This automatically implies necessary perturbations of other products and co-products as depicted in Figure 25.

When all perturbations are compensated, the variations of the impacts can easily be calculated. SPA can be considered as a consequential LCA where the system is expanded to the Belgian border. SPA does not use allocations within the considered system.

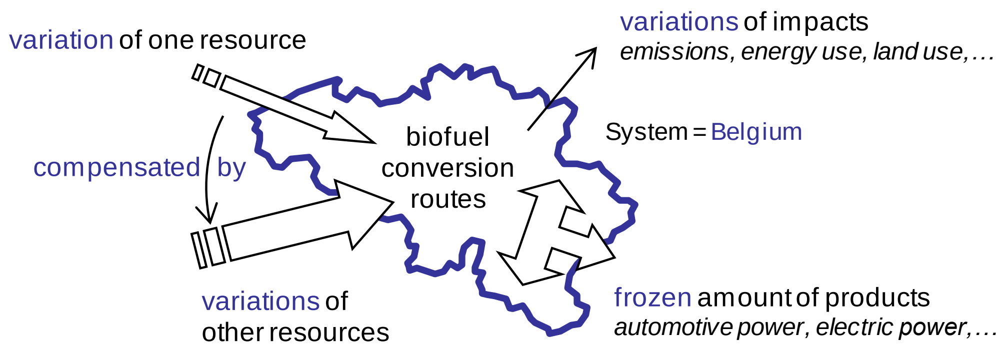



*Figure 25: SPA scenario - perturbation and compensations of the system*

Every scenario in SPA is a set of perturbations of resources and impacts. It is therefore possible to define evaluation criteria based on certain ratios of these perturbations. These criteria allow for a systematic comparison of different SPA scenarios. The six criteria that were used in the original SPA are shown in Table VI.

In this table, the produced and avoided energy flows are net values, hence after compensations for consumed utilities and produced co-products. Energy and GHG balances are real, provided the used data and import compensations correspond to reality. Criteria A and B indicate to what extent the produced renewable energy really reduces fossil energy use. Criteria C and D show avoided GHG emissions as function of fossil energy use reduction. Criteria E and F show how the use of land is related to a reduction in fossil fuel dependency and to GHG emission reduction within a system.

*Table VI: SPA criteria and corresponding perturbation ratios*

| | *SPA criterium* | *system* | *perturbation ratio* | | |
|---|---|---|---|---|---|
| *A* | Energy efficiency | world | $GJ_{prim}$ avoided worldwide | / | $GJ_{renew}$ produced worldwide |
| *B* | Energy efficiency | Belgium | $GJ_{fossil}$ import to Belgium avoided | / | $GJ_{renew}$ produced worldwide |
| *C* | Energy specific GHG emissions | world | kg $CO_{2eq}$ avoided worldwide | / | $GJ_{prim}$ avoided worldwide |
| *D* | Energy specific GHG emissions | Belgium | kg $CO_{2eq}$ avoided in Belgium | / | $GJ_{fossil}$ import to Belgium avoided |
| *E* | Energy specific land requirement | Belgium | hectare in Belgium | / | $GJ_{fossil}$ import to Belgium avoided |
| *F* | GHG specific land requirement | Belgium | hectare in Belgium | / | ton $CO_{2eq}$ avoided in Belgium |

### 2.3.2. New development within TEXBIAG

The interest for SPA has encouraged the authors to participate in the TEXBIAG project and to improve the SPA instrument in several respects. An upgraded approach has resulted which for convenience will be named SPA2, against the former SPA1.

The following incentives led to the definition of SPA2:

a. Extension to other impact types (including 'externalities')
b. Connecting the resources, conversion routes and impacts data to major data bases
c. Increased flexibility in use
d. Solve inherent problems inside SPA1 (utilities, route description, a.o.)
e. Maximum automatism in use, in order to deliver a tool for general use.
f. More flexibility in inside/outside allocation of processes

In the first phase of the Texbiag project, most attention was given to aspects *b* and *e*. The Ecoinvent database was chosen as the major resource for getting detailed data, automatically including aspect *a* through more than hundred different and detailed impacts.

The structure of the original SPA1 is shown in Figure 26. Data were to a large extent obtained from the CONCAWE report, but much missing information had to be searched through extensive literature surveys. Data were introduced manually in worksheets where a standardised input of data was programmed for the different route steps. Each input had to be located inside or outside of the system.

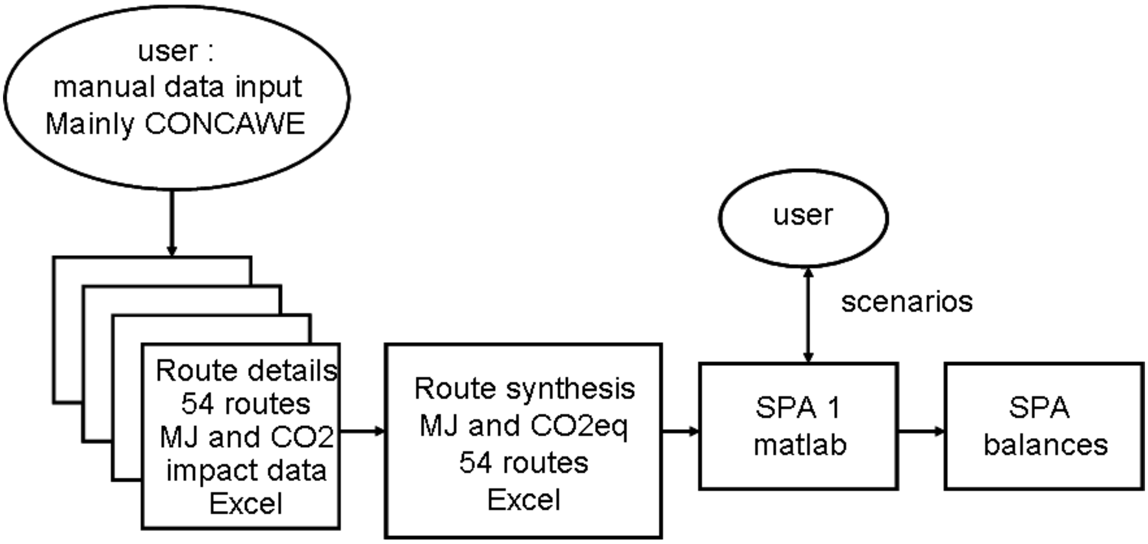



*Figure 26: Outline of the original SPA software*

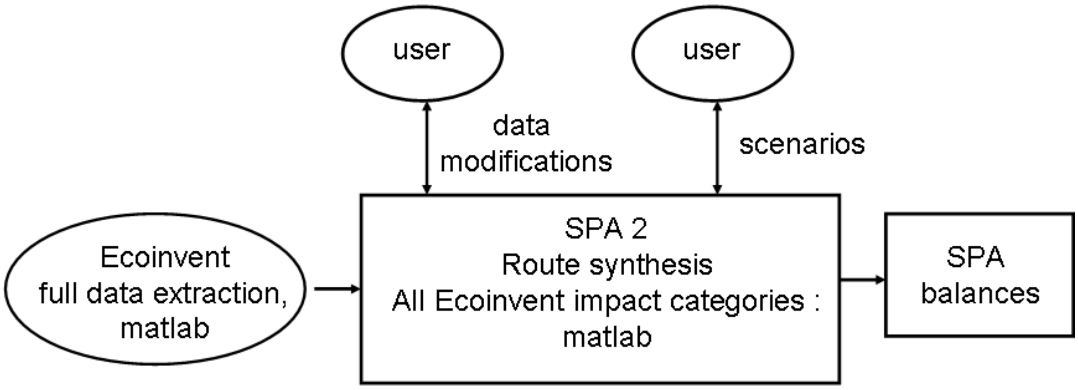



*Figure 27: Tentative SPA2 outline*

At the end of phase 1, the ambition was to realise a package outlined in Figure 27. In this approach, the whole package adhered strictly to Ecoinvent. One goal was to fully automate the entire data extraction process and to have all imaginable data within Ecoinvent at the disposal of the SPA user in no time. Unfortunately - and although the data extraction works perfectly - this approach had to be abandoned in the last phase of the project, for the following reasons:

- Incompatibility between Ecoinvent and SPA regarding the handling of multi-output processes and cyclic process loops.
- Overwhelming amount of information, where only a fraction is needed.
- Major difficulties in data modifications, because of incompatibility with Ecoinvent.
- Still missing data, even in Ecoinvent.
- No flexibility because of Ecoinvent adherence.

For these reasons, a drastic change in approach was realised in the last months of the Texbiag project, and the final approach as depicted in Figure 28 has been applied. In this approach the data supply and the SPA2 package are completely separated, thus allowing any type of data input.

The Ecoinvent data extraction is of course not lost work, but is now considered as a separate tool. The interface between the data supply and SPA2 now occurs through excel templates, which are made as simple, flexible and user friendly as possible. The templates can be generated by the Ecoinvent data extraction tool from Ecoinvent data or from within SIMAPRO. The templates are also suited to fully reproduce the original LIBIOFUELS data or simpler biofuel problem settings, and are capable of using other data types such as those provided within TEXBIAG or underlying data from the RED directive (Biograce, 2009). SPA2 also allow for easy addition of extra impact categories.
The two interface excel data tables are based on only two instructions which are able to describe the routes and streams with all required details.

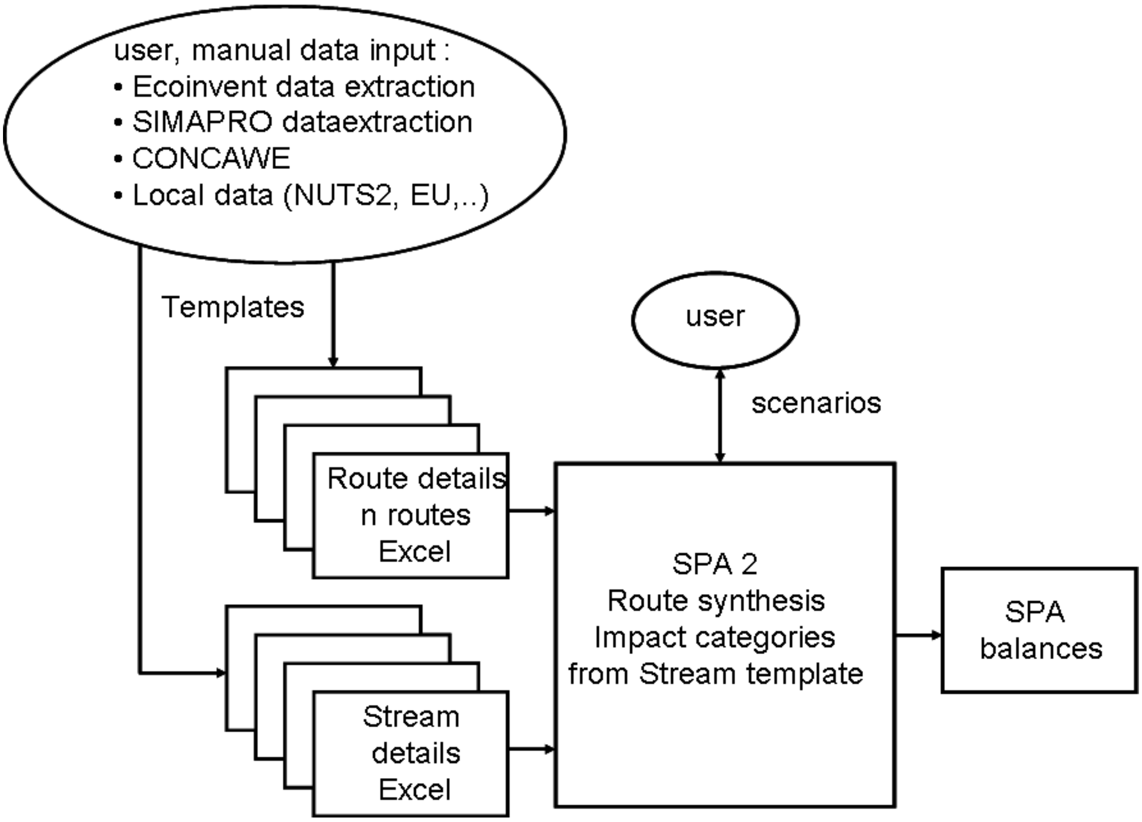



*Figure 28: Final SPA2 outline*

### 2.3.3. Route template description

The route description template is shown in Table VII. The route is described step by step, where each step corresponds to an ingoing or outgoing stream connected to the 'action' in the second column. The 'action' is pretty similar to a 'unit process' in Ecoinvent but it can interpreted in a more flexible way. The first column specifies the phase where the process or action takes place. The traditional sequence of Production, Transport, Conversion, Distribution and End-use is maintained in the shown example. Other denominations can be used and if so, they will be automatically taken over by the SPA2 program. The second column is an alphanumeric description of the action or process within the category. The third column tells what connection is considered.

The possible 'operators' are as follows:

- Needs
- Makes
- Creates
- Loses

'Needs' merely corresponds to an input to the process. It is irrelevant where this input is coming from, since this aspect will be treated through overall balancing. The input 'stream' is not necessarily a material stream, it can virtually be anything. 'Makes' merely corresponds to an output stream. It is again irrelevant where this stream is going to.

'Creates' is similar to 'Makes' but it indicates something which comes 'out of the blue'. For example, wheat grown within the system is 'created'. The difference with 'makes' is that this wheat is not materially imported but literally comes from within the system as a source term.

'Loses' is the opposite of 'Creates'. It represents for example the wheat lost during transport. It might also be used for heat or other losses. These streams act as a sink into the system.

The amount of ingoing and outgoing streams is unlimited, which solves the problem of multi-output processes, and it includes the harmful emissions or any other impact categories. As will be explained in the next section the 'stream' may also be a set of substreams defined in the stream template. In this way identical processes used in several routes can be introduced only one time as a set of substreams, e.g. the full wheat cultivation process. Such 'shortcuts' considerably simplify and reduce the amount of lines in the templates.

The stream quantity is the product of the columns 'quantity' and 'multiplier', where the multipliers can correspond to a conversion factor. This split makes it easier to work with references per unit of stream. In the example shown in Table VIII, 1 ha of land yields 8.8 tonnes of wheat and 1% is lost during transport, which reads easily in the multiplier column.

The last column tells to what extent the connection is to be considered as within the system, expressed in %.

The sequence of route descriptors is irrelevant, except for the first and the last one. The first is considered as the 'anchor' of the route and this stream is automatically considered for perturbation, which occurs by changing this stream with one functional unit. It is therefore advised to use the value 1 in the columns 'amount' and 'multiplier'. The last line is automatically considered as the prime product generated by the considered route. It is therefore strongly advised to use a stream of the type 'end-product' there, which is typically in kilometres, kWh electric or kWh heat. Since the available surface must be kept constant, a route 'making' hectares is also advised for easier analysis, but this is not a must.

*Table VII: SPA2 Route template example (LIBIOFUELS Route 9)*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Route ID** | | | | 9 | | | |
| **Route name** | | | | Wheat on set aside land for ethanol, straw for heating | | | |
| **Category** | **Action** | **Operator** | **Stream** | **Quantity** | **Multiplyer** | **unit** | **% system** |
| Production | Yield | needs | wheat cultivation | 1 | 1 | ha | 100 |
| Production | Yield | creates | wheat | 8.8 | 1 | ton | 100 |
| Production | Yield | creates | Straw | 4.4 | 1 | ton | 100 |
| Production | Yield | loses | Straw | 4.4 | 1 | ton | 100 |
| Production | Yield | creates | Energy renewable | -207020 | 1 | MJ | 100 |
| Transport | Losses | loses | Wheat | 0.01 | 8.8 | ton | 100 |
| Transport | To farm | needs | Km truck | 29 | 8.8 | ton.km | 100 |
| Transport | To depot | needs | Km truck | 145 | 8.8 | ton.km | 100 |
| Transport | Depot | needs | Electricity | 11.6 | 8.8 | kWhe | 100 |
| Transport | To conversion site | needs | Km ship inland | 116 | 8.8 | ton.km | 100 |
| Conversion | Yield | needs | Wheat | 1 | 8.71 | ton | 100 |
| Conversion | Yield | makes | Ethanol | 0.295 | 8.71 | ton | 100 |
| Conversion | Milling | needs | Electricity | 12.3 | 8.71 | kWhe | 100 |
| Conversion | Hydrolysis to distillation | needs | Steam | 847 | 8.71 | kg | 100 |
| Conversion | Dehydratation | needs | Steam | 5 | 8.71 | kg | 100 |
| Conversion | Drying | needs | Steam | 694 | 8.71 | kg | 100 |
| Conversion | Boiler | needs | Straw | 0.31 | 8.71 | ton | 100 |
| Conversion | Boiler | makes | Steam | 1546 | 8.71 | kg | 100 |
| Conversion | Yield | makes | DDGS | 0.371 | 8.71 | ton | 100 |
| Conversion | Plant construction | needs | Other primary energ | 62.8 | 8.71 | MJ | 100 |
| Distribution | To blending | needs | km ship inland | 100 | 2.57 | ton.km | 100 |
| Distribution | To distributor | needs | km truck | 200 | 2.57 | ton.km | 100 |
| End use | Yield | needs | Ethanol | 0.295 | 8.71 | ton | 100 |
| End use | Driving | makes | Km | 11964 | 2.57 | km | 100 |

### 2.3.4. Stream template description

The stream template illustrated in Table VIII is more complex in nature than the route template because streams must be divided into several categories. Also, the stream template contains important shortcuts. As a minimum, it must contain all the streams that are used in the route description, but it also contains substreams and streams that lead to impacts which are not necessarily used in the route template.
The first columns identify the streams and their units, which must be coherent with the streams already defined in Table VIII (no unit conversion is considered for the time being). The third column is similar to the 'operator' in Table VIII; the following operators are allowed:

- Includes
- Endproduct
- Impact
- Balanced

If a stream is merely a short-cut, thus only bundling other streams specified in the fourth column, the operator 'includes' must be used. It is essential not to use 'makes' or 'needs' in such cases because of possible sign inversions in the stream, with other words a 'needs' must remain a 'needs', etc. With 'includes' it is possible to include simplified process units in the stream template, in particular if the stream or process is identical in several routes, thus simplifying the data supply. In the last part of Table VIII the whole cultivation process of wheat is described as a stream bundle as an example; the actions can still be given in comment to provide more clarity. The wheat production data are thus introduced only one time.

'End-product' means the stream is an open end, and it corresponds to one of the end products considered by SPA1 and SPA2. The type 'end-product' automatically means the balance of this stream is frozen, and it therefore needs no further description since it will not vary during the analysis.
'Impact' is also an open end, but it corresponds to all the other desired or undesired streams such as for instance $CO_2$eq or any other emission or impact factor. These streams also do not need further description.

*Table VIII: Stream description, including several shortcuts (LIBIOFUELS route 9)*

| %Stream | Unit | Operator | Stream | Amount | Unit | %system | Comment |
|---|---|---|---|---|---|---|---|
| % | | | | | | | |
| **% impact** | | | | | | | |
| Energy non renewable | MJ | impact | | | | 100 | |
| Energy renewable | MJ | impact | | | | 100 | |
| CO2eq | kg | impact | | | | 100 | |
| Set aside land | ha | impact | | | | 100 | |
| % | | | | | | | |
| CO2 | kg | includes | CO2eq | 1 | kg | 100 | |
| CH4 | kg | includes | CO2eq | 23 | kg | 100 | |
| N2O | kg | includes | CO2eq | 296 | kg | 100 | |
| % | | | | | | | |
| **% end products** | | | | | | | |
| km | km | endproduct | | | | | frozen |
| electricity | kWhe | endproduct | | | | | frozen |
| heat | kWhth | endproduct | | | | | frozen |
| DDGS | ton DDG | endproduct | | | | | frozen |
| straw | ton straw | endproduct | | | | | frozen |
| Surface | ha | endproduct | | | | | frozen |
| % | | | | | | | |
| **% utilities all imported** | | | | | | | |
| Gasoline | kg | includes | Energy non renewable | 43.2 | MJ | 100 | |
| Gasoline | kg | includes | Energy non renewable | 6.05 | MJ | 0 | |
| Gasoline | kg | includes | CO2 | -3.19 | kg | 100 | |
| Gasoline | kg | includes | CO2 | -0.54 | kg | 0 | |
| % | | | | | | | |
| Diesel | kg | includes | Energy non renewable | 43.1 | MJ | 100 | |
| Diesel | kg | includes | Energy non renewable | 6.90 | MJ | 0 | |
| Diesel | kg | includes | CO2 | -3.15 | kg | 100 | shortcut |
| Diesel | kg | includes | CO2 | -0.61 | kg | 0 | shortcut |
| % | | | | | | | |
| Heavy fuel oil | kg | includes | Energy non renewable | 40.5 | MJ | 100 | |
| Heavy fuel oil | kg | includes | Energy non renewable | 4.05 | MJ | 0 | |
| Heavy fuel oil | kg | includes | CO2 | -3.28 | kg | 100 | shortcut |
| Heavy fuel oil | kg | includes | CO2 | -0.27 | kg | 0 | shortcut |
| % | | | | | | | |
| Natural gas | kg | includes | Energy non renewable | 44.8 | MJ | 100 | |
| Natural gas | kg | includes | Energy non renewable | 2.11 | MJ | 0 | |
| Natural gas | kg | includes | CO2 | -2.51 | kg | 100 | shortcut |
| Natural gas | kg | includes | CO2 | -0.20 | kg | 0 | shortcut |
| % | | | | | | | |
| Hard coal | kg | includes | Energy non renewable | 29.4 | MJ | 100 | |
| Hard coal | kg | includes | Energy non renewable | 2.76 | MJ | 0 | |
| Hard coal | kg | includes | CO2 | -2.82 | kg | 100 | shortcut |
| Hard coal | kg | includes | CO2 | -0.45 | kg | 0 | shortcut |
| % | | | | | | | |
| Electricity_imported | kWhe | includes | Energy non renewable | 6.73 | MJ | 100 | |
| Electricity_imported | kWhe | includes | Energy renewable | 0.00 | MJ | 0 | |
| Electricity_imported | kWhe | includes | CO2eq | -0.472 | kg | 0 | shortcut |
| % | | | | | | | |
| Other primary energy | MJ | includes | Energy non renewable | 1 | MJ | 100 | |
| Other primary energy | MJ | includes | Energy non renewable | 0 | MJ | 0 | |
| Other primary energy | MJ | includes | CO2 | 0.000 | kg | 100 | shortcut |
| Other primary energy | MJ | includes | CO2 | 0.000 | kg | 0 | shortcut |

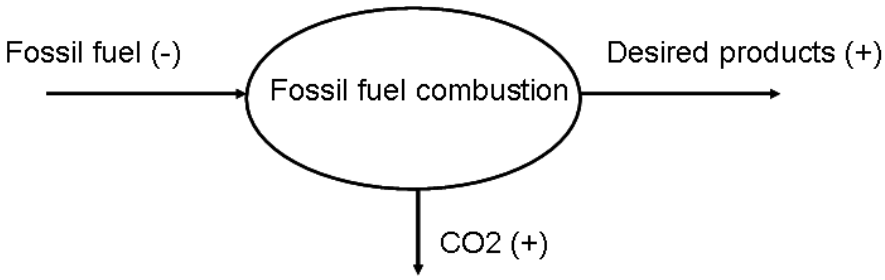
Table continued: Stream description, including several shortcuts (LIBIOFUELS route 9)

| %Stream | Unit | Operator | Stream | Amount | Unit | %system | Comment |
|---|---|---|---|---|---|---|---|
| % | | | | | | | |
| **% fertilizers** | | | | | | | |
| CaO fertiliser | kg | includes | Diesel | 4.64E-03 | kg | 100 | |
| CaO fertiliser | kg | includes | Natural gas | 6.70E-03 | kg | 100 | |
| CaO fertiliser | kg | includes | Electricity | 5.94E-02 | kg | 100 | |
| CaO fertiliser | kg | includes | Heavy fuel oil | 0.00E+00 | kg | 100 | |
| CaO fertiliser | kg | includes | Hard coal | 2.04E-02 | kg | 100 | |
| CaO fertiliser | kg | includes | CO2 | 0.00E+00 | kg | 100 | |
| CaO fertiliser | kg | includes | CH4 | -2.70E-04 | kg | 100 | shortcut |
| CaO fertiliser | kg | includes | N2O | -2.20E-06 | kg | 100 | shortcut |
| % | | | | | | | |
| K fertiliser | kg | includes | Diesel | 1.16E-02 | kg | 100 | |
| K fertiliser | kg | includes | Natural gas | 1.67E-01 | kg | 100 | |
| K fertiliser | kg | includes | Electricity | 2.97E-02 | kg | 100 | |
| K fertiliser | kg | includes | Heavy fuel oil | 0 | kg | 100 | |
| K fertiliser | kg | includes | Hard coal | 0 | kg | 100 | |
| K fertiliser | kg | includes | CO2 | 0 | kg | 100 | |
| K fertiliser | kg | includes | CH4 | -9.40E-04 | kg | 100 | |
| K fertiliser | kg | includes | N2O | -1.20E-06 | kg | 100 | |
| % | | | | | | | |
| N fertiliser | kg | includes | Diesel | 2.09E-02 | kg | 100 | |
| N fertiliser | kg | includes | Natural gas | 7.37E-01 | kg | 100 | |
| N fertiliser | kg | includes | Electricity | 8.91E-02 | kWhe | 100 | |
| N fertiliser | kg | includes | Heavy fuel oil | 1.09E-01 | kg | 100 | |
| N fertiliser | kg | includes | Hard coal | 3.06E-02 | kg | 100 | |
| N fertiliser | kg | includes | CO2 | -1.55 | kg | 100 | |
| N fertiliser | kg | includes | CH4 | -5.48E-03 | kg | 100 | shortcut |
| N fertiliser | kg | includes | N2O | -9.63E-03 | kg | 100 | shortcut |
| % | | | | | | | |
| P fertiliser | kg | includes | Diesel | 2.55E-02 | kg | 100 | |
| P fertiliser | kg | includes | Natural gas | 7.14E-02 | kg | 100 | |
| P fertiliser | kg | includes | Electricity | 2.38E-01 | kWhe | 100 | |
| P fertiliser | kg | includes | Heavy fuel oil | 1.23E-01 | kg | 100 | |
| P fertiliser | kg | includes | Hard coal | 2.04E-02 | kg | 100 | |
| P fertiliser | kg | includes | CO2 | -0.09 | kg | 100 | |
| P fertiliser | kg | includes | CH4 | -1.04E-03 | kg | 100 | shortcut |
| P fertiliser | kg | includes | N2O | -8.60E-06 | kg | 100 | shortcut |
| % | | | | | | | |
| Pesticides | kg | includes | Diesel | 1.35E+00 | kg | 100 | |
| Pesticides | kg | includes | Natural gas | 1.59E+00 | kg | 100 | |
| Pesticides | kg | includes | Electricity | 4.23E+00 | kWhe | 100 | |
| Pesticides | kg | includes | Heavy fuel oil | 8.02E-01 | kg | 100 | |
| Pesticides | kg | includes | Hard coal | 2.59E-01 | kg | 100 | |
| Pesticides | kg | includes | CO2 | 0 | kg | 100 | |
| Pesticides | kg | includes | CH4 | -1.93E-02 | kg | 100 | shortcut |
| Pesticides | kg | includes | N2O | -1.52E-04 | kg | 100 | shortcut |
| % | | | | | | | |
| Wheat seed | kg | includes | Other primary energy | 13.5 | MJ | 100 | |
| Wheat seed | kg | includes | CO2eq | -0.87 | kg | 100 | |
| % | | | | | | | |
| **% Transport** | | | | | | | |
| km truck | ton.km | includes | Diesel | 0.0225 | kg | 100 | makes emiss |
| km ship inland | ton.km | includes | Diesel | 0.0100 | kg | 100 | makes emiss |
| km ship offshore | ton.km | includes | Heavy fuel oil | 0.0049 | kg | 0 | makes emiss |
| hours tractor | hour | includes | Diesel | 8.8000 | kg | 100 | |
| % | | | | | | | |
| **% Other** | | | | | | | |
| DDGS imported | ton | includes | Energy non renewable | 9193 | MJ | 0 | |
| DDGS imported | ton | includes | Energy renewable | 18200 | MJ | 0 | |
| DDGS imported | ton | includes | CO2eq | -538 | kg | 0 | |
| DDGS | ton | balanced | | | | | |
| Ethanol | ton | balanced | | | | | |
| Steam | kg | balanced | | | | | |
| Wheat | ton | balanced | | | | | |

Table continued: Stream description, including several shortcuts (LIBIOFUELS route 9)

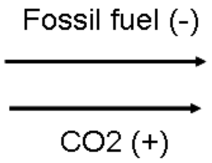
| %Stream | Unit | Operator | Stream | Amount | Unit | %system | Comment |
|---|---|---|---|---|---|---|---|
| % | | | | | | | |
| **% shortcut wheat cultivation** | | | | | | | |
| wheat cultivation | ha | includes | Surface | 1 | ha | 100 | |
| wheat cultivation | ha | includes | N fertiliser | 185 | kg | 100 | |
| wheat cultivation | ha | includes | P fertiliser | 72 | kg | 100 | |
| wheat cultivation | ha | includes | K fertiliser | 50.2 | kg | 100 | |
| wheat cultivation | ha | includes | CaO fertiliser | 8.7 | kg | 100 | |
| wheat cultivation | ha | includes | Pesticides | 3.27 | kg | 100 | |
| wheat cultivation | ha | includes | Wheat seed | 185 | kg | 100 | |
| wheat cultivation | ha | includes | Hours tractor | 1.89 | hour | 100 | Tillage |
| wheat cultivation | ha | includes | Hours tractor | 0.95 | hour | 100 | soilbed prepa |
| wheat cultivation | ha | includes | Hours tractor | 1.89 | hour | 100 | seedbed prep |
| wheat cultivation | ha | includes | Hours tractor | 0.95 | hour | 100 | sowing/planti |
| wheat cultivation | ha | includes | Hours tractor | 0.71 | hour | 100 | crop protectic |
| wheat cultivation | ha | includes | Hours tractor | 2.84 | hour | 100 | harvesting |
| wheat cultivation | ha | includes | Hours tractor | 0.57 | hour | 100 | post harvest |
| wheat cultivation | ha | includes | N2O | -5.24 | kg | 100 | |

It must be observed that all emissions (e.g. $CO_2$) from fossil fuels can be introduced as 'shortcuts'. Normally speaking the $CO_2$ should be an outgoing stream 'made' during all $CO_2$ emitting processes, as shown in Figure 29. Since we are working in a system we can however consider that all incoming fossil fuel leads to full combustion and corresponding $CO_2$ emissions, unless of course the fuel is used for other purposes (which is definitely not the case in the present analysis). It is therefore much easier to use the stream bundling in Figure 30 for consideration of the $CO_2$ emitted from fossil fuels. Care must be taken with the minus sign, because a sign change occurs from incoming fuel (-) to outgoing $CO_2$ (+). Such shortcuts can be applied for any type of impact.




| Category | Action | Type | Stream | Quantity | Multiplyer | unit | % system |
|---|---|---|---|---|---|---|---|
| End use | Combustion | needs | diesel | 1 | 1 | kg | 100 |
| End use | Combustion | makes | heat | 0.9 | 43.1 | MJ | 100 |
| End use | Combustion | makes | $CO_2$ | 3.15 | 1 | kg | 100 |

*Figure 29: Normal way to produce the $CO_2$ in SPA2 route description (many times)*




| Stream | Unit | Type | Stream | Quantity | unit | % system | comment |
|---|---|---|---|---|---|---|---|
| Diesel | kg | makes | $CO_2$ | -3.15 | kg | 100 | shortcut |

*Figure 30: Shortcut to produce the $CO_2$ in SPA2 stream description (1 time)*

### 2.3.5. Other routes to be considered

TEXBIAG mainly concentrates on the cultivation part of the bioenergy chains. Task 3.5 however considered extension of the routes considered in LIBIOFUELS to other ones downstream of the cultivation, mainly hydrogen, DME and Biogas. A detailed report about these routes is available in the detailed report of delivery D12. The report is almost entirely based on Ecoinvent data.
It must be observed that in the course of the TEXBIAG project, focus on adding a few single routes has shifted to an approach where all available routes and processes within Ecoinvent become accessible from SPA2. Problems such as dealing with refineries are fully covered by this approach, and the available tools allow inclusion in virtually no time. SIMAPRO appears to be a handy data extraction tool, and will be applied more systematically to feed SPA2 for any route to be taken into consideration for substitution and system impact analysis.

### 2.3.6. Impacts on animal feed market

→ **Summary**

The aim of this subtask was to determine what happens when increased amounts of co-products such as DDGS and rape meal will become available on the Belgian market. The correct modelling of this market is important because the indirect effect of the animal feed products on the Belgian GHG balances are very significant (De Ruyck *et al.*, 2006). The modelling is based on facts and figures collected through literature research of animal feed technology, consultation of the animal feed industry and federations, and national statistics.
Results are given in detail in the delivery report D8, including a literature review, an overview of the production, consumption and trade of animal feed in Belgium, a general description of the applied natural resources for feed production. The substation mechanism of animal feed is modelled and, as an example, some results are presented to illustrate the capabilities of the model.
In the model, all agricultural animals are divided into 6 animal types: pigs, piglets, beef cattle, dairy cattle, bulls and poultry. For each type, an average diet is formulated, the most important specifications are identified and recommended amounts determined. Resources with the potential of being used in animal feed mixtures in Belgium are selected and prices and utilization ranges for every resource are collected.
The model is capable of calculating the most cost-effective feed compositions under a set of constraints; based on the linear programming method.

The model searches for the cheapest combination of resources to satisfy the feed needs (expressed in the animal's diet) while resource volumes stay within their specified utilization range. By inversion, the model is capable to determine the competitive prices for the biofuel co-products for admission in the animal feed market.

### → Key results

All common compound feed for pigs, cattle and poultry are listed in Tabellenboek Veevoeding 2007 tabel 8.2 en 8.3, together with their specifications (composition and nutritional values). From this extensive list, a selection of 35 resources was made, based on information of feedmanufacturing.com (www.feedmanufacturing.com, 2007) and BEMEFA (BEMEFA, 2007) and they can be categorized according to the different types of resources listed in Table IX.

*Table IX - Selection of resources for animal feed*

| **Resource** | **Type** |
|---|---|
| Alfalfa meal | Protein plants |
| Barley | Cereals |
| Beet pulp | Co-product food production |
| Copra meal | Meal (Co-product oil extraction) |
| Corn gluten meal | Cereals |
| Cotton seed meal | Meal (Co-product oil extraction) |
| Fish meal | Meal (fish) |
| Linseed | Oils and fats |
| Mais/corn | Cereals |
| Millet | Cereals |
| Molasses | Co-product food production |
| Oat | Cereals |
| Palm oil flakes | Meal (Co-product oil extraction) |
| Palm oil meal | Meal (Co-product oil extraction) |
| Peas | Protein plants |
| Potatoes | Co-product food production |
| Rapeseed | Protein plants |
| Rapeseed meal | Meal (Co-product oil extraction) |
| Rice | Cereals |
| Rye | Cereals |
| Sesame cake | Meal (Co-product oil extraction) |
| Skim milk powder | Milk products |
| Sorghum | Cereals |
| Soybean meal | Meal (Co-product oil extraction) |
| Soybeans | Protein plants |
| Sunflower meal | Meal (Co-product oil extraction) |
| Sunflower seeds | Oils and fats |
| Sweet potatoes | Co-product food production |
| Tapioca | Co-product food production |
| Triticale | Cereals |
| Vinasse | Co-product food production |
| Wheat | Cereals |
| Wheat bran | Cereals |
| Wheat meal | Cereals |
| Whey, dried | Milk products |
| Yeast, brewers | Co-product food production |

Some resources have been used in the past but are not allowed anymore due to current legislations (ILVO, 2008); e.g. the use of bone meal, feather meal and meat meal are no longer allowed and fish meal can only be used in poultry feed. In general, products from animal origin are avoided nowadays in favour of vegetable products.

The introduction of new resources, like for instance wheat DDGS, will happen slowly; animal feed producers will only consider these new resources at prices that are competitive, if nutritional values are sufficient and last but not least if the taste is appreciated by the animals. New resources will be introduced in mixtures by using very small amounts initially. If experiences are positive, amounts might be increased gradually.

Looking at the animal diets, resource specifications important to take into account are listed in Table X.

*Table X – Resource specifications*

| **Specification** | **Unit** | **Description** |
|---|---|---|
| NEv | MJ / kg | Net energy (Energy value x 8,8) |
| dLYS | g (dLYS) / kg | Digestible lysine |
| dM+C | g (dM+C) / kg | Digestible methionine + cystine |
| Ca | g (Ca) / kg | Calcium |
| vP | g (vP) / kg | Digestible phosphor |
| DS | g (DS) / kg | Dry matter |
| DVE | g (DVE) / kg | Digestible proteins |
| OE | MJ / kg | Convertible energy |
| dMET | g (dMET) / kg | Digestible methionine |
| P | g (P) / kg | Phosphor |

Indicative costs are given in Table XI, taken from the LEI, a research group of the Dutch University and research centre of Wageningen (LEI, 2008), from BEMEFA or were estimated if data was missing. The costs of course vary and must be updated for any cost optimisation.

*Table XI – Resource cost*

| Resource | Euro/ton | Resource | Euro/ton |
|---|---|---|---|
| Alfalfa meal | 283 | Rice | 192 |
| Barley | 194 | Rye | 178 |
| Beet pulp | 165 | Sesame cake | 164 |
| Copra meal | 185 | Skim milk powder | 199 |
| Corn gluten meal | 175 | Sorghum | 192 |
| Cotton seed meal | 185 | Soybean meal | 235 |
| Fish meal | 882 | Soybeans | 295 |
| Linseed | 320 | Sunflower meal | 185 |
| Mais/corn | 199 | Sunflower seeds | 295 |
| Millet | 192 | Sweet potatoes | 145 |
| Molasses | 130 | Tapioca | 171 |
| Oat | 202 | Triticale | 198 |
| Palm oil flakes | 156 | Vinasse | 98 |
| Palm oil meal | 156 | Wheat | 198 |
| Peas | 235 | Wheat bran | 297 |
| Potatoes | 145 | Wheat meal | 192 |
| Rapeseed | 320 | Whey, dried | 100 |
| Rapeseed meal | 165 | Yeast, brewers | 183 |

Figure 31 shows an example of results. The case considered deals with pig feed because it is the most important animal feed category. The abscissa contains the list of considered animal feed products in Table IX. The figure shows how pig feed is affected by a falling price of sugar beet pulp, relative to the numbers given in Table XI, and taking the constrains in Table X into account.

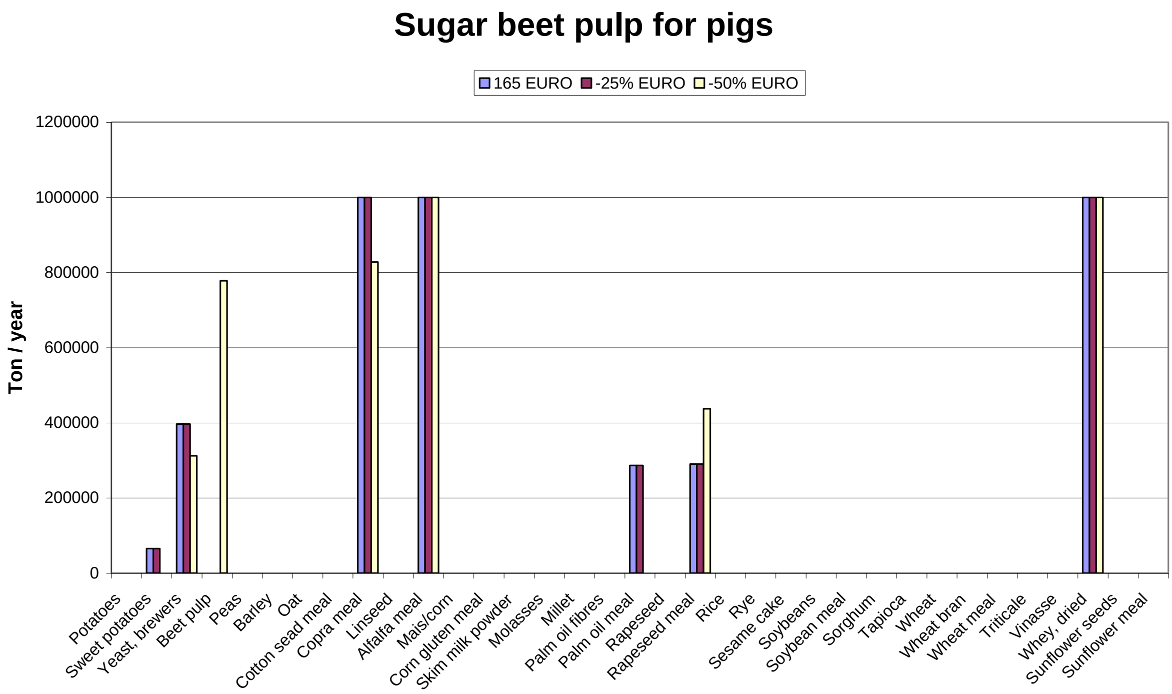



*Figure 31 – Example of calculated feed composition*

Sugar beet pulp at a price of 165 euro per ton is apparently too expensive to be used in pig feed. Lowering its price with 25% does not change this situation; all resource volumes remain the same. A 50% price reduction makes beet pulp suitable to apply in the feed mixture. In contrast, the use of brewers yeast and copra meal is reduced.

### → Conclusions

The main mechanisms of animal feed market are explained, and a linear programming code was prepared to optimise animal feed composition taking constraints into account. As a consequence it is now possible to select the appropriate substitution in SPA2, taking such mechanisms into account. This may lead to conclusions where the residues may better be redirected to other uses such as heat production, export or other.

Unfortunately, practice learns that many other aspects determine the substitution of animal feed, such as taste, risc for change, available stocks, local choices a.o..The prices are also subject to the market mechanisms, and it appears very difficult to apply a theoretical model in practice. Simulating such impact therefore seems hazardous, and in conclusion it pays more to run different substitution scenarios in SPA2, keeping in mind the reality of this market.

It also became clear that as long as the extra residues put on the animal feed market are rather limited, there are no major shifts in impacts to be expected, and the original LIBIOFUELS approach of substituting animal feed seems to be acceptable. On the other hand, use of residues for energy purposes remains a valid and even growing alternative to be weighed against animal feed substitution.

### 2.3.7. Substitution of electric energy production

**→ Summary**

The aim of this subtask was to determine what happens when increased amounts of electricity become available on the Belgian market, by substituting central production by decentralised production of bioenergy resources. The correct modelling of substitution is important because such substitution impacts on the overall electric production, and simple linear compensation from import as done in LIBIOFUELS might prove to lead to wrong conclusions. Results are given in detail in the Deliverable D10.
So far, injection of additional electrical power in the grid from rather small-scale biomass systems was assumed to lead to a linear compensation by a reduced import of electrical power. The reality is however much more complex. The grid perturbation depends on connection level (low, medium, high voltage), production time (peak or low demand) and predictability of the power injection (how dispatchable is the considered biomass; is it linked to heat-demand driven CHP-units?). The correct modelling of this type of perturbation is again important with respect to emissions and monetary balances, because Belgium is normally speaking net importer of electricity.
In the D10 report an overview is given of the different technologies available for generating electricity from biomass. Different co-firing technologies are dealt with. Next, gasification and cogeneration are treated. A short overview of the Belgian electricity system is finally given.
The model applied is E-simulate from KUL, and conclusion is given below. E-simulate shows the impact on the generation dispatch when the generation park of a country has been changed. This model captures most, but not all, of the highly complex operation of an electricity generation system by reflecting the capacity, fuel use, and technology of every generating plant in the system and by resolving dispatch to meet demand on an hourly basis.
Finally, a description is given in the D10 report of voltage regulation and protection aspects to be taken into account at higher decentral production penetration levels, which will not be further discussed here.

**→ Key results**

The impact of introducing small amounts of biomass is a complex and very sensitive matter, with a lot of assumptions linked to local conditions. Therefore it is hard to define cases (and thus results) which represent an accurate image of the future. In order to overcome this uncertainty by trying to forecast future scenarios, some reference cases have been assumed and trends were investigated.
A first series of simulations are the "must-runs", where an additional installation, on biomass, is added to the Belgian system. This additional generation must be accepted in the generation dispatch of Belgium, not considering the actual price. This is simulated by setting the (market) price for biomass to zero. In this way all available biomass is accepted before other primary resources and used for electricity generation. An extra plant powered on biomass is added to the (unchanged) Belgian production park. Simulations with this extra plant with a size of 1, 2, 3, 4, 5, 10, 50, 100 and 200 MW were successively carried out.

Upon adding extra generation of biomass two aspects can be observed:

- Less electrical power is imported from the neighbouring countries
- A shift in production towards production with biomass

Both aspects can be easily explained as “must run” power plants will replace the more expensive generation and/or generation from abroad. Generation by the most expensive fuel types is decreased. The most expensive fuels are in decreasing order, first gas and next coal. For gas a constant decrease can be observed. Coal does not show steady characteristic. This is due to the fact that Belgium, which is a net importer, will import less electric energy from abroad.

Next to “must-run” scenarios, scenarios with different prices are simulated. The prices for biomass vary from 1 to 10 €/GJ. For comparison, price amount for nuclear energy: 0.748 €/GJ, price of coal: 2.5 €/GJ, price of gas: 5 €/GJ, price of oil: 11 €/GJ.

The values in Figure 32, are obtained by adding 100 MW of biomass production to the Belgian system. Similar behaviour is obtained by adding smaller amounts of biomass, but effects are more outspoken with a larger amount of biomass. If the price for biomass goes up, this generation is taken over by other fuel types and by generation abroad. If prices for biomass are extremely high, it is pushed completely out of the generation dispatch.

→ **Conclusions**

Although the impact of the extra biomass is rather small, trends and changes can be observed. Conclusions are that as long as Belgium is a net importer, the assumption made in LIBIOFUELS of linear compensation by reduced imports is certainly valid. As long as the perturbations are 'limited' (MegaWatts), such assumption still holds.

In case of large scale substitution, application of a model such as E-simulate is needed to assess the perturbation on the Belgian Market. At this time it is important to consider if the biomass is supported (must run) or subject to normal market mechanisms. Pending on the scenario, the SPA choice of substitution route will lead to less import of gas or coal, pending again on the assumed technology. It is to be observed that such scenario was already considered by LIBIOFUELS for the replacement of coal by woody biomass in co-fired coal plants, which of course assuming a perturbation of at least 20-30 MWe.

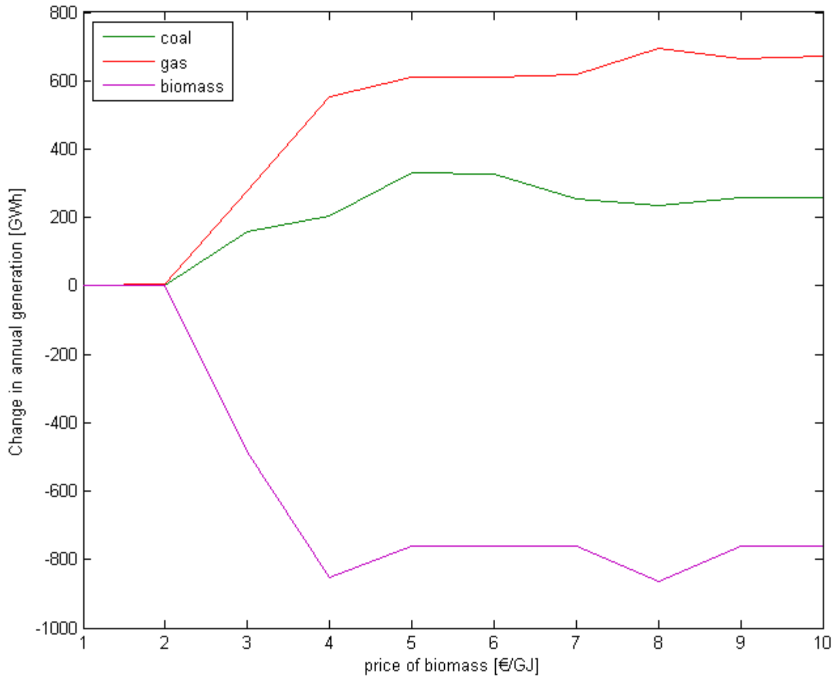



*Figure 32 - Change in production upon a varying price for biomass*

### 2.3.8. Scenario selection

As test case for this new SPA2 tool, the following question has been addressed:

*To what extent can the use of different datasets or approaches affect the decision making?*

Thus, rather than starting from one database and compare different scenarios, one single scenario was chosen using several datasets, which can easily be realised within SPA2.
Two scenarios have been selected :

- Find the impacts of cultivating one hectare of (set aside) land for wheat production, for subsequent production of ethanol for transportation purposes. Frozen products and co-products are kilometers, electricity consumption, surface area and DDGS.
- Find the impacts of cultivating one hectare of (set aside) land for rapeseed production, for subsequent production of RMA for transportation purposes. Frozen products and co-products are kilometers, electricity consumption, surface area and rapemeal. The byproduct glycerine is used for steam generation purposes within the RME production.

The datasets are named:

- LIBIOFUELS
- ECOINVENT/SIMAPRO
- TEXBIAG
- RED/EU
- NUTSVL

The LIBIOFUELS case considers the original data from the LIBIOFUELS report, which are mainly from CONCAWE.

In the ECOINVENT case 'conventional wheat production - FR - Barrois' and 'conventional rapeseed production - FR - Barrois' were taken as most representative. The data extraction was done through SIMAPRO, where other data bases are also considered for some data. It will therefore be further denoted as SIMAPRO.

TEXBIAG cases are taken from the present study (see section 2.1.5), being the case without K and P fertilisers on soil with a low mineralisation rate (scenario 1, labelled TEXBIAG LOW) and the case with K and P fertilisers on soil with a high mineralisation rate (scenario 4, labelled TEXBIAG HIGH).

The RED/EU case is based on the underlying data used for the calculations according the methodology in the Directives 2009/28/EC and 2009/30/EC (Biograce, 2009). This underlying data comes from two sources.
The input data (describing the biofuel conversion routes) as well as the standard values (for agro-inputs, fuels, conversion inputs, electricity production and transport efficiencies) are provided by the JEC consortium (JRC, EUCAR and CONCAWE), being the main source of data (JEC, 2008). Some unpublished numbers by the JEC consortium come from the E3database used by LBST, a consultant to the JEC consortium and a subcontractor to the BioGrace project.

The NUTSVL case is based on average cultivation data for the so-called NUTS2 regions within Flanders. Belgium communicated these data to the Commission for the NUTS2-regions inside Belgium, as foreseen in Article 19, part 2 of the Directive 2009/28 (Campens, 2010; Guns, 2010). This article stipulates that by 31 March 2010: "Member States shall submit to the Commission a report including a list of those areas on their territory classified as level 2 in the nomenclature of territorial units for statistics (NUTS) (…) where the typical GHG emissions from cultivation of agricultural raw materials can be expected to be lower than or equal to the emissions reported under the heading 'Disaggregated default values for cultivation' in part D of Annex V to this Directive (...)"

For impacts other than energy and global warming, the impact assessment method used was ' CML 1992 V2.06 / W-European territory', because of its compactness. The CML impacts (air, liquid and soil) are grouped into 5 categories :

- Ecotoxicity
- Human toxicity
- Eutrophication potential (or nutrification potential, NP, expressed in kg $PO_4^{3-}$)
- Acidification potential (AP, expressed in kg $SO_2$ eq.)
- Summer smog

Ecotoxicity refers to toxicity to flora and fauna. The main substances are heavy metals. Values have been established for emissions to water and to soil, i.e.:

- Aquatic ecotoxicity (ECA)
- Terrestrial ecotoxicity (ECT)

Only the ECA values have been included in the CML 92 method because emissions to soil eventually appear in the groundwater and are thus already covered.

We have added a number of values for groups of hydrocarbons to this class. Values for the hydrocarbons are shown in Table 4. An equivalent has been selected for most other values that were not defined.
The effect score for ecotoxicity is calculated as follows:
Ecotoxicity ($m^3$) = (ECA ($m^3$. kg-1) x waterborne emission (kg))10^6

Human toxicity concerns effects of toxic substances on the human environment. Health risks of exposure in the working environment are not included. Characterisation factors, Human Toxicity Potentials (HTP), are calculated with USES-LCA, describing fate, exposure and effects of toxic substances for an infinite time horizon. For each toxic substance HTP's are expressed as 1,4-dichlorobenzene equivalents/ kg emission. The geographic scope of this indicator determines on the fate of a substance and can vary between local and global scale

More details about air, liquid or soil impacts, or any other method can be applied by detailing the appropriate instructions in the 'Streams template'.
Only the wheat and rapeseed production steps are varied, whilst the remaining processing to ethanol and RME up to the end product 'kilometers' is kept identical in the different scenarios. In this way, differences are mostly due to the different approaches in the cultivation step. For coherent comparisons utility data and wheat, straw and rapemeal heating values were taken identical in all datasets, respectively 15.1, 14.6 and 26.4 MJ/kg.
The scenarios labelled 'EU' use the utility data as used in LIBIOFUELS and RED/EU, but also apply to TEXBIAG. The scenarios labelled 'Ecoinv' use the utility data from Ecoinvent, which in general consider higher indirect energy consumption for utilities. As mostly done, the renewable energy production considers only the wheat grains, but in reality straw is also produced which potentially can be valorised as an energy source. The scenarios labelled 'Ecoinv/straw' therefore consider both wheat and straw to create renewable energy, whereas others consider wheat only.
The CML impact categories are applied to all utilities and fertilizers in the cases LIBIOFUELS, RED/EU and NUTSVL, *thus the direct field emissions - as described in 2.1.4. - are however excluded, because not included in these approaches*. In the cases TEXBIAG LOW, TEXBIAG HIGH and BARROIS, these direct field emissions are included and the impact of direct field emissions can be seen from the results.
The detailed Stream and Route templates are given in Annex, and only results will be further discussed.

### 2.3.9. Results for the wheat case

Results are shown in Figure 33 to Figure 44. Figure 33, Figure 34 and Figure 37 to Figure 40 correspond to the SPA criteria given in Table VI.
Figure 33 shows the worldwide energetic efficiencies of the different scenarios. The figure shows to what extent fossil energy is really replaced by renewable energy: this efficiency should at least be positive and preferably close to 100%. Figure 34 shows the same information, but defined within the system Belgium.
Although not dramatic, significant differences are observed in these results. TEXBIAG, EU and NUTSVL expect efficiencies somewhat better than LIBIOFUELS, whereas the ECOINVENT/SIMAPRO is significantly lower. These differences strongly correlate with the differences in wheat surface yields (Figure 35) and energy needs to process one tonne of wheat (Figure 36). The differences between RED/EU and Ecoinvent are due to higher indirect energy needs for the utilities in Ecoinvent. They are all assumed outside of the system, which explains the differences in Figure 33 and the absence of difference in Figure 34. Considering the energy content of the straw in the balance of course reduces the efficiency considerably, since the straw is left on the field in all cases.

The differences in $CO_2$eq savings (Figure 37 and Figure 38) follow the same trends, except that LIBIOFUELS finds savings lower than expected. This is almost entirely due to higher $N_2O$ field emissions, which at the time of LIBIOFUELS was a hazardous estimation. Today the procedures to estimate $N_2O$ are standardised and estimations are more similar in the other datasets.

The surface requirements (Figure 39 and Figure 40) follow the trends of yield and energy consumptions per ton shown in Figure 35 and Figure 36.

Figure 41 to Figure 43 finally show the other impacts according to the CML impact method. Only the full TEXBIAG and BARROIS cases include the full impact assessment, which is not possible in the other datasets because the direct field emissions are not included (only $N_2O$ actually is, contributing to the Global warming). Eutrophication and acidification in Figure 41 and Figure 42 show the same trends. The impacts of the direct field emissions emerge in the TEXBIAG and BARROIS cases, whereas the other methods only show the impacts from utilities and fertiliser production. The differences between TEXBIAG LOW, TEXBIAG HIGH and BARROIS are due to higher amounts of P and K fertilisers in the TEXBIAG HIGH case, and higher amounts of N fertilizers in the BARROIS case. The impact of the direct land emissions is less pronounced for the Ecotoxicity and Human toxicity (Figure 43 and Figure 44). The differences mainly correlate with the use of P and K fertilizers, which are absent in the TEXBIAG LOW case and small in the NUTSVL and EU cases, as compared with the older LIBIOFUELS case.

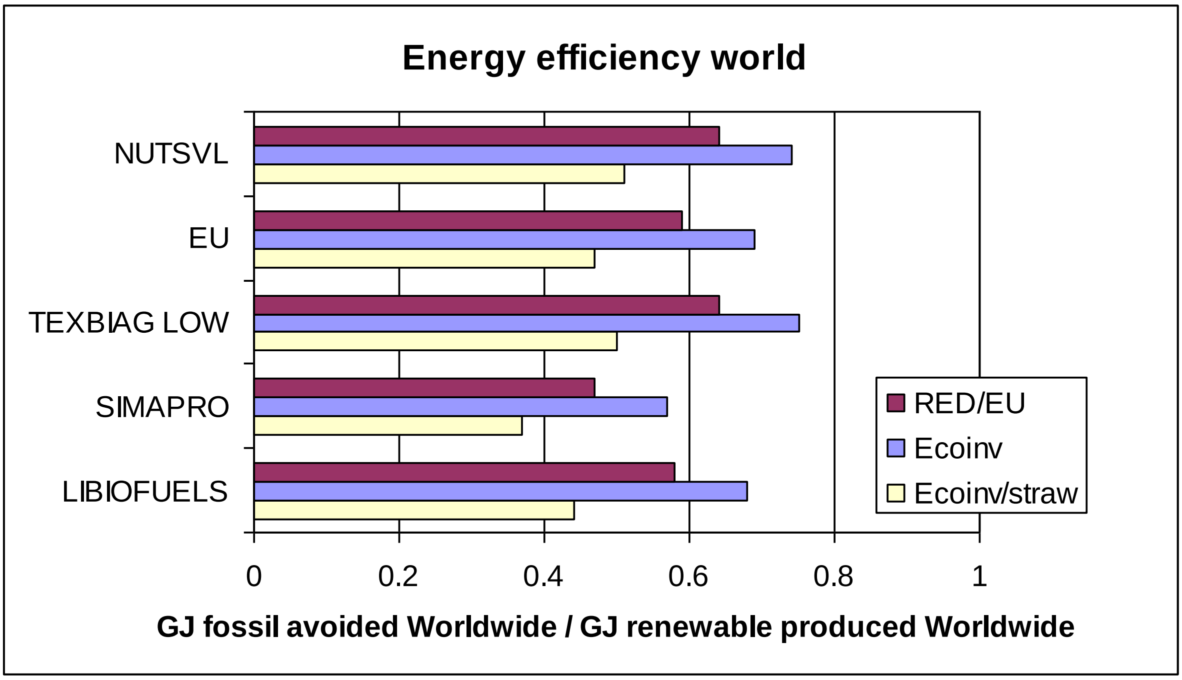



*Figure 33: Energy efficiency World, RED/EU: EU utilities, Ecoinv : Ecoinvent utilities, straw : straw LHV included in renewable energy produced. Wheat case*

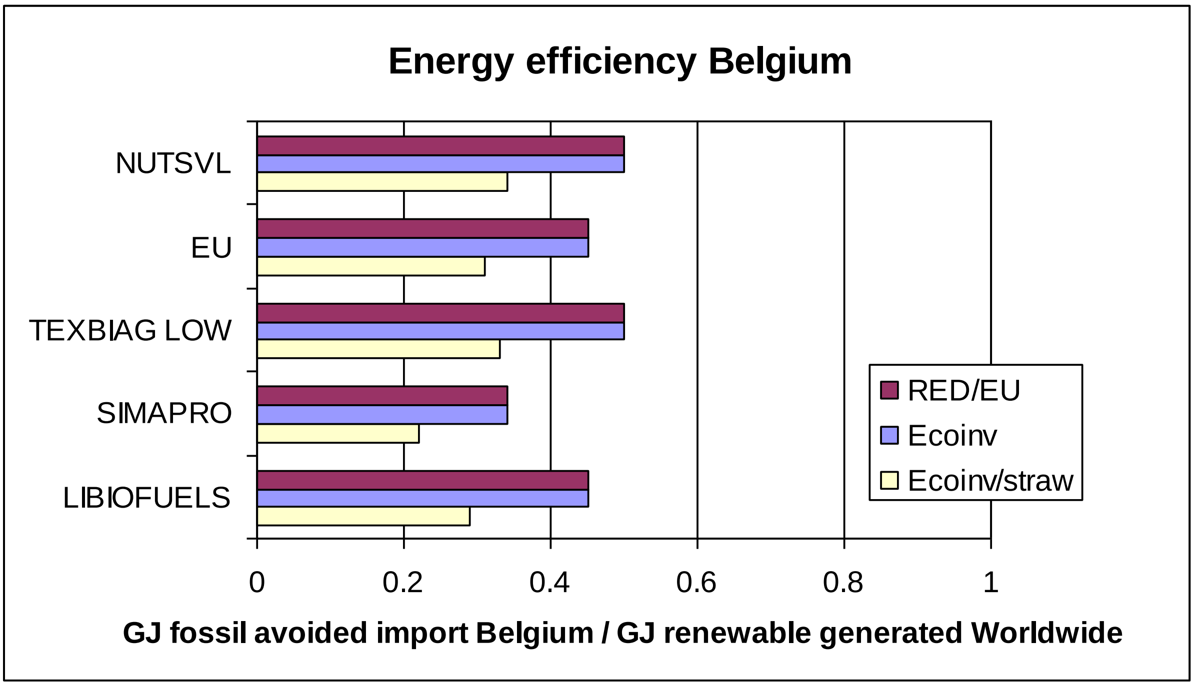



*Figure 34: Energy efficiency Belgium, RED/EU: EU utilities, Ecoinv: Ecoinvent utilities, straw : straw LHV included in renewable energy produced. Wheat case*

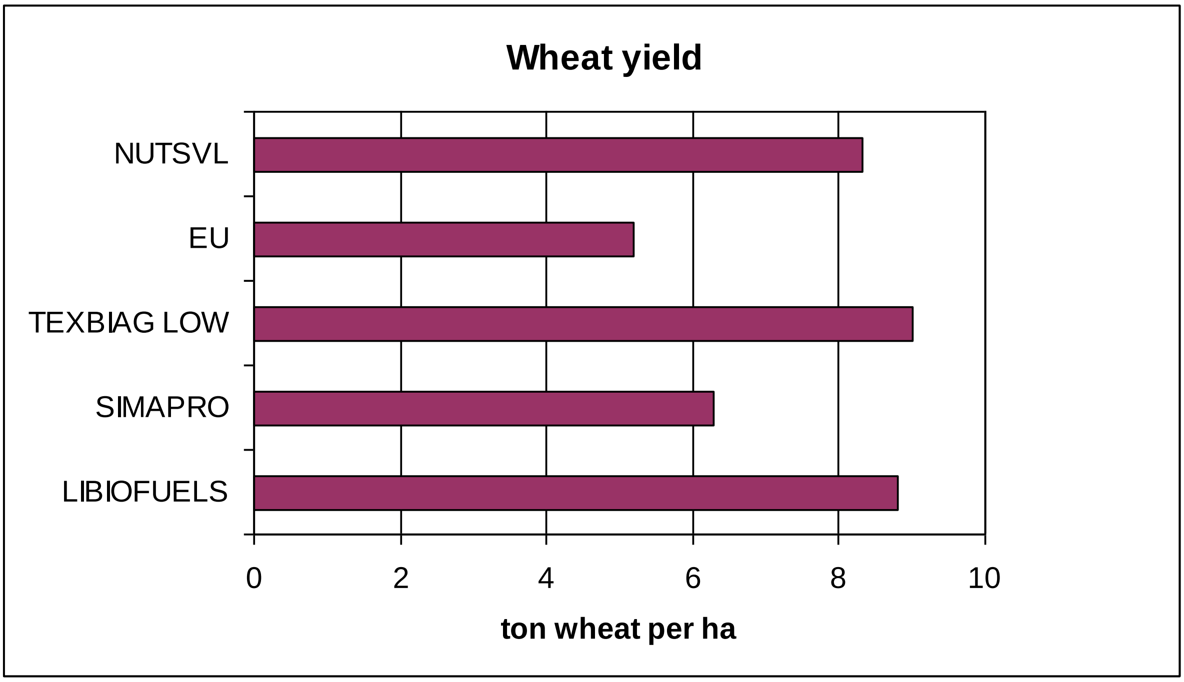



*Figure 35: wheat yields assumed in the different datasets*

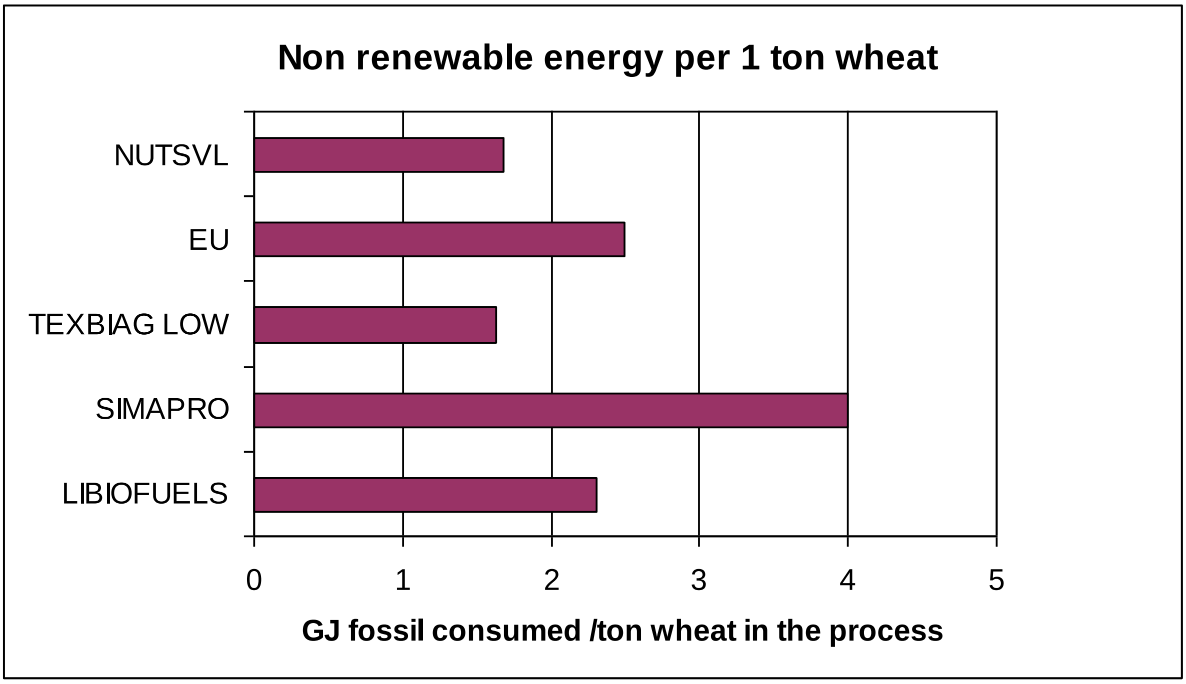



*Figure 36: Non-renewable energy consumption to process one ton of wheat to kilometers*

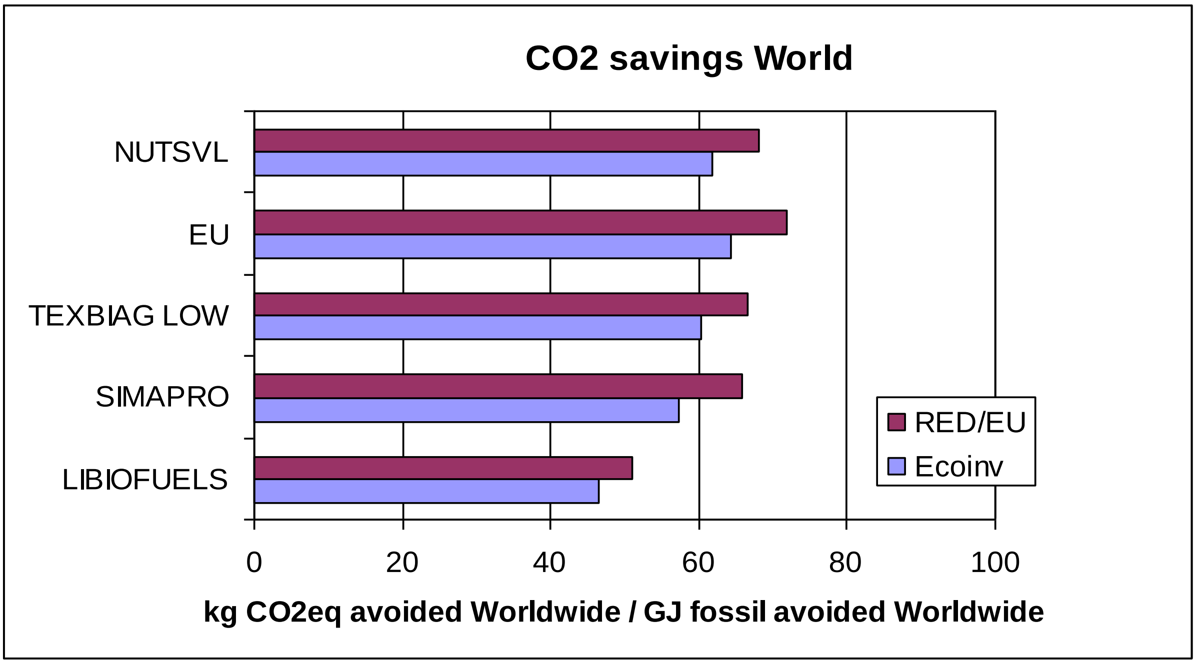



*Figure 37: $CO_2$eq savings World, RED/EU: EU utilities, Ecoinv : Ecoinvent utilities, wheat case*

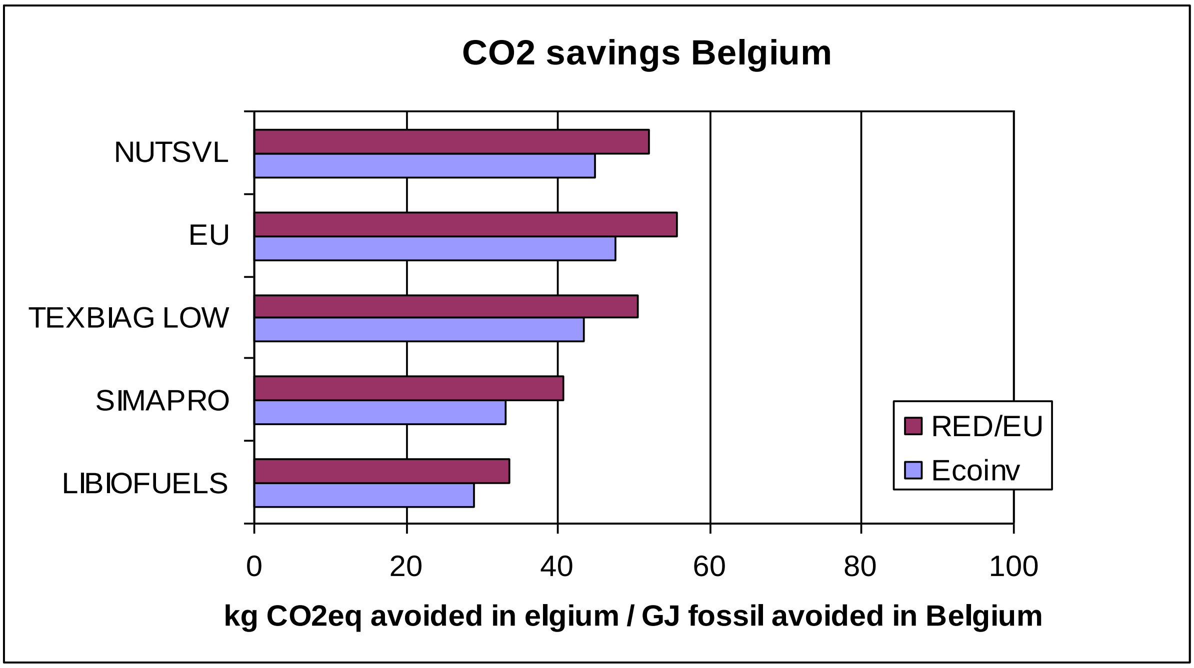



*Figure 38: $CO_2$eq savings Belgium, RED/EU: EU utilities, Ecoinv: Ecoinvent utilities, wheat case*

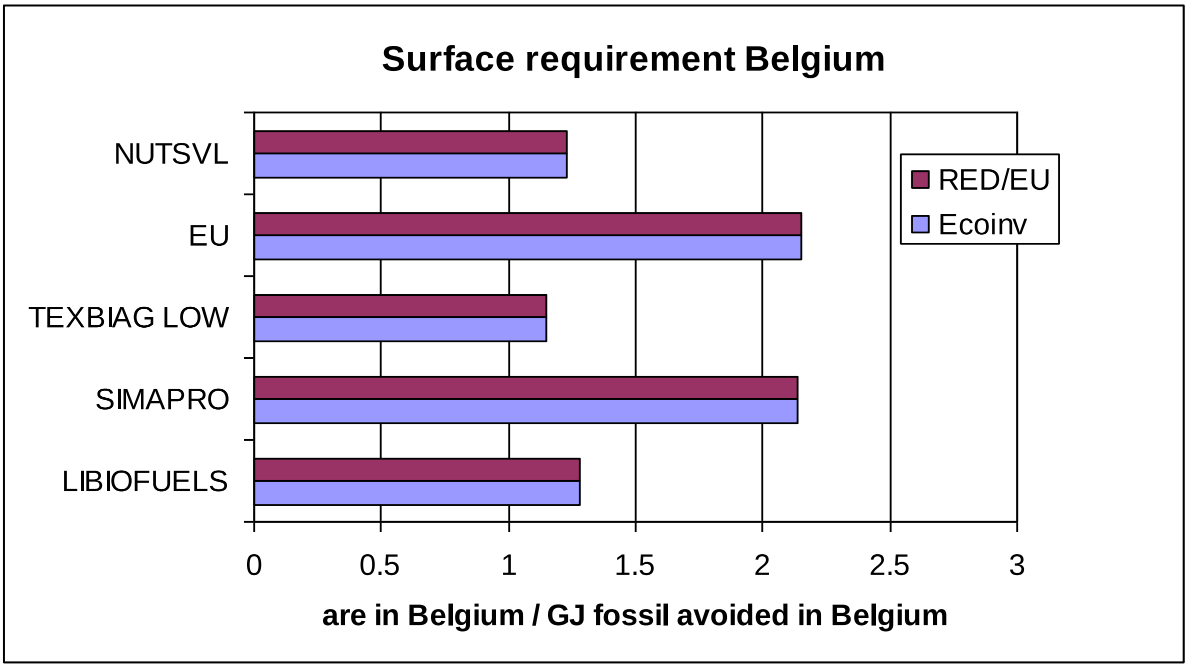



*Figure 39: Surface requirements Belgium, RED/EU: EU utilities, Ecoinv: Ecoinvent utilities, wheat case*

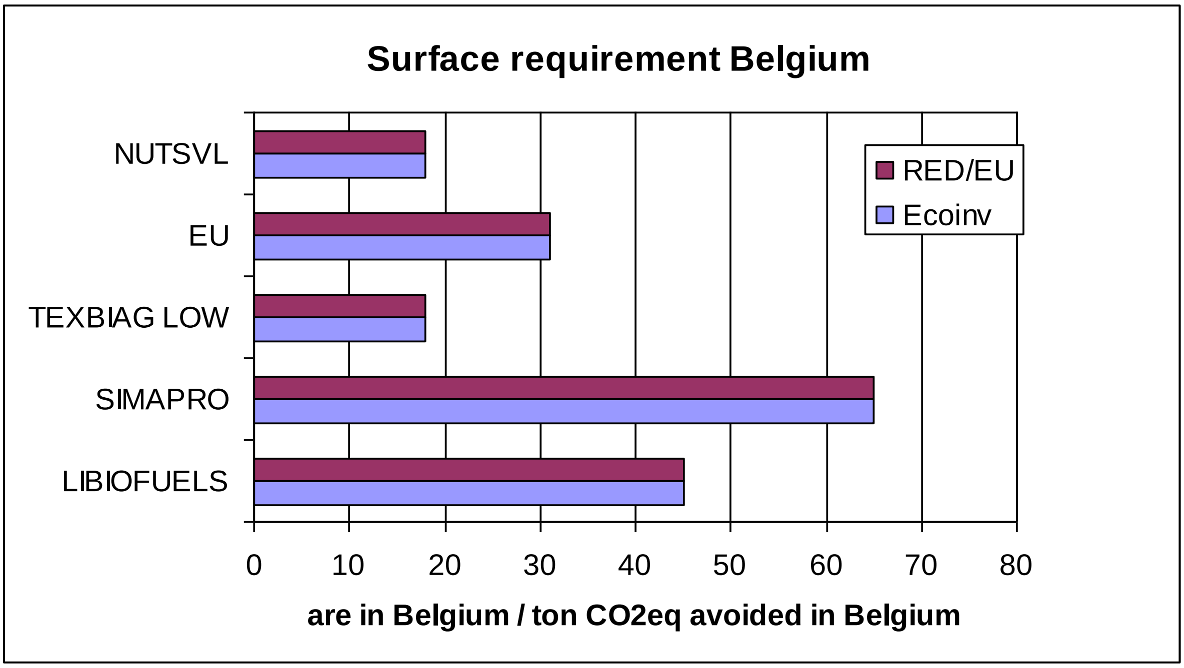



*Figure 40: Surface requirements Belgium, RED/EU: EU utilities, Ecoinv : Ecoinvent utilities, wheat case*

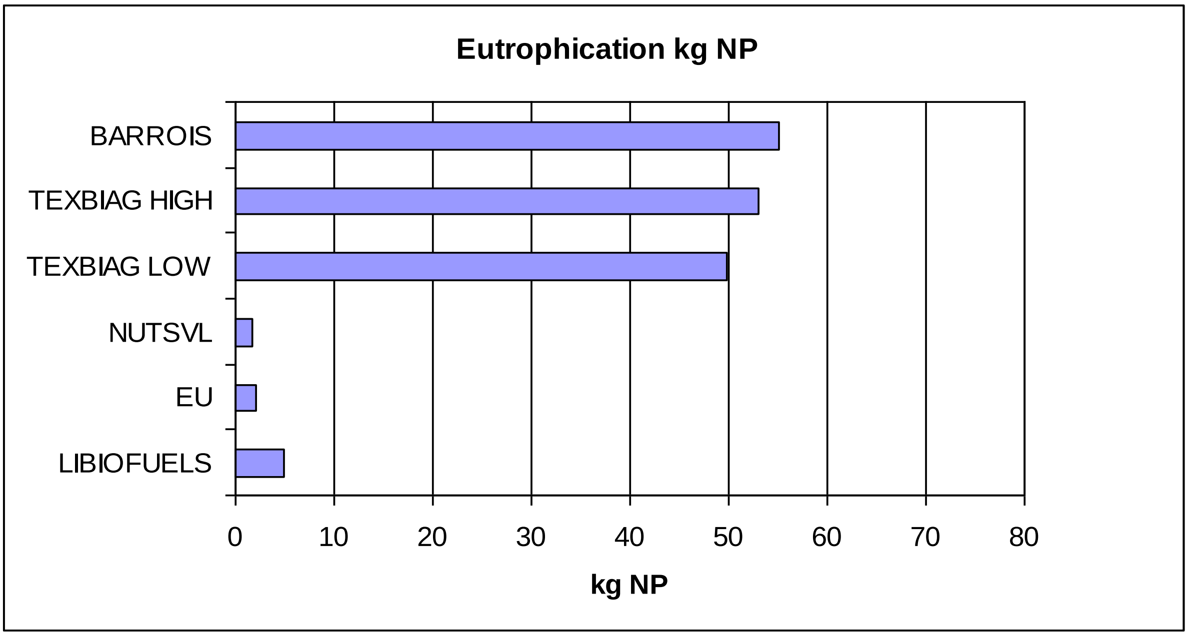



*Figure 41: Increased eutrophication, CML, wheat case*

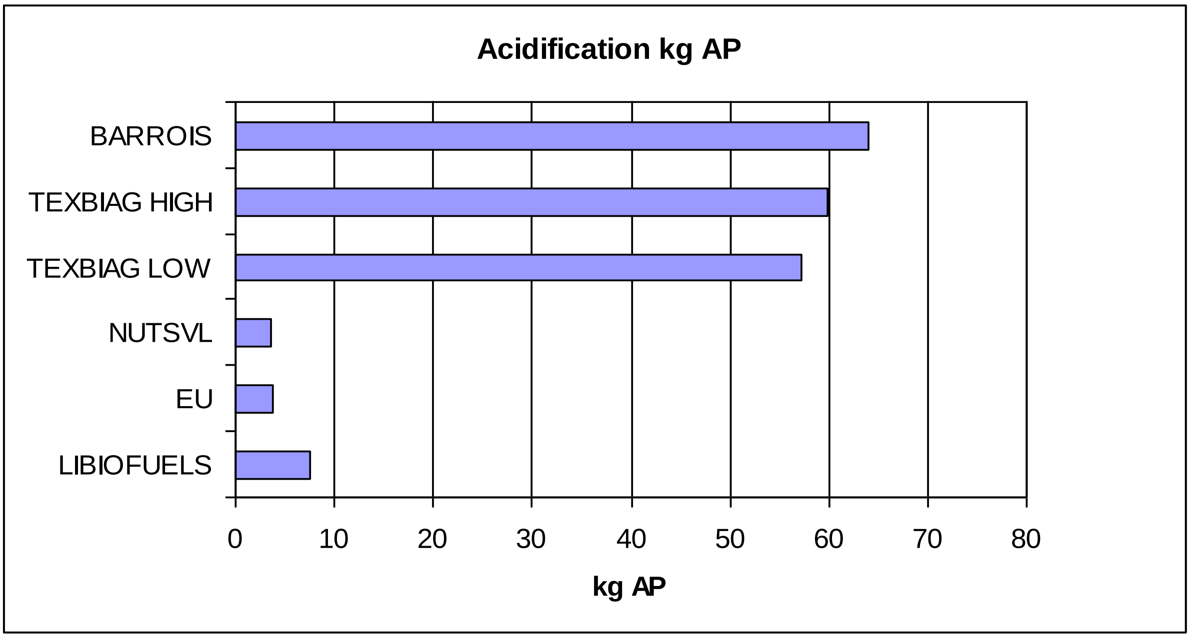



*Figure 42: Increased acidification, CML, wheat case*

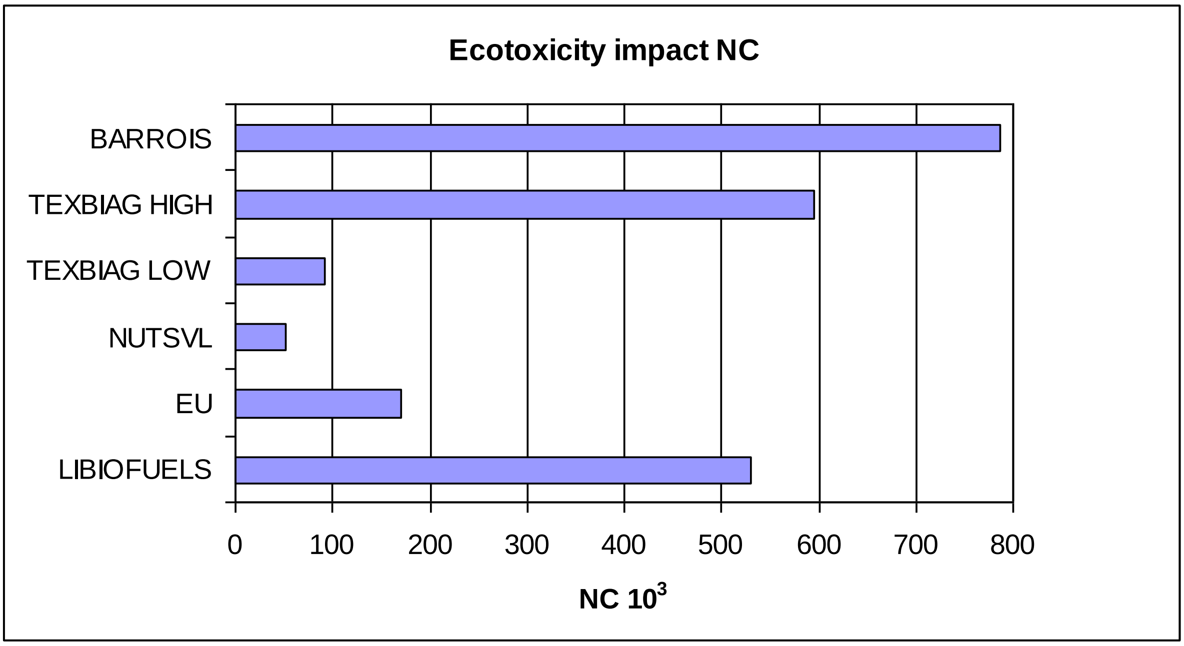



*Figure 43: Increased ecotoxicity, CML, wheat case*

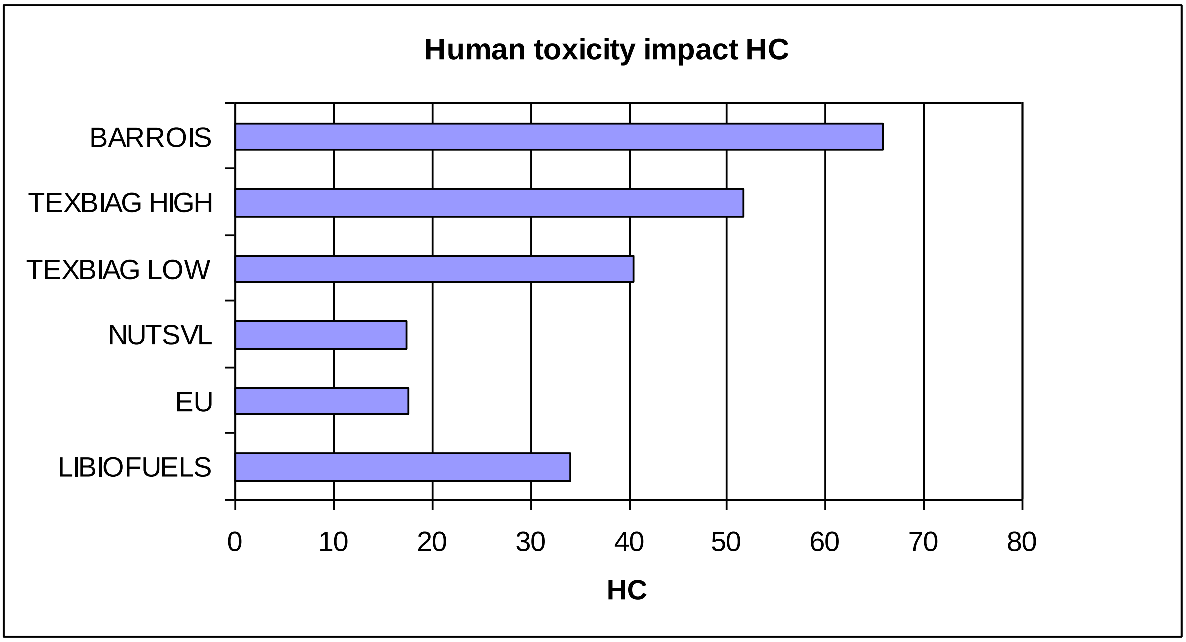



*Figure 44: Increased human toxicity, CML, wheat case*

### 2.3.10. Results for the rapeseed case

A similar set of results is shown from Figure 33 to Figure 56 for the rapeseed case.
Figure 33 shows the worldwide energetic efficiencies of the different scenarios. The figure shows to what extent fossil energy is really replaced by renewable energy: this efficiency should at least be positive and preferably close to 100%. Figure 34 shows the same information, but defined within the system Belgium.
Differences are again observed the efficiencies Figure 45 and Figure 46, but less pronounced when compared to the wheat case. These differences again correlate with the differences in wheat surface yields (Figure 47) and energy needs to process one tonne of wheat (Figure 48). The differences in $CO_2$eq savings (Figure 49 and Figure 50) are high, in particular for the BARROIS case. This is mostly due to the higher amounts of $N_2O$ emissions, which tend to offset the $CO_2$eq savings obtained by the substitution. The surface requirements (Figure 51 and Figure 52) follow the trends of yield and energy consumptions per ton shown in Figure 47 and Figure 48, but the increased $N_2O$ emissions in the LIBIOFUELS and BARROIS cases lead to much higher or even irrelevant surface requirements.
Figure 53 to Figure 56 finally show the other impacts according to the CML impact method. Only the full TEXBIAG and BARROIS cases again include the full impact assessment, which is not possible in the other datasets because the direct field emissions are not included (only $N_2O$ actually is, contributing to the Global warming). Eutrophication and acidification in Figure 53 and Figure 54 show again the same trends. The impacts of the direct field emissions emerge in the TEXBIAG and BARROIS cases, whereas the other methods only show the impacts from utilities and fertiliser production. The differences between TEXBIAG LOW, TEXBIAG HIGH and BARROIS are due to higher amounts of P and K fertilisers in the TEXBIAG HIGH case, and higher amounts of N fertilizers in the BARROIS case. The impact of the direct land emissions is less pronounced for the Ecotoxicity and Human toxicity (Figure 55 and Figure 56). The differences mainly correlate with the use of P and K fertilizers, which are absent in the TEXBIAG LOW case and small in the NUTSVL and EU cases, as compared with the older LIBIOFUELS case.

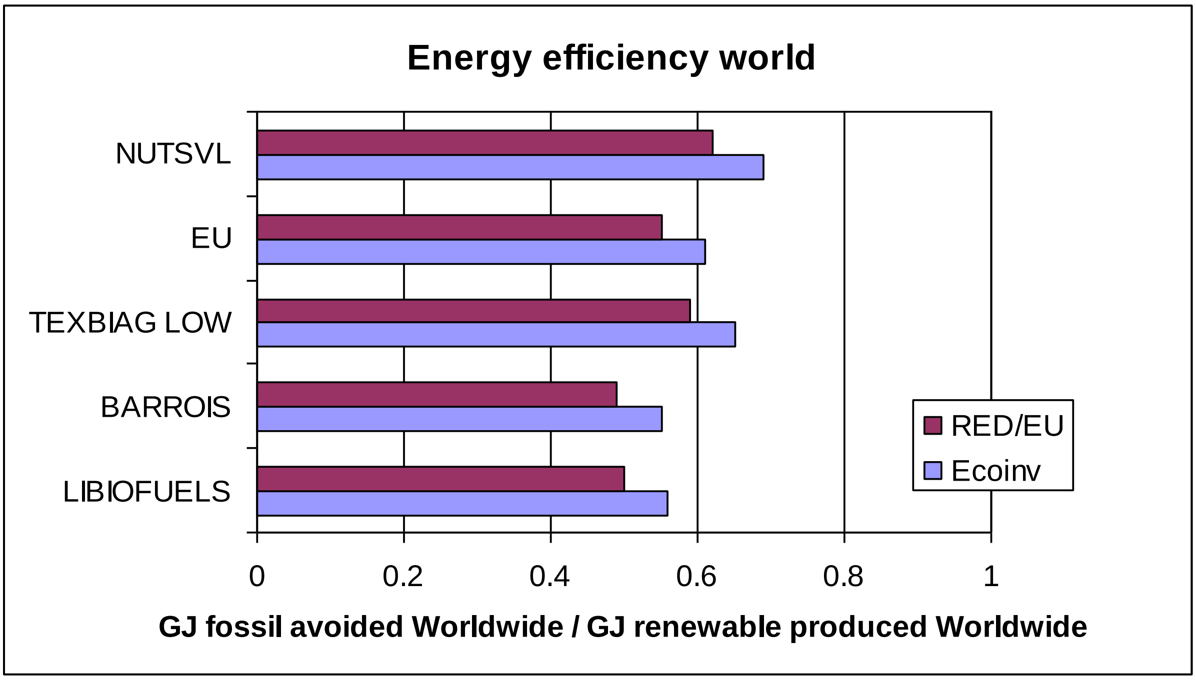



*Figure 45: Energy efficiency World, RED/EU: EU utilities, Ecoinv: Ecoinvent ultilities, rapeseed case*

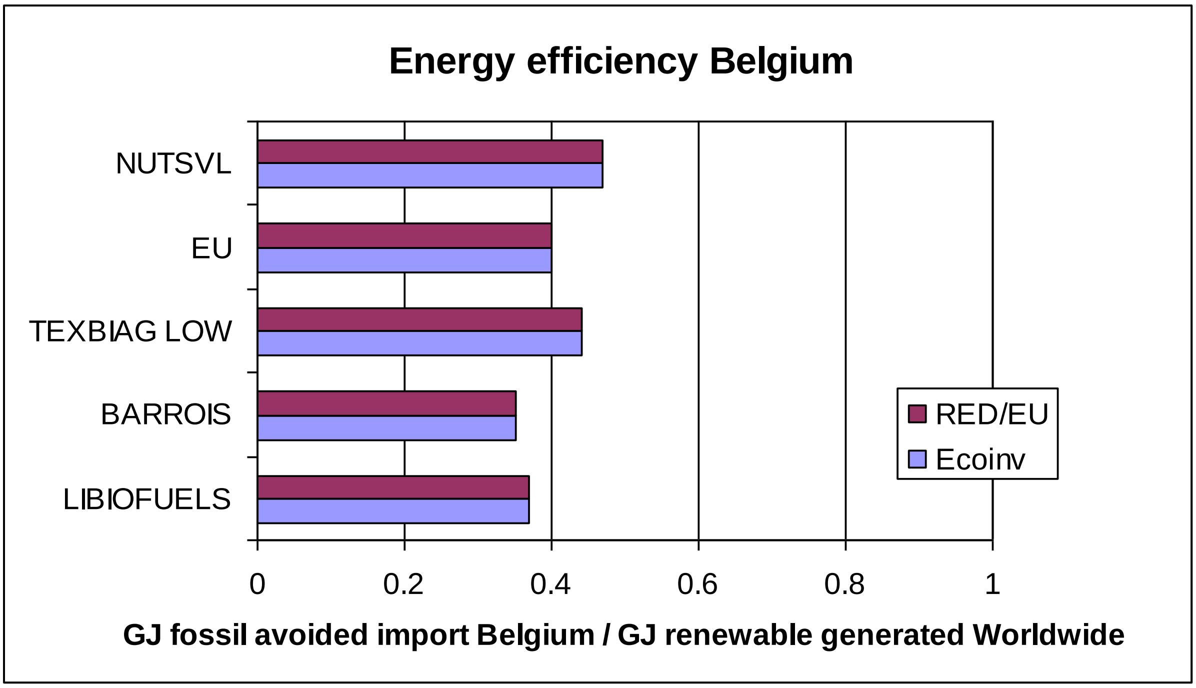



*Figure 46: Energy efficiency Belgium, RED/EU: EU utilities, Ecoinv: Ecoinvent ultilities, rapeseed case*

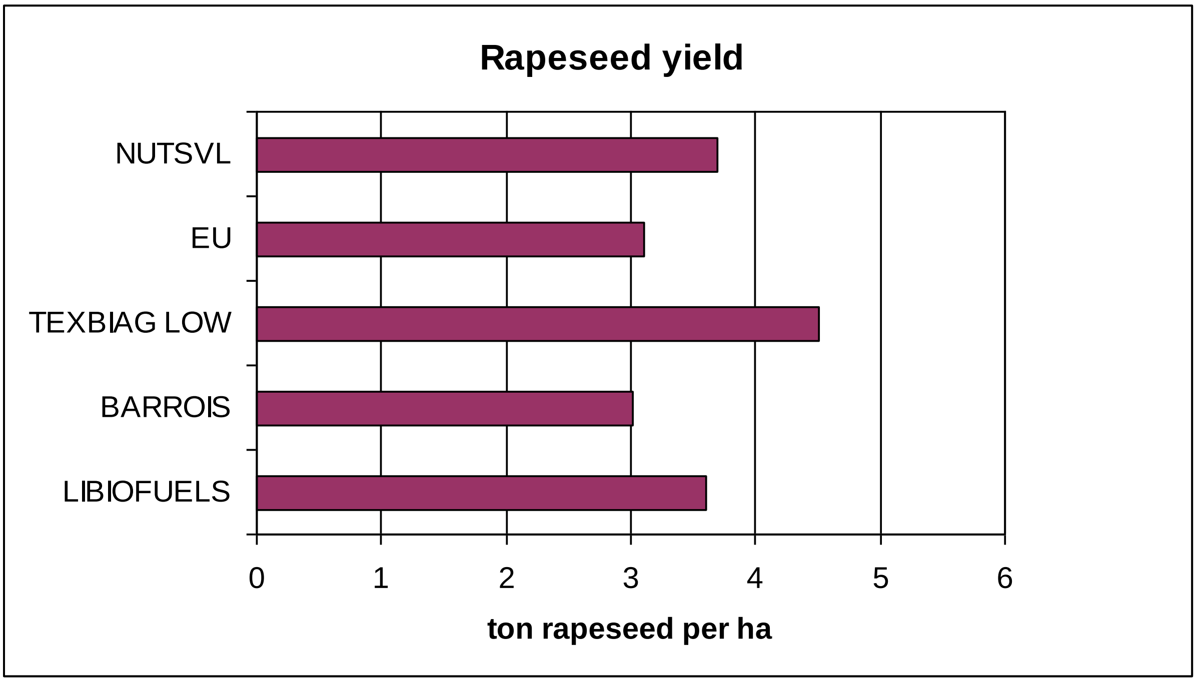



*Figure 47: rapeseed yields assumed in the different datasets*

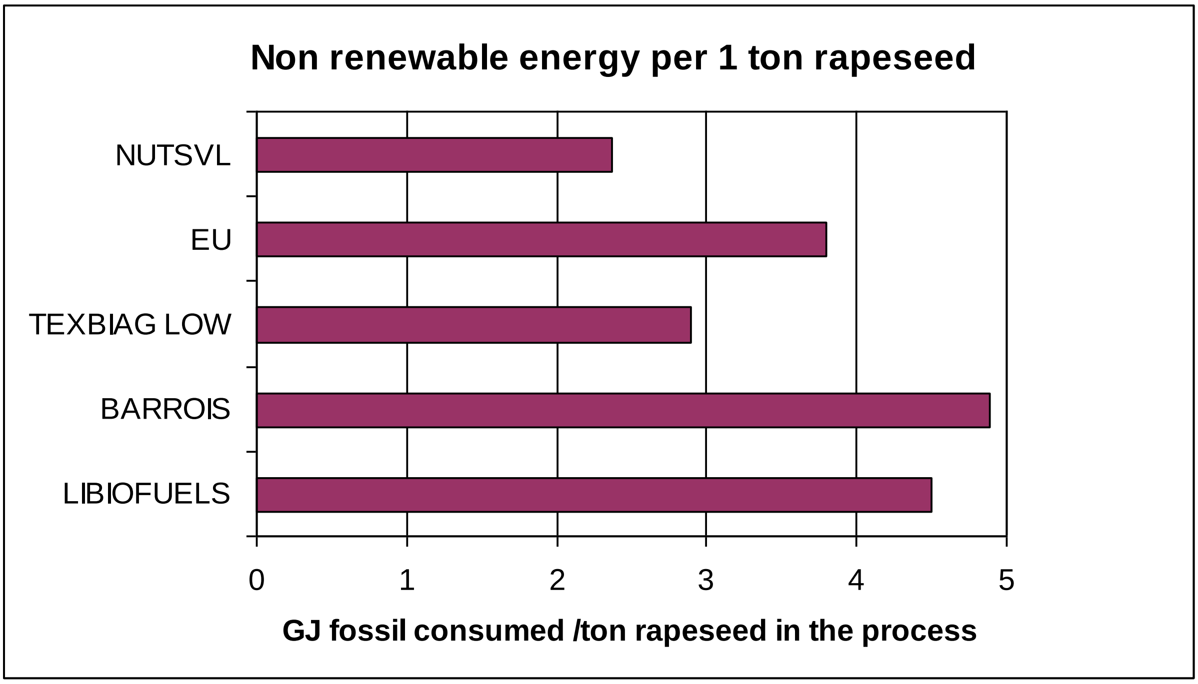



*Figure 48: Non-renewable energy consumption to process one ton of wheat to kilometers*

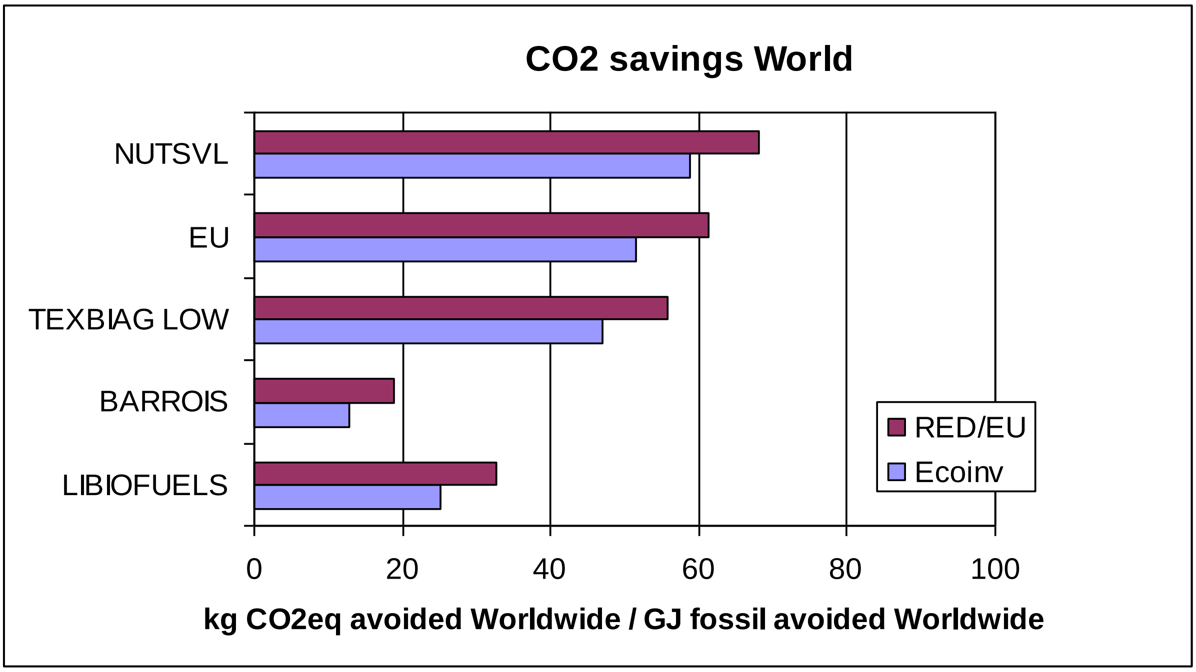



*Figure 49: $CO_2$eq savings World, RED/EU: EU utilities, Ecoinv : Ecoinvent utilities, rapeseed case*

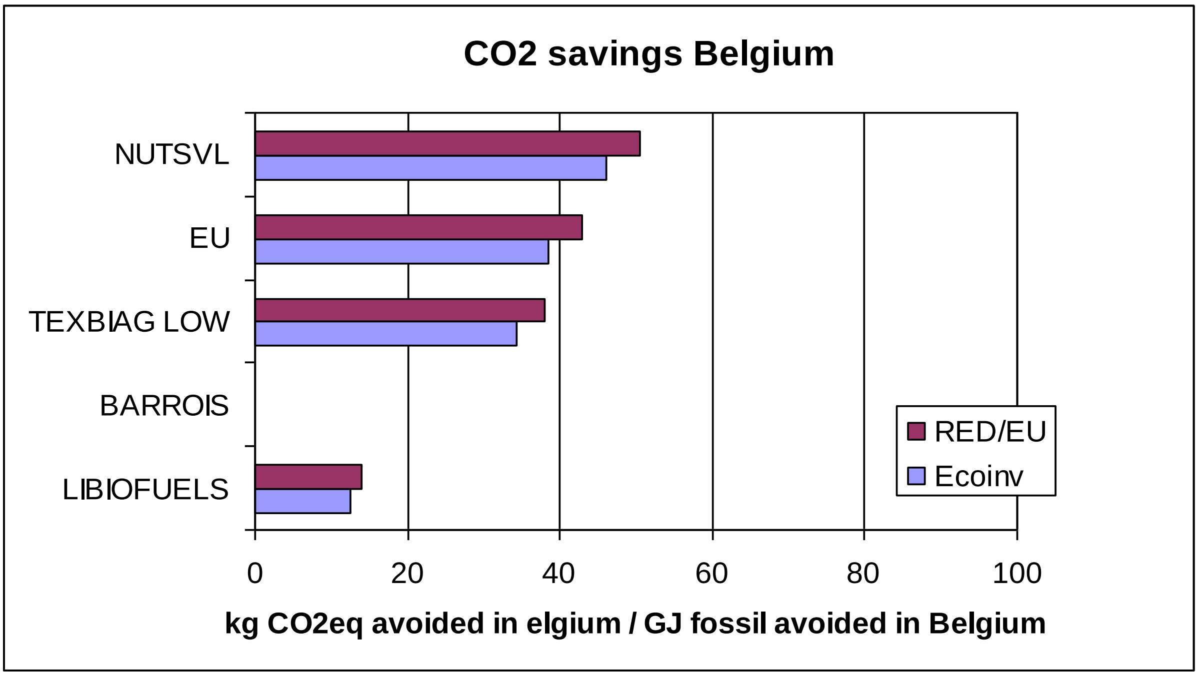



*Figure 50: $CO_2$eq savings Belgium, RED/EU: EU utilities, Ecoinv: Ecoinvent utilities, rapeseed case*

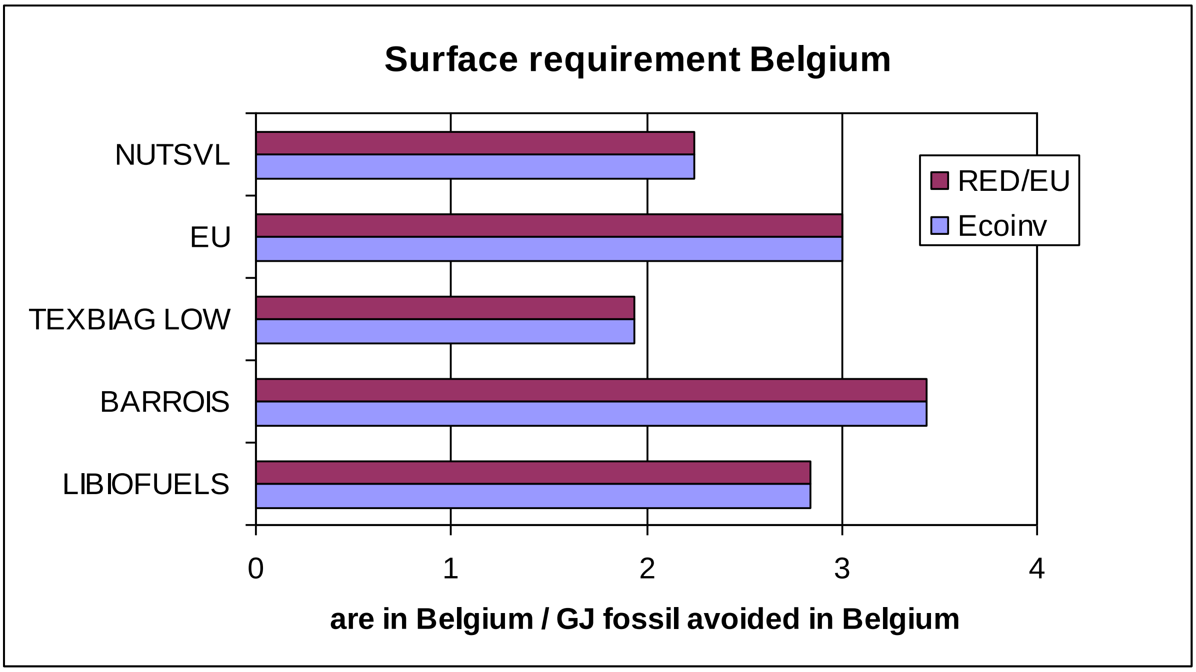



*Figure 51: Surface requirements Belgium, RED/EU: EU utilities, Ecoinv: Ecoinvent utilities, rapeseed case*

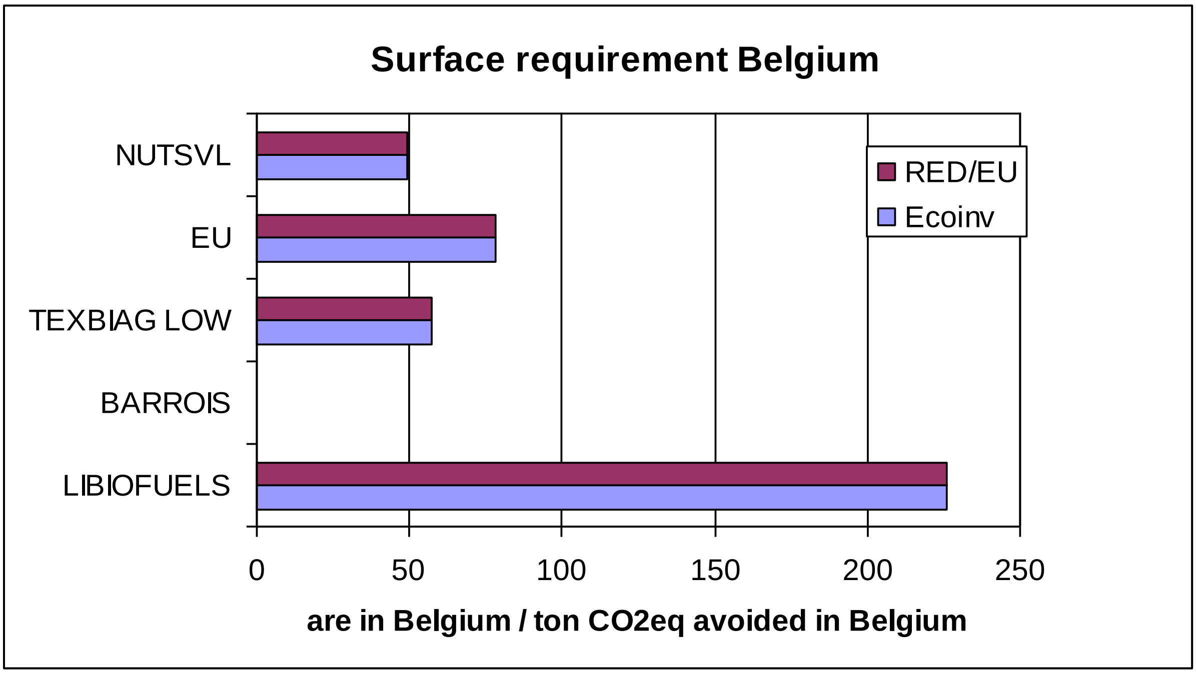



*Figure 52: Surface requirements Belgium, RED/EU: EU utilities, Ecoinv: Ecoinvent utilities, rapeseed case*

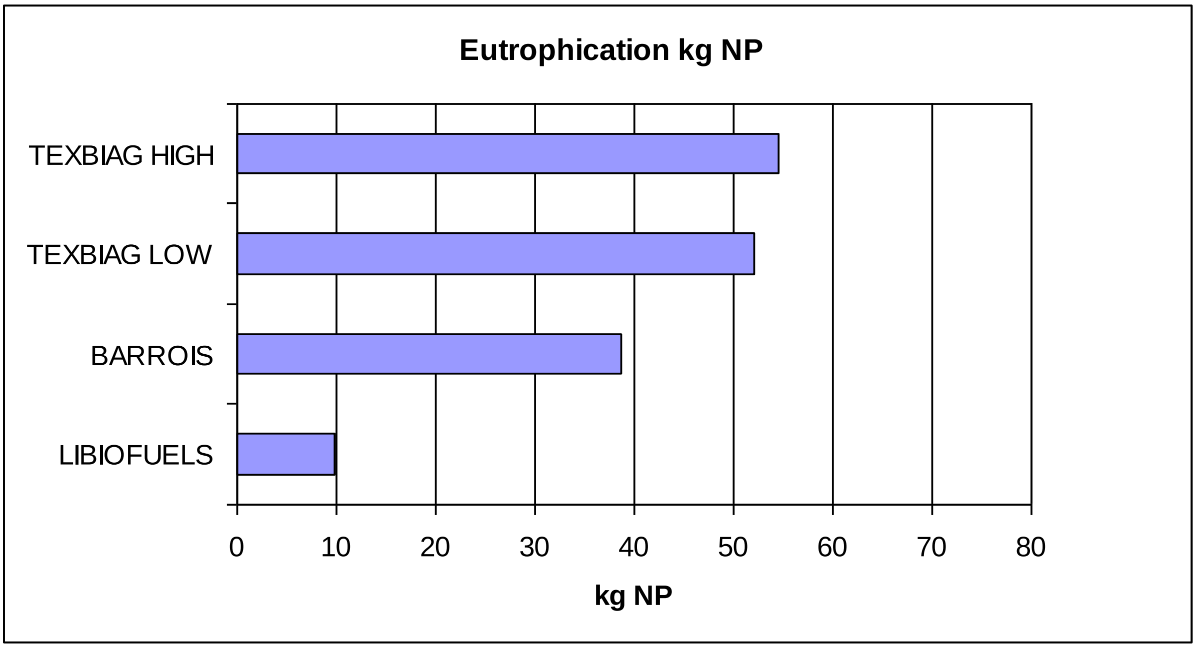



*Figure 53: Increased eutrophication, CML, rapeseed case*

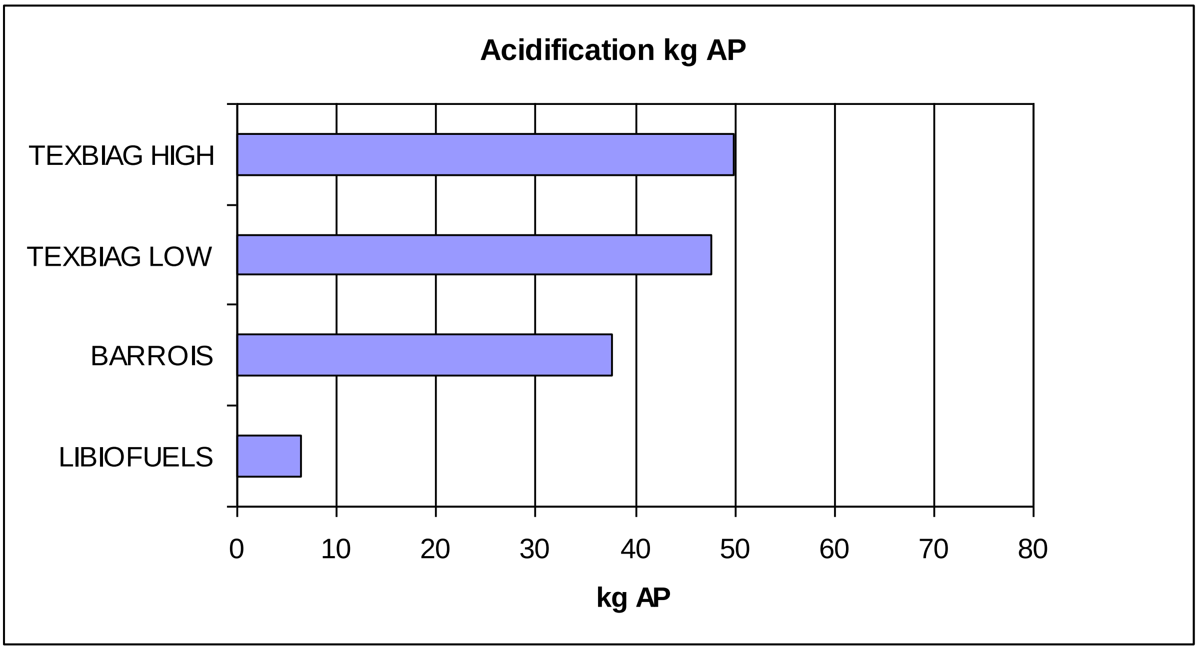



*Figure 54: Increased acidification, CML, rapeseed case*

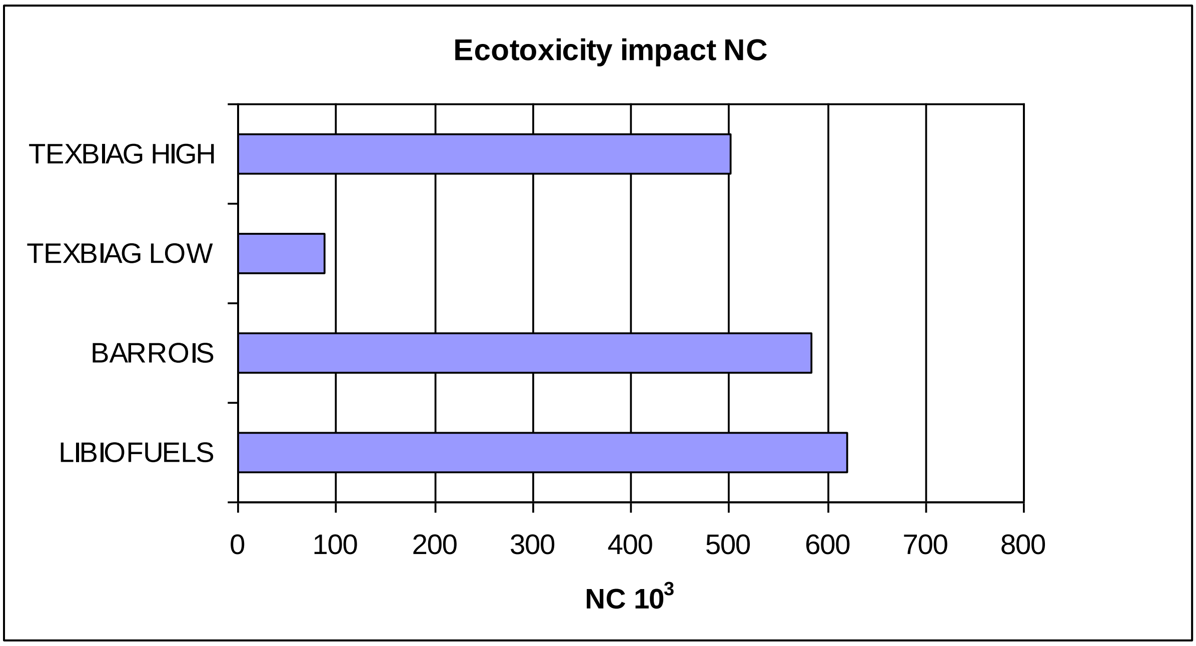



*Figure 55: Increased ecotoxicity, CML, rapeseed case*

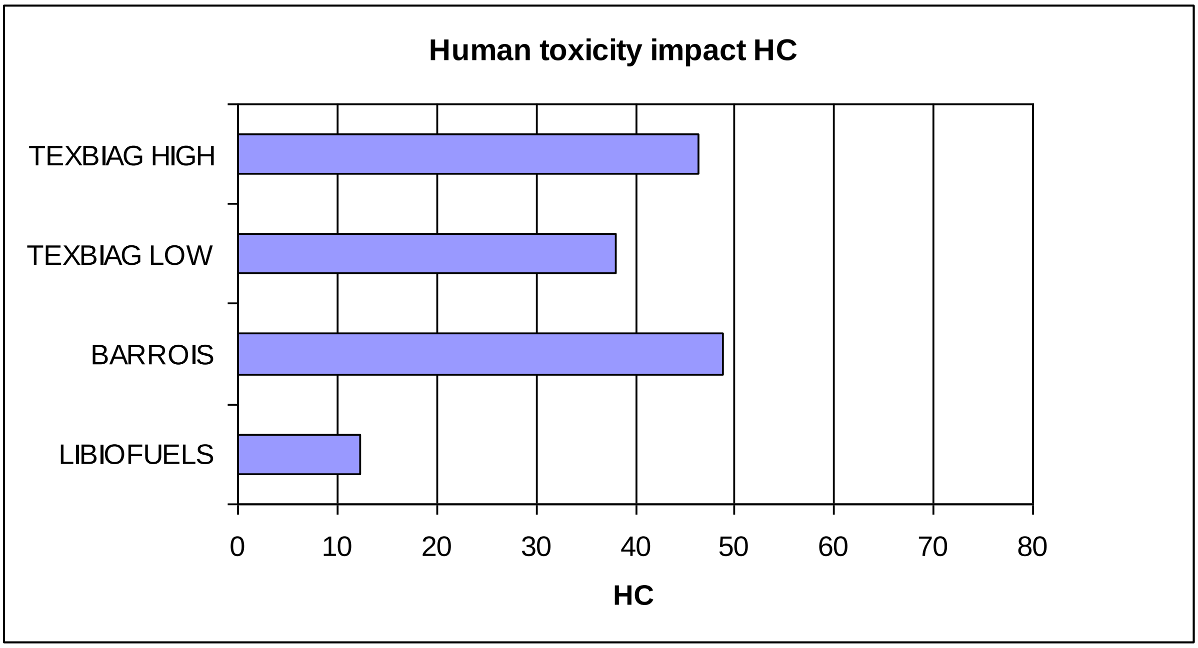



*Figure 56: Increased human toxicity, CML, rapeseed case*

### 2.3.11. Conclusions and future work

A new version of SPA is presented, which is much more flexible and versatile than the original SPA presented in the LIBIOFUELS report, and more confidence is obtained in the substitution mechanisms regarding animal feed, electric energy and other aspects such as refineries a.o.
Very different datasets can now easily be combined into processes fully defined by the user. Scenarios with different datasets can also easily be compared.
From the comparisons it appears that differences between datasets are strongly related to the difference in yields, combined with differences in specific energy consumption per ton wheat produced. Differences in $N_2O$ emissions assumptions also have strong effects. Most results change accordingly, and these two basic data are therefore *quite dominant*.
The direct field emissions are dominating for the acidification and eutrophication, which are not considered in the LIBIOFUELS, RED/EU and NUT procedures. Use of Ecoinvent or any other model is therefore indicated to assess the impacts of land use. The considered cases show differences in acidification potential and eutrophication potential which are not too significant, and probably would not affect decision making.
P and K fertilizers have a strong impact on ecotoxicity, but *not* through direct field emissions.
Human toxicity shows a mixed picture: direct field emissions play partly, and correlates with the use of P and K fertilizers.
As further work, the SPA2 tool will be made available for custom users. The program needs to be made more robust in terms of debugging the data entered by the user and issuing warnings of data looking abnormal. A user guide will be prepared.
The tool is now available for upgrading the work done in LIBIOFUELS, including new routes, impacts factors and local data provided in TEXBIAG.

# CHAPTER 3 POLICY SUPPORT

## 3.1. SCOPE

The production of biomass or biofuels, wherever it takes place, comes along with externalities (positive or negative) and the need for ensuring biomass and bioenergy sustainability is therefore more than ever felt.
The European Commission has asked its Member States to express their position regarding the policy debate on the consequences of the increased use of liquid biofuels blended with transport fuels. The Belgian position was communicated during the Environmental Council held in Strasbourg on the 30th of October 2007. The challenge was to develop a clear and harmonized methodology at European scale, regarding emissions assessment all along the fuels life cycle, as well as the verification of these emissions at the supplier's side, possibly coming with sanctions. The other point important for Belgium was the need for certification. It is indeed essential to make sure that biomass is produced in a sustainable manner, while minimizing negative effects, such as deforestation, increased use of pesticides, excessive demand for water for irrigation, competition with food, etc. Sustainability criteria should also take into account the socio-economic impacts and costs for the final user.

TEXBIAG must be seen as a contribution to the impact assessment of bioenergy in general, with focus on the cultivation step, which is one of the biggest, if not the biggest, contributing step to the overall impact of a given bioenergy chain. Impact criteria are under continuous development at national and European levels to allow producers bioenergy to demonstrate to potential consumers the quality of their products (through the observance of standards) along the process-chain. TEXBIAG contributes to a clear and harmonized methodology at European scale, regarding emissions assessment all along the fuels life cycle, as well as the verification of these emissions at the supplier's side.

An extensive report is made available about the different Policy Support Initiatives in Europe, to be found in Deliverable D26 and updates. The considered sustainability schemes were:

- The Netherlands – The Cramer Commission;
- Germany – The Biofuel Quota Act and Biofuel Sustainability Ordinance;
- United Kingdom – The Renewable Transport Fuel Obligation;
- Roundtable on Sustainable Palm Oil;
- Roundtable on Sustainable Biofuels;
- European Commission – the new RES and Fuel Quality Directives;
- European Commission DG TREN – Biomass Technology Group.

For each of these initiatives, the report describes

- The selected sustainability criteria and implementation system;
- The calculation methodology, if any;
- The certification system, if any;

The report summarizes the characteristics of these main initiatives regarding their:

- Scope: bioenergy or biofuels only;
- System implementation: voluntary or mandatory scheme;
- Choice of sustainability criteria: methodology, level of details;
- Propositions for dealing with indirect land-use changes, if any;

- GHG calculation methodology, if any, with:
    - GHG emission targets;
    - Selected bioenergy chains (see also Annex 14);
    - Methodology for default values propositions (for bioenergy and fossil energy references);
    - Direct land-use changes evaluation process;
    - Co-product allocation choice;
- Under development or implemented certification system;
- Strong points and weaknesses.

From these conclusions, it was possible to draw propositions for the TEXBIAG methodology, adapted to the Belgian context, as described in section 2.2.

### 3.2. TOOLS (MADE) AVAILABLE

Powerful tools to support the policy making process became available in the last ten years, and are subject to continuous improvement.

Among the three tools developed by TEXBIAG the database of environmental and socio-economic impacts gathers a considerable amount of data adapted to the local context. Focussing on the cultivation step, several crop management scenarios were selected matching realistic situations according to farm size, soil characteristics and fertilisation preferences.

The externalities assessment model assembles quantitative, qualitative and monetization results for the cultivation step of considered routes. It enables the comparison of these routes according to an extended set of sustainability criteria and allows the user to decide whether a category of impact weighs more than another in a particular situation.

The choice of using the Ecoinvent database as the reference has met the expectations, and it remains the preferred base to work on and with.
The best 'Ecoinvent interpreter' appears to be Simapro, which offers the advantages of being a good navigator in the forest of information which is Ecoinvent, and also offers the calculation of impact factors according to most available standards. Simapro moreover offers easy modifications of Ecoinvent data, and this facility was used in the present work.
Simapro however does not allow getting all details from Ecoinvent, and a homemade data extraction tool is made available, although not for public use. This tool is written in Matlab and is available for further research purposes, or to answer policy questions.
SPA2 finally is made available, and can best be used in combination with Ecoinvent and Simapro. This tool allows the following:

- To define an arbitrary 'system' by assembling streams and components (e.g. Belgium)
- To study the substitution of components within the considered system
- To feed in data from arbitrary sources, which in practice occurs through Simapro, with or without data modifications, and in combination with local data
- To determine the impacts of any substitution, with any assumption about impact methodology

Additional specific advantages of SPA2 are

- Flexibility in mixing different types of data sources
- Unlimited streams going in and out of process units
- No allocation assumptions needed inside the system

The impact balances must allow policy makers to take decisions, and the combined tool allows to assess/compare the decisions taken by them.

The tools can be made available for public use.

# CHAPTER 4 DISSEMINATION AND VALORISATION

This chapter concerns the thorough dissemination of results and deliverables of the project towards its target groups. The three main target groups that benefit from the project are: the government officials and policy makers in the field of agriculture, energy and environment in Belgium and its two main regions, the small, medium and large energy companies and the agricultural sector. Through the performance of the decision-making tools and awareness campaign, it is expected that the project will:

- Improve the understanding of government officials and policy makers on the barriers towards implementation of bioenergy from agriculture and the measures to improve these policies and their implementation;
- Enhance the capacity of policy makers and public administrations in setting up adequate policy and policy implementation guidelines that could promote bioenergy from agriculture;
- Enhance the capacity of small, medium and large energy companies as well as the agricultural sector in implementing bioenergy from agriculture by developing strategic know-how and approaches towards bioenergy from agriculture development and implementation;
- Demonstrate to government officials and policy makers, small, medium and large energy companies, agricultural sector the benefits of bioenergy from agriculture, in terms of environmental and health protection, potential energy supply security, jobs creation and economic development;
- Encourage government officials and policy makers, small, medium and large energy companies, agricultural sector to develop bioenergy projects from agriculture.

Communication and valorisation took place all along the project through written documents edition and scientific publications, through participations in conferences and through contacts with experts and policy makers.

Results were disseminated through the following channels:

- Deliverables (see list in chapter 5 and copy in Annex 1) were handed over to Belspo and target groups represented by Follow-up Committee members (see list in Annex 2);
- Several scientific publications have been written in order to disseminate the project results among the scientific community (see list in chapter 5 and copy in Annex 1);
- Posters and a leaflet have been edited to present the project objectives and results to target groups and in targeted events;
- A Website was implemented in order to facilitate the communication between the coordinator, the partners, the target groups and PPS;
- Participation to several conferences enabled the partners to introduce the project to the public and target groups;
- A brainstorming session with target experts (experts in agriculture) has been organised in order to consolidate the externalities assessment model;
- Follow up committee meetings were organised on a regular basis (see Annex 2);

- A seminar has been organised by the partners. Government officials, policy makers, various energy company stakeholders, the agricultural sector attended (see Deliverable D23). This seminar was dedicated to the presentation of the results. It was also an opportunity to discuss the orientations of the project.

# CHAPTER 5 PUBLICATIONS

## 5.1. PEER REVIEW

VAN STAPPEN F., BROSE I. & SCHENKEL Y. (in press). Direct and indirect land-use changes issues in sustainability initiatives: state-of-the-art, open issues and future developments. Biomass&Bioenergy, submitted 31 October 2009. Special Issue on Land use impacts of bioenergy – Selected papers from the IEA Bioenergy Task 38 Meetings in Helsinki, 2009 and Brussels, 2010.

BROSE I, VAN STAPPEN F & CASTIAUX A (2010). Articulation of environmental and socio-economical externalities from bioenergy. Management of Environmental Quality 2010; 21(6) 812-829. Special Issue on "Renewable energy".

BROSE I., VAN STAPPEN F., CASTIAUX A. (2009). Artic ulation of environmental and socio-economic externalities of bioenergy: A qualitative model. Proceedings of the 15th Annual International Sustainable Development Research Conference – Utrecht, the Netherlands. 13p.

VAN STAPPEN F., BROSE I. & SCHENKEL Y. (2009). Sustainability criteria and certification for biomass and bioenergy: state-of-the-art and methodological issues in the Belgian context. Proceedings of the 15th Annual International Sustainable Development Research Conference – Utrecht, the Netherlands. 18p.

BRAM S., DE RUYCK J., LAVRIC D. (2009). Using Biomass: a System Perturbation Analysis. Applied Energy, Vol. 86, Issue 4, pp. 194-201, 2009.

MARCHAL D., VAN STAPPEN F. & SCHENKEL Y. (2009). Critères et indicateurs de production "durable" des biocombustibles solides : état des lieux et recommandations. Biotechnol. Agron. Soc. Environ. 2009 13(1), 165-176.

## 5.2. TEXBIAG PROJECT DELIVERABLES

FUNDP & CRA-W (2007). Synthesis of the existing studies and models on monetization of bioenergy impacts. TEXBIAG Deliverable #5. 22p.

CRA-W & FUNDP (2008). Sustainability criteria and certification systems for biomass and bioenergy: state-of-the-art and propositions in the Belgian context – version 1. TEXBIAG Deliverable #26. 92p.

VUB & CRA-W (2008). Animal feed market modeling. TEXBIAG Deliverable #8. 54p.

VUB (2008). Refinery modeling. TEXBIAG Deliverable #9. 31p.

VUB (2008). Food market modeling. TEXBIAG Deliverable #11. 54p.

FUNDP & CRA-W (2008). Critical review of existing studies and models on environmental and socio-economic impacts of bioenergy, and their monetization. TEXBIAG Deliverable #2+5. 40p.

CRA-W (2008). Logistics of biomass supply chain from agriculture: main existing studies. TEXBIAG Deliverable #3. 19p.

TEXBIAG consortium (2008). TEXBIAG project leaflet. TEXBIAG Deliverable #21. 2p.

FUNDP, CRA-W & VUB (2008). Consolidated list of indicators to be used to build the qualitative model. TEXBIAG Deliverable #6. 50p.

FUNDP & CRA-W (2008). Consolidated qualitative model. TEXBIAG Deliverable #7. 18p.

KUL (2009). Modelling of non-linear perturbations of the electrical system. TEXBIAG Deliverable #10. 34p.

CRA-W & FUNDP (2009). Sustainability criteria and certification systems for biomass and bioenergy: state-of-the-art and propositions in the Belgian context – version 2. TEXBIAG Deliverable #26. 123p.

FUNDP, CRA-W & VUB (2009). Consolidated list of indicators to be used to build the qualitative model. TEXBIAG Deliverable #6'. 50p.

KUL (2009). Modelling of non-linear perturbations of the electrical system. TEXBIAG Deliverable #10 revised. 34p.

FUNDP & CRA-W (2009). Report of brainstorming session with target experts in order to consolidate the qualitative model. Deliverable #13. 30p.

FUNDP & CRA-W (2009). Consolidated qualitative model. TEXBIAG Deliverable #14. 19p.

TEXBIAG consortium (2009). Publications of the project teams. TEXBIAG Deliverable #20. 6p.

TEXBIAG consortium (2009). Organisation of the first TEXBIAG seminar – 17 September 2009. TEXBIAG Deliverable #23. 6p.

TEXBIAG consortium (2009). Project presentation in conferences and seminars in 2009. TEXBIAG Deliverable #25. 7p.

CRA-W & FUNDP (2009). Sustainability criteria and certification systems for biomass and bioenergy: state-of-the-art and propositions in the Belgian context – version 3. TEXBIAG Deliverable #26. 140p.

FUNDP & CRA-W (2010). Quantification of the environmental and socio-economic impacts of bioenergy production, conversion and use – Quantitative model. TEXBIAG Deliverable #16. 23p.

CRA-W & FUNDP (2010). Environmental and socio-economic impacts of bioenergy production, conversion and use – Missing data collection. TEXBIAG Deliverable #4. 45p.

CRA-W (2011). Database on environmental and socio-economic impacts of bioenergy routes from agriculture. Excel files. TEXBIAG Deliverable #1.

### 5.3. OTHERS

BROSE I., VAN STAPPEN F., CASTIAUX A. (2009). Environmental and socio-economic externalities of bioenergy: sustainability indicators and qualitative model. Proceedings of the 17th European Biomass Conference & Exhibition – from research to industry and markets – Hamburg, Germany. pp 2516-2524.

VAN STAPPEN F., BROSE I. & SCHENKEL Y. (2009). Sustainability criteria and certification for biomass and bioenergy: state-of-the-art and methodological issues in the Belgian context. Proceedings of the 17th European Biomass Conference & Exhibition – from research to industry and markets – Hamburg, Germany. pp 2341-2349.

VAN STAPPEN F., SCHENKEL Y., BROSE I., CASTIAUX A., BRAM S., DE RUYCK J., DRIESEN J. & BEKAERT D. (2009). Decision-making tools to support the development of bioenergy from agriculture. Proceedings of the 17th European Biomass Conference & Exhibition – from research to industry and markets – Hamburg, Germany. pp 2531-2540.

VAN STAPPEN F., BROSE I. & SCHENKEL Y. (2009). Sustainability criteria and certification for biomass and bioenergy: state-of-the-art and methodological issues in the Belgian context. Poster at the Fifth International Conference on Renewable Resources and Biorefineries – Ghent, 10 June 2009.

VAN STAPPEN F. (2009). Decision-making tools to support the development of bioenergy from agriculture. Presentation at the Fifth International Conference on Renewable Resources and Biorefineries – Ghent, 10 June 2009.

BROSE I., VAN STAPPEN F., CASTIAUX A. (2010). Articulation of environmental and socio-economical externalities from bioenergy: A qualitative model, University of Vaasa Publication Series. Proceedings of the Corporate Responsibility Research Conference: "Responsible leadership" - University of Vaasa, Finland.

BIRD D.N., CHERUBINI F., COWIE A., DOWNING M., GUSTAVSSON L., KOJAKOVIC A., Jungmeier G., Möllersten K., Pingoud K., Rueter S., Schlamadinger B., Soimakallio S., Van Stappen F. & Woess-Gallasch S. (2009). IEA Bioenergy Task 38 – Ten years of analysing the greenhouse gas balances of bioenergy systems. Proceedings of the 17th European Biomass Conference & Exhibition – from research to industry and markets – Hamburg, Germany. pp 2320-2324.

# CHAPTER 6 ACKNOWLEDGMENTS

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CRA-W would like to thank all experts who accepted to share their knowledge and test results regarding cultivation pathways, enabling the production of agricultural data adapted to the Belgian context.

# CHAPTER 7 REFERENCES

ABT Associates (2003). Cost of Illness Handbook. Cambridge, Massachusetts.

Atkinson G., Mourato S. (2007). Environmental Valuation: A Brief Overview of Options. Milan European Economy Workshops Working Paper No. 07.

Bergstrom J.C., Taylor L.A. (2007). Using Meta-Analysis for Benefits Transfer: theory and Practice. Review draft.

BIOGRACE (2009) Harmonised calculations of Biofuel GHG emissions in Europe, version 2 public. Workbook with transparant greenhouse gas (GHG) calculations using the methodology as given in the Directives 2009/28/EC and 2009/30/EC. www.biograce.net

Bovea M.D., Vidal R. (2004). Increasing Product Value by Integrating Environmental Impact, Costs and Customer Valuation. Resources, Conservation and Recycling, Vol. 41, pp. 133-145.

Bram S., De Ruyck J., Lavric D. (2009) Using Biomass: a System Perturbation Analysis', Applied Energy, Vol.86, Issue 4, pp. 194-201.

Campens V., Holmstock K. (2010) Verslag van de berekening van de emissies ten gevolge van de teelt van de gewassen voor de productie van biobrandstoffen. Departement Landbouw en Visserij, afdeling monitoring en studie, afdeling duurzame landbouwontwikkeling. Vlaams Gewest, België.

Colombo S., Calatrava-Requena J., Hanley N. (2006). Analysing the Social Benefits of Soil Conservation Measures Using Stated Preference Methods. Ecological Economics, Vol. 58, No. 4, pp. 850-861.

Cramer J. & Members of the project group "Sustainable Production of Biomass" (2007). Testing framework for sustainable biomass – final report of the project group "Sustainable Production of Biomass". Energy Transition Task Force.

De Palma A., Zaouali N. (2007). Monétarisation des Externalités de Transport : un Etat de l'Art.

De Ruyck J., Jossart J.M., Palmers G., Hamelinck C., Lavric D., Bram S., Novak A., Remacle M.S., Dooms G., van den Broek R. (2006) Liquid biofuels in Belgium in a global bio-energy context. Final report. SPSD II. 137p.

Dziegielewska D.A.P., Mendelsohn R. (2005). Valuing Air Quality in Poland. Environmental and Resource Economics, Vol. 30, pp. 131-163.

EC (2003) Directive 2003/30/EC of the European Parliament and of the Council of 8 May 2003 on the promotion of the use of biofuels or other renewable fuels for transport, May 2003.

EC (2009a) Directive 2009/28/EC of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC. Official

Journal of the European Union.

EC (2010a) Updated figures communicated - Update on Data on pathways for RES Directive. Workbook with updated figures for the typical values and default values in Annex V of the Directive 2009/28/EC reflecting the updating of underlying data by JEC.

EC (2010b) Communication from the EC of 10 June 2010 on the practical implementation of the EU biofuels and bioliquids sustainability scheme and on counting rules for biofuels.

Fankhauser S. (1994). The Social Costs of Greenhouse Gas Emissions: An Expected Value Approach. Energy Journal, Vol. 15, No. 2, pp. 157-185.

Freeman A.M. (1996). Estimating the Environmental Costs of Electricity: An Overview and Review of the Issues. Resource and Energy Economics, vol. 18, pp. 347-362.

Frischknecht R. and Jungbluth N. (2007) Ecoinvent report no 1: Overview and Methodology, Dübendorf.

Gallagher P.W., Dikeman M., Fritz J., Wailes E., Gauthier W., Shapouri H. (2003). Supply and Social Cost Estimates for Biomass from crop Residues in the United States. Environmental and Resource Economics, Vol. 24, pp. 335-358.

Goedkoop M. and R. Spriensma. (2001). The Eco-indicator 99. A Damage Oriented Method for Life Cycle Impact Assessment: Methodology Report. Amersfoort: Pre Consultants.

Gnansounou E., Panichelli L., Dauriat A. & Villegas J.D. (2008). Accounting for indirect land-use changes in GHG balances of biofuels. Review of current approaches. Ecole Polytechnique Fédérale de Lausanne.

Groothuis P.A., Groothuis J.D., Whitehead J.C. (2007). Green vs. Green: Measuring the Compensation Required to Site Electrical Generation Windmills in a Viewshed. Working Paper.

Guns A. (2010) Bilan des emissions de gaz à effet de serre resultant de la culture de matières premières agricoles en vue de la production de biocarburants. Agence Wallone de l'air et du Climat ; 2010.

JEC (2008) Description and detailed energy and GHG balance of individual pathways. Appendix 2 of the "Well-to-wheels analysis of future automotive fuels and powertrains in the European context". Well-to-tank Report Version 3.0 November 2008.

Jenkins G., Kuo C.-Y., Ozbafli A. (2007). Cost-Benefit Analysis Case Study on Regulations to Lower the Level of Sulphur in Gasoline, Queen's Economic Department Working Paper, No. 1134.

Johnson F.X. & Roman M. (2008). Biofuels Sustainability Criteria: Relevant issues to the proposed Directive on the promotion of the use of energy from renewable sources {COM(2008) 30 final}. Consolidated study at the request of the European Parliament's Committee on Environment, Public Health and Food Safety. IP/A/ENVI/ST/2008-10&11.

Jungbluth, N., Chudacoff, M., Dauriat, A., Dinkel, F., Doka, G., Faist Emmenegger, M., Gnansounou, E., Kljun, N., Spielmann, M., Stettler, C., Sutter, J. (2007) Life Cycle Inventories of Bioenergy. Final report, ESU-services, Uster, CH.

Pearce D., Atkinson G., Mourato S. (2006). Cost-Benefit Analysis and the Environment – Recent

Developments. OECD.

Rambonilaza M., Point P., Dachary-Bernard J. (2007). Stability of the WTP Measurements with Successive Use of Choice Experiments Method and Multiple Programmes Method. Cahiers du GREThA, No. 2007-12.

RFA – Renewable Fuels Agency (2008). Carbon and Sustainability Reporting within the Renewable Transport Fuel Obligation – Technical Guidance Parts One & Two.

Secchi S. (2007). Watching Corn Grow: A Hedonic Study of the Iowa Landscape. Center for Agricultural and Rural Development Working Paper No. 445.

Smith V.K., Sieg H., Banzhaf H.S., Walsh R. (2002). General Equilibrium Benefit Transfers for Spatial Externalities: Revisiting EPA's Prospective Analysis. Resources for the Future Discussion Paper No. 44.

Spash C.L. (2007). Deliberative Monetary Valuation (DMV) in Practice. Socio-Economics and the Environment in Discussion, CSIRO Working Paper Series, No. 4.

Tchouate Héteu P.M. (2003). Contribution des énergies renouvelables au développement durable du secteur électrique : le cas du Cameroun. Université Catholique de Louvain. Thèse de doctorat.

Welsch H. (2003). Environment and Happiness: Valuation of Air Pollution in Ten European Countries. DIW Berlin, Discussion Paper, No. 356.

## ANNEX 1: COPY OF THE PUBLICATIONS

The links to the publications are on the BELSPO website
http://www.belspo.be/belspo/ssd/science/pr_energy_fr.stm
http://www.belspo.be/belspo/ssd/science/pr_energy_nl.stm
http://www.belspo.be/belspo/ssd/science/pr_energy_en.stm

### PEER REVIEW

VAN STAPPEN F., BROSE I. & SCHENKEL Y. (in press). Direct and indirect land-use changes issues in sustainability initiatives: state-of-the-art, open issues and future developments. Biomass&Bioenergy. Special Issue on Land use impacts of bioenergy – Selected papers from the IEA Bioenergy Task 38 Meetings in Helsinki, 2009 and Brussels, 2010.

BROSE I, VAN STAPPEN F & CASTIAUX A (2010). Articulation of environmental and socio-economical externalities from bioenergy. Management of Environmental Quality 2010; 21(6) 812-829. Special Issue on "Renewable energy".

BROSE I., VAN STAPPEN F., CASTIAUX A. (2009). Articulation of environmental and socio-economic externalities of bioenergy: A qualitative model. Proceedings of the 15th Annual International Sustainable Development Research Conference – Utrecht, the Netherlands. 13p.

VAN STAPPEN F., BROSE I. & SCHENKEL Y. (2009). Sustainability criteria and certification for biomass and bioenergy: state-of-the-art and methodological issues in the Belgian context. Proceedings of the 15th Annual International Sustainable Development Research Conference – Utrecht, the Netherlands. 18p.

BRAM S., DE RUYCK J., LAVRIC D. (2009). Using Biomass: a System Perturbation Analysis. Applied Energy, Vol. 86, Issue 4, pp. 194-201, 2009.

MARCHAL D., VAN STAPPEN F. & SCHENKEL Y. (2009). Critères et indicateurs de production "durable" des biocombustibles solides : état des lieux et recommandations. Biotechnol. Agron. Soc. Environ. 2009 13(1), 165-176.

### TEXBIAG PROJECT DELIVERABLES

FUNDP & CRA-W (2007). Synthesis of the existing studies and models on monetization of bioenergy impacts. TEXBIAG Deliverable #5. 22p.

CRA-W & FUNDP (2008). Sustainability criteria and certification systems for biomass and bioenergy: state-of-the-art and propositions in the Belgian context – version 1. TEXBIAG Deliverable #26. 92p.

VUB & CRA-W (2008). Animal feed market modeling. TEXBIAG Deliverable #8. 54p.

VUB (2008). Refinery modeling. TEXBIAG Deliverable #9. 31p.

VUB (2008). Food market modeling. TEXBIAG Deliverable #11. 54p.

FUNDP & CRA-W (2008). Critical review of existing studies and models on environmental and socio-economic impacts of bioenergy, and their monetization. TEXBIAG Deliverable #2+5. 40p.

CRA-W (2008). Logistics of biomass supply chain from agriculture: main existing studies. TEXBIAG Deliverable #3. 19p.

TEXBIAG consortium (2008). TEXBIAG project leaflet. TEXBIAG Deliverable #21. 2p.

FUNDP, CRA-W & VUB (2008). Consolidated list of indicators to be used to build the qualitative model. TEXBIAG Deliverable #6. 50p.

FUNDP & CRA-W (2008). Consolidated qualitative model. TEXBIAG Deliverable #7. 18p.

KUL (2009). Modelling of non-linear perturbations of the electrical system. TEXBIAG Deliverable #10. 34p.

CRA-W & FUNDP (2009). Sustainability criteria and certification systems for biomass and bioenergy: state-of-the-art and propositions in the Belgian context – version 2. TEXBIAG Deliverable #26. 123p.

FUNDP, CRA-W & VUB (2009). Consolidated list of indicators to be used to build the qualitative model. TEXBIAG Deliverable #6'. 50p.

KUL (2009). Modelling of non-linear perturbations of the electrical system. TEXBIAG Deliverable #10 revised. 34p.

FUNDP & CRA-W (2009). Report of brainstorming session with target experts in order to consolidate the qualitative model. Deliverable #13. 30p.

FUNDP & CRA-W (2009). Consolidated qualitative model. TEXBIAG Deliverable #14. 19p.

TEXBIAG consortium (2009). Publications of the project teams. TEXBIAG Deliverable #20. 6p.

TEXBIAG consortium (2009). Organisation of the first TEXBIAG seminar – 17 September 2009. TEXBIAG Deliverable #23. 6p.

TEXBIAG consortium (2009). Project presentation in conferences and seminars in 2009. TEXBIAG Deliverable #25. 7p.

CRA-W & FUNDP (2009). Sustainability criteria and certification systems for biomass and bioenergy: state-of-the-art and propositions in the Belgian context – version 3. TEXBIAG Deliverable #26. 140p.

FUNDP & CRA-W (2010). Quantification of the environmental and socio-economic impacts of bioenergy production, conversion and use – Quantitative model. TEXBIAG Deliverable #16. 23p.

CRA-W & FUNDP (2010). Environmental and socio-economic impacts of bioenergy production, conversion and use – Missing data collection. TEXBIAG Deliverable #4. 45p.

CRA-W (2011). Database on environmental and socio-economic impacts of bioenergy routes from agriculture. Excel files. TEXBIAG Deliverable #1.

#### **OTHERS**

BROSE I., VAN STAPPEN F., CASTIAUX A. (2009). Environmental and socio-economic externalities of bioenergy: sustainability indicators and qualitative model. Proceedings of the 17th European Biomass Conference & Exhibition – from research to industry and markets – Hamburg, Germany. pp 2516-2524.

VAN STAPPEN F., BROSE I. & SCHENKEL Y. (2009). Sustainability criteria and certification for biomass and bioenergy: state-of-the-art and methodological issues in the Belgian context. Proceedings of the 17th

European Biomass Conference & Exhibition – from research to industry and markets – Hamburg, Germany. pp 2341-2349.

VAN STAPPEN F., SCHENKEL Y., BROSE I., CASTIAUX A., BRAM S., DE RUYCK J., DRIESEN J. & BEKAERT D. (2009). Decision-making tools to support the development of bioenergy from agriculture. Proceedings of the 17th European Biomass Conference & Exhibition – from research to industry and markets – Hamburg, Germany. pp 2531-2540.

VAN STAPPEN F., BROSE I. & SCHENKEL Y. (2009). Sustainability criteria and certification for biomass and bioenergy: state-of-the-art and methodological issues in the Belgian context. Poster at the Fifth International Conference on Renewable Resources and Biorefineries – Ghent, 10 June 2009.

VAN STAPPEN F. (2009). Decision-making tools to support the development of bioenergy from agriculture. Oral presentation at the Fifth International Conference on Renewable Resources and Biorefineries – Ghent, 10 June 2009.

BROSE I., VAN STAPPEN F., CASTIAUX A. (2009). Articulation of environmental and socio-economical externalities from bioenergy: A qualitative model, University of Vaasa Publication Series. Proceedings of the Corporate Responsibility Research Conference: "Responsible leadership" - University of Vaasa, Finland.

BIRD D.N., CHERUBINI F., COWIE A., DOWNING M., GUSTAVSSON L., KOJAKOVIC A., JUNGMEIER G., MÖLLERSTEN K., PINGOUD K., RUETER S., SCHLAMADINGER B., SOIMAKALLIO S., VAN STAPPEN F. & WOESS-GALLASCH S. (2009). IEA Bioenergy Task 38 – Ten years of analysing the greenhouse gas balances of bioenergy systems. Proceedings of the 17th European Biomass Conference & Exhibition – from research to industry and markets – Hamburg, Germany. pp 2320-2324.

VAN STAPPEN F (2009). Direct and indirect land-use changes issues in European sustainability initiatives. Oral presentation at the IEA Bioenergy Task 38 workshop "Land Use Changes due to Bioenergy: Quantifying and Managing Climate Change and Other Environmental Impacts" – Helsinki, 30 March – 01 April 2009.

VAN STAPPEN F (2009). First implementations of sustainability schemes in European countries. Oral presentation at the IEA Bioenergy Task 40 – VITO workshop "Sustainability certification for biofuels and bio-energy" – Brussels, 29 January 2009.

VAN STAPPEN (2008). Critères de durabilité pour la biomasse et la bioénergie: Initiatives existantes et mise en œuvre de systèmes de certification. Cours Energies Renouvelables, FSAGx, 3ème Master Bioingénieur. Gembloux, 9 décembre 2008.

VAN STAPPEN F (2008). Contribution to the implementation of a certification system for liquid biofuels, based on environmental and socio-economic criteria. Poster presentation, "Which life on an impoverished planet?", seminar FUNDP, University of Namur – 23 January 2008.

# ANNEX 2: MINUTES OF THE FOLLOW-UP COMMITTEE MEETINGS

The following experts were members of the Follow-up Committee of TEXBIAG:

| Name | | Institution |
|---|---|---|
| Anne | Fierens | Belspo |
| Igor | Struyf | Belspo |
| Olivier | Gérard | FWA (Walloon Federation of Farmers) |
| Bart | Vleeschouwers | Boerenbond (Flemish Federation of Farmers) |
| Wim | Soetaert | University of Gent - Belgian Integrated Platform for Industrial Biotechnology |
| Olivier | Squilbin | CWaPE (Walloon Commission for Energy) |
| Jean-Marie | Delincé | ELIA (Belgium's transmission system operator ) |
| Gaëlle | Warnant | Agrobiopôle Wallon |
| Luc | Pelkmans | VITO (Flemish Institute for Technological Research) |
| Jean-Marc | Jossart | University of Louvain - ValBiom - AEBIOM |
| Michel | Degaillier | Federal Public Service Health, Food chain safety and Environment |
| Nora | Pieret | ValBiom (Biomass Valorisation association) |
| Charles | Debouche | University of Liège - Gembloux Agro Bio Tech |
| Dirk | Van Gijseghem | Flemish Government - Agriculture and Fisheries |
| José | Renard | Walloon Government - Agriculture and Natural Resources |
| Hilde | Wustenberghs | ILVO (Institute for Agricultural and Fisheries Research) |
| Marie | Schippers | Walloon Government - Energy |
| Jean-Louis | Nizet | Belgian Petroleum Federation |

## 7.1. 1ST FOLLOW-UP COMMITTEE MEETING (13 SEPTEMBER 2007)

Present: Anne FIERENS (Belspo), Marc Van Heuckelom (Belspo), Bart Vleeschouwers (Boerenbond), Jean-Marie Delincé (Elia), Luc Pelkmans (VITO), Jean-Marc Jossart (UCL), Michel Degaillier (SPF Environnement), Didier MARCHAL (ValBiom), Hilde Wustenberghs (ILVO), Dirk Van Gijseghem (Departement Landbouw en Visserij), Isabelle BROSE (FUNDP), Annick CASTIAUX (FUNDP), Jacques DERUYCK (VUB), Svend BRAM (VUB), Thomas NEVEN (VUB), Dirk Van Hertem (KUL), Yves SCHENKEL (CRA-W), Florence VAN STAPPEN (CRA-W)

Apologies for absence: Françoise LINERS (Agrobiopôle wallon), Wim Soetaert (Ugent), Olivier SQUILBIN (CWaPE), Charles DEBOUCHE (FUSAGx), Johan DRIESEN (KUL), Thong VU VAN (KUL), David BEKAERT (KUL)

### 7.1.1. Tour de table

Each participant briefly presents him/herself.

### 7.1.2. Presentation of the SSD Programme by BELSPO

Mr VAN HEUCKELOM presents the "Science for a Sustainable Development" Programme 2005-2009 and explains the role of the Follow-Up Committee (see copy of the slides in annex).

#### 7.1.3. Overview of the TEXBIAG project by CRA-W

Mr SCHENKEL presents an overview of the TEXBIAG project, with its objectives, methodology and expected results (see copy of the slides in annex).
Mr Van Heuckelom asks if the project intends to also consider the liquid biofuels taxation system. Mr PELKMANS says the issue is going to be tackled by another SSD project, BIOSES, a project with which TEXBIAG foresees to interact (the coordinator of TEXBIAG is a member of the BIOSES Follow-Up Committee and vice versa).

#### 7.1.4. Work progress of Task 1 – Database construction and Task 4 – Results dissemination and valorisation by CRA-W

Mrs VAN STAPPEN presents the work progress and the methodology of Task 1 – Database construction, as well as the first achievements of Task 4 – Results dissemination and valorisation (see copy of the slides in annex).
Regarding the agricultural resources to be considered Mr. PELKMANS and Mr. JOSSART point at the difficulty to assess the impact of imported biomass, such as sugar cane or palm oil. CRA-W will seek for relevant information/publication on this tricky issue. Additionally, CRA-W has submitted a proposal, jointly with a consortium of European experts, aiming at evaluating the environmental and socioeconomic sustainability of biomass import in Europe in order to give possible directions for the issuing of a standard. If accepted, this project will bring a lot of useful information to TEXBIAG.
Furthermore, TEXBIAG aims at comparing different import bioenergy routes, whether they import rough or already processed biomass to be converted to bioenergy, with routes cultivating and converting biomass in Belgium
Mr Vleeschouwers proposes to add Jatropha to the list of imported biomass to be considered, since it is forecasted to become an important source for bioenergy import in Europe.

#### 7.1.5. Work progress of Task 2 – Externalities monetization model by FUNDP

Ms BROSE presents the achievements and tasks in progress for Task 2 – Externalities monetization model (see copy of the slides in annex).
Mr JOSSART emphasises the importance of a proper choice of values for externalities and the weight to give to each of them. The partners and the Follow-Up Committee members agree that it is crucial to carry out a sensitivity analysis in order to assess uncertainties and to allow for a systematic comparison of different externalities. The case of the nitrous oxide ($N_2O$) for instance reveals to be a very difficult one, not to be underestimated.
Mr PELKMANS asks if externalities values are going to be absolute or relative. The aim is to integrate absolute values in the SPA model and to allow for the comparison of different scenarios.
Furthermore, basic data will not be hidden after monetizing but will remain available for assessment.
Mr Delincé suggests a multi-criteria approach for the monetizing methodology and stresses the delicate handling of assumptions. It is clear that – here too – the sensitivity analysis will have a role to play.
Mr JOSSART says that data reliability is a tricky issue and that the collection of conversion data is not an easy matter.
Ms Wustenberghs wonders about the limits of the benefit transfer method and Ms BROSE underlines that this track is still currently under investigation.

#### 7.1.6. Work progress of Task 3 – policy prediction tool by VUB and KUL

Mr BRAM presents the methodology used in Task 3 – policy prediction tool, explains the System Perturbation Analysis (SPA) model, used in the Libiofuels project, and describes the modifications that are being made in the new version of the model, developed in the TEXBIAG project (see copy of the slides in annex).
Mr PELKMANS calls attention to the complexity of the Belgian situation and inquires about the validation of the data used in the Libiofuels project. These data, gathered from literature sources (mainly the CONCAWE study) and from interviews with liquid biofuels professionals, are going to be updated in the TEXBIAG project.

Mr Van Gijseghem asks whether it is possible to add other routes in the SPA model. It is indeed feasible since this model enables users building their own scenarios.
Mr NEVEN presents the results of the report, entitled 'Animal feed market modelling' (see copy of the slides in annex).
Mr JOSSART asks clarifications about the conclusions of this report, in particular if it is possible to differentiate the amount of ready-to-use animal feed imported to Belgium from the separate feed ingredients imported and reprocessed in Belgium. Mr PELKMANS also suggests specifying the quantities issued from the Belgian agriculture. The figures of the report are going to be integrated into the SPA model.
Mr Van Hertem presents the impact of biomass on the electrical power system, achieved in the frame of Task 3.3. – Electrical grid modelling (see copy of the slides in annex).
Grid balancing seems an important issue because of the lower reliability of bioelectricity production. However, Mr Delincé recommends not to assess the impact of bioenergy introduction on the transmission congestion because this very complex issue is region specific and difficult to integrate into a general model. On the other hand, the impact on system generation is more relevant in this project. Mr DE RUYCK says it is nevertheless worth having a look on the transmission issue, even if it is not successful.
Mr JOSSART reminds that this project relates to bioenergy from agriculture where bioelectricity units scarcely exceed 1 MW. He therefore wonders where in Belgium there will ever be bioenergy-from-agriculture plants big enough to really perturb the transmission system.
Mr Van Hertem confirms that below 100 MW no effect on the grid is indeed detectable but Mr DE RUYCK points out that the interest of the SPA model is to use this tool to test scenarios. This might for instance allow the identification of possible locations in Belgium where to transform (imported or not) biomass into bioenergy, whether in existing or in new units.
The intermittent production of bioelectricity for system reserve is nonetheless worth studying.

### 7.1.7. Questions and discussion

The floor is open to discussion.
Mr JOSSART inquires about the timeframe of the externalities valuation. Are they current or expected values? This will have a significant impact on the project results.
It is also important to compare externalities on the same level and the question of how to deal with externalities with a large range of value demonstrates again the relevance of a sensitivity analysis.
Ms Wustenberghs insists on taking into account the impact of agricultural practices on soil erosion, for instance perennial versus annual crops.
Regarding the critical matter of land use, the questions relate to how to give a figure and the difficulty to find relevant studies. TEXBIAG might try to develop its own multicriteria model in order to give clues to assess the best use to make of a piece of land (food/feed or bioenergy?) or the impact of fertilizing to increase the yield, versus using less fertilizers to the detriment of yield and the benefit of the environment. Land best use differs according to the chosen criteria: from the environmental point of view (soil or emissions, etc.) or the socioeconomic point of view (employment, etc.).
Some Follow-Up Committee members propose to forward contacts of experts that might be interested in joining the land use advisory group. Links with this group need to be clarified for the next Follow-Up Committee meeting.
The Follow-Up Committee members agree to say the visual presentation of the studied bioenergy routes in flow sheets will be an asset but wonders about the dissemination level of the results of the project since many data will be taken from an access-restricted database.

### 7.1.8. Next Follow-Up Committee meeting

The next Follow-Up Committee meeting is foreseen to be held beginning of 2008.

## 7.2. 2ND FOLLOW-UP COMMITTEE MEETING (22 FEBRUARY 2008)

Present: Anne FIERENS (Belspo), Jean-Marc Jossart (UCL), Marie MANGUETTE (Agrobiopôle wallon), Luc Pelkmans (VITO), Dominique PERRIN (SPF Environnement), Olivier SQUILBIN (CWaPE), Hilde Wustenberghs (ILVO), Isabelle BROSE (FUNDP), Annick CASTIAUX (FUNDP), Thomas NEVEN (VUB), Johan DRIESEN (KUL), Thong VU VAN (KUL), Yves SCHENKEL (CRA-W), Florence VAN STAPPEN (CRA-W)

Apologies for absence: Charles DEBOUCHE (FUSAGx), Michel DEGAILLIER (SPF Environnement), Jean-Marie Delincé (Elia), Françoise LINERS (Agrobiopôle wallon), Didier MARCHAL (ValBiom), Wim Soetaert (Ugent), Bart Vleeschouwers (Boerenbond), Jacques DE RUYCK (VUB), Svend BRAM (VUB), David BECKAERT (KUL)

### 7.2.1. Tour de table

Each participant briefly presents him/herself.

### 7.2.2. Work progress of Task 1 – Database construction and Task 4 – Results dissemination and valorisation by CRA-W

Mrs VAN STAPPEN presents the work progress of Task 1 – Database construction and Task 4 – Results dissemination and valorisation (see copy of the slides in annex). She adds that a part of the work now focuses on sustainability criteria and certification (see slide 6).
Mr SQUILBIN asks who would be the experts participating to the Land-Use advisory group. The way this advisory group would work still needs to be discussed, on the base of the works existing on the subject.
Mr PERRIN enquires for the motivation of the choice of the 3 bioenergy chains (biodiesel from rapeseed, palm oil and Jatropha) to be studied in the framework of Mrs VAN STAPPEN's PhD thesis. This is because, among others, these bioenergy chains are currently very much discussed. This choice was motivated also by the possibility of gathering relevant data on the subject.

### 7.2.3. Work progress of Task 2 – Externalities monetization model by FUNDP

Ms BROSE presents the achievements and tasks in progress for Task 2 – Externalities monetization model (see copy of the slides in annex).
Mr JOSSART asks if the results of the monetization are going to be expressed in euros and stresses the importance of comparing bioenergy chains with different reference fossil chains, and not one average, because the origin of the fossil fuels influences a lot the results. The monetary unit to be used is indeed the euro but it is possible to choose another unit if required. The monetization model is still in its quantitative part and can be adapted if too integrative. In order to avoid presenting results as a "black box" to be taken as granted, the data quality from the database also needs to be assessed.
Mr PELKMANS wonders how to monetize energy security and underlines that import security is also important. Information on how to prevent fossil fuel stocks and options for diversification can be found with the JRC.
Regarding Deliverable D5 submitted to the Follow-up Committee members, Ms FIERENS suggests having it first validated by experts in modelling (Plan Bureau, VITO, KUL, etc.).
Mr JOSSART thinks that the most relevant externalities should be discussed longer (for instance, is it good or bad to have increasing food prices?), that it is even more important that figures on monetization.
Ms WUSTENBERGHS asks about the type of benefit transfer to be used. This depends on the final choice of the methodology and is still in progress.
Mr SQUILBIN points out that issues related to the import of biomass are always at the centre of debates while problems concerning fossil fuels import are commonly disregarded. It would be interesting to give an answer to politicians on what are really the best or worst options.

#### 7.2.4. Work progress of Task 3 – Policy prediction tool by VUB and KUL

Mr NEVEN presents the achievements and work progress for Task 3.1 – Modelling of non-linear perturbations of the animal feed market (see copy of the slides in annex).
Mr SQUILBIN draws attention to the fact that figures vary from one region to another and that using the Dutch case (seemingly not even specific to the Netherlands) may not be relevant for Belgium. He indicates that useful information could be found with the ILVO where people are working on animal feed co-products.
Mr SQUILBIN also wonders about organic agriculture and if the comparison between intensive versus extensive agriculture is going to be taken into account. Mr SCHENKEL acknowledges that feed mixes differ from one farm to another but here we look at the total amounts for Belgium in order to determine equivalences between feeds (soybean meal versus rapeseed meal, etc.).
Ms WUSTENBERGHS stresses that there are a lot of feeding differences depending on the animal type and that more categories than the current three (pigs, cattle and poultry) should be distinguished. She therefore suggests differentiating piglets from pigs for meat, dairy from beef cattle, egg layers from poultry for meat (6 animal types instead of 3).
Mr PELKMANS asks if this task could give an idea of the sectors that would be influenced by animal feed replacements.
Ms WUSTENBERGHS underlines that results are very dependent on the assumptions made all along the modelling process.
Mr JOSSART enquires about the justification of going into such a detailed analysis, which would rather fall into a nutritionist's competences and wonders if using rough figures would not be enough. Mr SCHENKEL replies that the aim is to assess the impact on the animal feed market of a higher introduction of biofuels, as a result of political decisions, and test different scenarios.
Mr SQUILBIN stresses that the animal feed market is a very international one and asks if building a larger model would not be more relevant than limiting the system to Belgium. Mr SCHENKEL reminds that a model needs limits and its interest will be to provide trends in order to support decisions on the direction to take. As an example, he puts up the difference between biomass grown and transformed in Belgium, thus generating by-products here, and palm oil imported crude, leaving by-products elsewhere.
Mr PELKMANS suggests that, since the outcomes are to evaluate the effect of replacing one by-product with another, specialists should be consulted to check the results. He also advises to assess the economic balance of the feed market, depending on the prices affected to these by-products.
Mr PERRIN stresses the importance of validating and calibrating the model in order to demonstrate its representativeness, with respect to reality.
Mr NEVEN presents the achievements and work progress for Task 3.2 – Modelling of non-linear perturbations of the refineries (see copy of the slides in annex).
Mr DRIESEN asks whether the $CO_2$ output in the model also includes indirect outputs. This has to be checked.
Mr PELKMANS points out that the balance between diesel and gasoline use will be influenced by biofuels introduction (diesel being favoured in Europe).
Mr PELKMANS also emphasizes the influence of biofuels introduction on diesel and gasoline quality. Standards set requirements for the vapour pressure of gasoline that will be affected by biofuel blending. This will have an impact on refineries operation.
Mr JOSSART says that diesel prices differ depending on the country of origin. Locally produced biofuels introduced on the Belgian market will replace the most expensive diesel, therefore influencing the expense balance.
Mr SQUILBIN wonders if it is possible to distinguish the import of refined oil products from crude oil. Mr NEVEN replies that this information appears in the figures from the import/export balance.
Mr NEVEN presents the achievements and work progress for Task 3.4 – Modelling of perturbations of the food market (see copy of the slides in annex).
Ms WUSTENBERGHS asks if the model is going to be an equilibrium model. Mr NEVEN replies that the model will integrate what comes in and out of the food market, including quotas and prices. Ms WUSTENBERGHS says some of her colleagues from ILVO have modelled the sugar market and could therefore provide useful information on the subject.
Mr JOSSART wonders how and where to mention the references of the data used in models and stresses the importance of validating results. He then indicates the B- and C-quotas for sugar are no longer in application.

Mr PELKMANS asks about the outcome of this model. Mr NEVEN explains that the aim is to improve SPA since food market modelling was absent from the Libiofuels version of SPA. Balances between food crops will help determine the percentage used for food, feed or energy and will give an idea of the future changes in food production.
Mr PELKMANS also suggests including rapeseed into the food market model, in addition to cereals and sugar beets.
Mr DRIESEN presents the achievements and work progress for Task 3.3 – Electrical grid modelling (see copy of the slides in annex).
Regarding the impact of biomass on the electrical power system, Mr DRIESEN explains that there will be changes in the future in the system congestions because potential and existing biomass co-fired coal power plants are spread across the country.
Mr SQUILBIN confirms that increasing distributed generation will cause perturbation on the grid and asks about the costs of this disturbance. Mr DRIESEN replies that to answer this complicated question, the model needs to be upgraded. Only general figures are available, such as foreseen investments in the distribution grid. It is however unknown who would bear individual investments: the final consumer or the installer?
Mr SQUILBIN remarks that 99% of the local production is self-consumed, so the impact on the grid should not be so high. This also permits to reduce losses. This is true but Mr DRIESEN recalls that the grid is dimensioned for the worst case scenario and it is therefore worth studying dynamic effects. In practice, simulations often foresee a rise in losses because the current increases. There is an optimum but it is difficult to control what people produce.
Mr SQUILBIN asks whether it is possible to have a clear view of the perturbation on the Belgian grid because of bioenergy use. Mr DRIESEN replies that currently there are overloads everywhere because of the multiplication of small CHP plants.
Regarding slide 68 and the possible future use of units of Amercoeur, Monceau and Kallo for biomass co-combustion, Mr DELINCE had sent comments by email. Monceau is a 125 MW coal-fired unit that has been "permanently" stopped since September 2006. Considering its high number of operating hours (all similar units are already out of order or their stop is planned) its restart requires huge investments. Constructed in the 70's Kallo units 1 and 2 are designed to be fired indifferently with natural gas or heavy fuel but they use mainly natural gas. Converting them to coal or biomass is technically feasible but again would require important investments. This retrofitting has been done previously on similar but more recent units. The coal-fired unit of Amercoeur is still in usage and seems the only serious candidate to use biomass. This information should however be validated with Electrabel.
Regarding possible scenarios of biomass use and electricity prices evolution (see slide 69), the baseline scenario is 2005 and the timescale is 2010. Mr PERRIN proposes extending timescale to 2020.
For reasons of clarity, Mr SQUILBIN suggests to add biomass shares for co-fired coal power plants on slide 68 (only renewable installed capacity is mentioned so far).
Mr SQUILBIN also asks about the impact of biomass use on the grid at this level. Mr DRIESEN replies that ranking between power plants shifts because production varies but also because of Green Certificates, $CO_2$ permits, etc.
Mr JOSSART asks if it is possible to make concrete recommendations to policy makers about the increase in bioenergy use. Mr DRIESEN says that their work on modelling starts from current power plants, taking their lifetime into account, and then possible new plants will be considered, such as biodiesel power plants, through the optimisation of the software. This will help ranking based on marginal generation costs (including Green Certificates).
Mr SQUILIBIN proposes using CWaPE assumptions based on different scenarios, considering decisions regarding electricity generation have been taken until around 2012.
Ms FIERENS also advises consulting another Science Policy project, making such assumptions based on the Plan Bureau (VITO, KUL are involved).

### 7.2.5. Questions and discussion

The floor is open to discussion.
The consortium asks the Follow-up Committee to validate the reorientation of the work towards studying sustainability criteria for biomass and bioenergy. The Committee members agree.
Mr PELKMANS adds that a PhD thesis has been started in VITO on the same subject and that exchanges could be fruitful.

### 7.2.6. Next Follow-Up Committee meeting

The next Follow-Up Committee meeting will be held in June 2008, before the evaluation of the first phase of the project.

## 7.3. 3RD FOLLOW-UP COMMITTEE MEETING (12 SEPTEMBER 2008)

Present: Igor STRUYF (Belspo), Gaëlle WARNANT (Agrobiopôle wallon), Luc Pelkmans (VITO), Jean-Marie Delincé (Elia), Annick CASTIAUX (FUNDP), Jacques DE RUYCK (VUB), Svend BRAM (VUB), David BEKAERT (KUL), Yves SCHENKEL (CRA-W), Florence VAN STAPPEN (CRA-W).

Apologies for absence: Charles DEBOUCHE (FUSAGx), Didier MARCHAL (ValBiom), Marie SCHIPPERS (DGTRE), Olivier SQUILBIN (CWaPE), Dirk Van Gijseghem (Departement Landbouw en Visserij), Bart Vleeschouwers (Boerenbond), Isabelle BROSE (FUNDP), Johan DRIESEN (KUL).

### 7.3.1. Foreword

This 3rd meeting of the Follow-up Committee of TEXBIAG is the opportunity to present the reports delivered in June, just before the first phase evaluation report. The following deliverables were sent to the Committee members in advance:

- D2 + D5 – Critical review of existing studies and models on environmental and socio-economic impacts of bioenergy, and their monetization;
- D3 – Logistics of biomass supply chain from agriculture: main existing studies;
- D6 – Consolidated list of indicators to be used to build the qualitative model;
- D8 – Animal feed modelling;
- D9 – Refinery modelling;
- D11 – Food market modelling;
- D26 – Sustainability criteria and certification systems for biomass and bioenergy: State-of-the-art and propositions in the Belgian context.

### 7.3.2. Work progress of Task 1 – Database construction and Task 4 – Results dissemination and valorisation by CRA-W

Mrs VAN STAPPEN presents the work progress of Task 1 – Database construction (see copy of the slides in annex).
The database is going to be displayed in a matrix with bioenergy chain steps in lines and inputs and outputs in columns. The filling of the database is to be automated, in order to save time and to avoid the risk of error, in collaboration with VUB, in particular with the people working on BIOSES.
Regarding the main initiatives presented in D26, Mr Pelkmans points out that since the study of the Biomass Technology Group was commissioned by DG TREN it should be considered as a European initiative.
In the summary of the characteristics of the main initiatives, Mr Pelkmans reminds that the Cramer Commission (the Dutch initiative) chose, in their GHG calculation methodology, to allocate the co-products according to their energy content because this was the solution favoured by the EC.
Concerning the bioenergy chains selected by the different initiatives, Mr Pelkmans believes the "Nesté Oil Process" can be assimilated to a "hydrogenated oil" process.
Mr Pelkmans also wonders whether it is reasonable to take into account bioenergy chains such as Pure Plant Oil (PPO) from used oils, palm oil, soybean oil, etc. Mr Schenkel replies that these chains are proposed in order to take into account what is happening in other countries but, since the project has to focus on most important bioenergy chains, PPO, because of its high price compared to biodiesel, will probably remain a secondary choice. Mr Schenkel also underlines that all biomass uses (not biofuels only) must be considered to make them comparable.
Mr Pelkmans suggests trying to take part to the CEN working group CEN/TC 383 on "Sustainability criteria for biomass", who plans to produce a first draft by the end of the year.

Regarding the propositions made in the Belgian context, Mr Pelkmans wonders how far Belgium can go since the European Commission prepares a new RES Directive and Fuel Quality Directive that overrule national regulations. Mrs Van Stappen reminds that this report was originally commissioned by SPF Environment in order to give them ideas and arguments to defend the Belgian position in the European negotiations. This report can therefore be helpful to prepare the future and influence the evolution on this topic.
Regarding Task 4 – Results dissemination and valorisation, the leaflet has been printed (1000 copies). This first version presents the objectives and methodology of the project. A new version with first results is planned for the end of the first phase of the project.

### 7.3.3. Work progress of Task 2 – Externalities monetization model by FUNDP

Ms Castiaux presents the achievements and tasks in progress for Task 2 – Externalities monetization model (see copy of the slides in annex).
The joined report D2 + D5 is presented.
Based on existing initiatives, D6 considers quantitative indicators when possible and/or qualitative indicators. A table will gather quantitative and qualitative indicators and monetization methodologies for environmental and socio-economic externalities of each selected bioenergy route.

### 7.3.4. Work progress of Task 3 – Policy prediction tool by VUB and KUL

Mr BRAM presents the report D8 for Task 3.1 – Modelling of non-linear perturbations of the animal feed market (see copy of the slides in annex).
The model was discussed with ILVO. ILVO acknowledged that the mathematical technique of the model (linear programming) is also used by animal feed mixers/producers. The model now needs to be completed with missing data for some resources (wheat DDGS, synthetic lysine, additives, amino acids, etc.) and validated with animal feed mixers/producers and software makers.
Mr BRAM presents the report D9 for Task 3.2 – Modelling of non-linear perturbations of the refineries (see copy of the slides in annex).
Locally produced biofuels introduced on the Belgian market will replace the most expensive diesel. Mr BRAM assumes this diesel is the imported diesel, which is confirmed by the Committee members.
Mr BRAM presents the report D11 for Task 3.4 – Modelling of perturbations of the food market (see copy of the slides in annex).
Mr BRAM and Mr DE RUYCK confirm that the SPA model is flexible and can evolve with science progress. New routes and specific externalities (such as indirect land-use change) can easily be added if data is available.
Mr BEKAERT presents the evolutions of the model for Task 3.3 – Electrical grid modelling (see copy of the slides in annex). The model is now operational; it only requires calibration and simulations.
As settled previously, the model is limited to the transmission level, and does not consider the distribution level. It is constructed to answer the question: "What happened if a biomass plant injects electricity on the grid?". As said before no difference will be recorded under 50 MW. Since bioenergy plant are never that big, the model will have to assume that several units are implemented together.
Mr BEKAERT adds that indirect effects on the grid (such as losses) are considered too.
Mr PELKMANS underlines that some potential bio-electricity producers do not get a licence because the grid has not the sufficient capacity. Does the model look at that? Mr BEKAERT replies the model considers the price of building a new line and whether it is interesting or not.
Since the modelling so far is spread over 1 year, Mr Delincé wonders how it is possible to take a decision when the lifetime of a new line is 20 years. Mr BEKAERT replies that they consider first what will happen on existing grid but that connection lines investment should be considered also.
Mr Delincé also stresses that the location point of the injection on the grid is crucial: depending on the grid shape it may be beneficial for one region and not for another.
KUL and VUB will try to define some typical cases of distribution grids where bioenergy plants can be added.
Another solution is to work with a theoretical network and imagine different saturation issues.

#### 7.3.5. Questions of the experts for the evaluation of the first phase of the project

The evaluation report for the first phase of the project has been submitted in July and questions of the experts evaluating the progress of the project have been sent to the partners.
The project will be defended during a panel meeting on September 30th. In preparation of this meeting, the partners present the questions received and discuss the possible answers with the Committee members.
It is agreed that project management meetings between the partners of TEXBIAG and BIOSES are beneficial and should take place on a regular basis.

#### 7.3.6. Next Follow-Up Committee meeting

The next Follow-Up Committee meeting will be held beginning of 2009.

### 7.4. 4TH FOLLOW-UP COMMITTEE MEETING (20 MARCH 2009)

Present: Igor STRUYF (Belspo), Jean-Marie Delincé (Elia), Leen GORISSEN (VITO), Elsy LIEVENS (UCL), Lara MERTENS (UCL), Olivier SQUILBIN (CWaPE), Gaëlle WARNANT (Agrobiopôle wallon), Hilde WUSTENBERGHS (ILVO), David BEKAERT (KUL), Isabelle BROSE (FUNDP), Svend BRAM (VUB), Annick CASTIAUX (FUNDP), Frank DELATTIN (VUB), Jacques DE RUYCK (VUB), Yves SCHENKEL (CRAW), Florence VAN STAPPEN (CRAW).

Apologies for absence: Charles DEBOUCHE (FUSAGx), Jean-Marc JOSSART (UCL), Jean-Louis NIZET (FPB), Luc Pelkmans (VITO), Nora PIERET (ValBiom), Marie SCHIPPERS (DGTRE), Dirk Van Gijseghem (Departement Landbouw en Visserij), Bart Vleeschouwers (Boerenbond), Johan DRIESEN (KUL).

#### 7.4.1. Tour de table

Each participant briefly presents him/herself.

#### 7.4.2. Work progress of Task 1 – Database construction by CRA-W

Mrs VAN STAPPEN presents the work progress of Task 1 – Database construction (see copy of the slides in annex).
The data extraction from the EcoInvent database is in the process of being fully automated via Matlab. It is therefore possible to directly extract raw data or life cycle inventory (LCI) data for any bioenergy chain.
Mrs VAN STAPPEN also makes a review of new developments regarding sustainability initiatives since the last Follow-up committee meeting (updated D26).
Based on studied methodologies TEXBIAG proposes a GHG (and other externalities) calculation methodology using EcoInvent data adapted to the Belgian context (especially regarding region specific crop cultivation).
Regarding the selection of bioenergy chains relevant for the Belgian market, an enquiry will be sent to FUC members in order to ask them their opinion (selected bioenergy chains should be studied in priority by the project).
Mr SQUILBIN asks whether partners of the TEXBIAG project take part to the standardisation technical committee CEN/TC 383 "Sustainably produced biomass for energy applications". Indeed the partners participate to the working groups:

- WG 1: Terminology & cross-cutting issues (Y. Schenkel)
- WG 2: GHG emissions balance, calculations, fossil fuel balance (F. Van Stappen)
- WG 3: Biodiversity & environmental issues (F. Van Stappen)
- WG 4: Economic & social aspects (I. Brose & Y. Schenkel)
- WG 5: Verification & auditing (I. Brose)
- WG 6: Indirect effects (F. Van Stappen)

Feedback from these working groups will be given in the framework of the project.
Mr SQUILBIN suggests comparing the methodology developed by the project (especially regarding GHG calculation) with those already under operation, such as the "$CO_2$ tools" developed by SenterNovem in the Netherlands (based on the work of the Cramer Commission). Since these operational tools are going to be used for GHG balance calculation by private companies, such as Electrabel, it would be highly interesting to be able to weigh those against the TEXBIAG methodology. Thanks to the automation of the data treatment, it should be easy to compare results of different GHG calculation methodologies.
This matter will be further discussed in a future update of D26.
Additionally Mr SQUILBIN also recommends including in D26 the work carried out in the electricity sector in Belgium, such as the already well advanced methodology used for the calculation of the Green Certificates in Wallonia.

#### 7.4.3. Work progress of Task 4 – Results dissemination and valorisation by CRA-W

The TEXBIAG seminar is planned to be held according to partners' availabilities on the week of the 14th September 2009. It is proposed to hold the seminar on a morning and have the 5th Follow-up Committee meeting in the afternoon.
The provisional agenda for this seminar is the following:

1. Introduction on the SSD programme by Belspo
2. Presentation of TEXBIAG
3. Presentation of EcoInvent and other relevant databases: choice, limits, data quality, etc.
4. Bioenergy externalities and sustainability criteria, building of a qualitative model
5. Animal feed market modelling: complexity, choices, assumptions, etc.
6. Electrical grid modelling
7. Development of the SPA model
8. Panel discussion

Furthermore Mrs VAN STAPPEN summarises the conferences where the project will be presented in 2009 (oral presentations, posters and/or full papers).

#### 7.4.4. Work progress of Task 2 – Externalities monetization model by FUNDP

Ms BROSE presents the work progress for Task 2 – Externalities monetization model (see copy of the slides in annex). The qualitative model (D7) is presented.
Brainstorming sessions have to be organized on soil and water quality, on biodiversity, as well as on local prosperity. Regarding the organisation of these brainstorming sessions suggestions are welcome. Ms GORISSEN will send references regarding brainstorming topics and possible interdisciplinary participants. Ms WUSTENBERGHS also have colleagues who may be interested. All members of the Follow-up Committee are welcome to participate to these brainstorming sessions.

#### 7.4.5. Work progress of Task 3 – Policy prediction tool by VUB and KUL

Mr BEKAERT presents the work progress of Task 3.3 – Electrical grid modelling (see copy of the slides in annex) and Deliverable 10 "Modelling of non-linear perturbations of the electrical grid".
Three types of simulations are made:

- Must-run scenarios
- Varying prices scenarios
- Co-firing scenarios

Mr Delincé suggests modifying the title into "Modelling of non-linear perturbations of the electrical system" since it is more modelling of generation systems then grid. Indeed Mr BEKAERT confirms that since the simulated scenarios only contain small changes, no detailed grid data was taken into account.
Mr SQUILBIN advises asking Electrabel (see Mr Ryckmans) for more accurate information on biomass co-firing; the percentage of biomass co-fired in coal power plants in Belgium is higher than in the simulations.
Mr SQUILBIN also recommends taking into account the influence of the Green Certificates systems.

Different members (MM. DE RUYCK and SQUILBIN) point out that in practice the biomass generation units will be connected to the lower voltage grids and not to the high voltage grid.. Mr BEKAERT argues that the impact on the system will be the same if it comes from high or low voltage. It is very difficult to analyse the impact of biomass generation on the medium voltage grids. Mr. DELINCE informs the committee that a research project funded by the European Commission has tried to give an answer to this question: it is the EU-DEEP project where KUL was also a partner.
In conclusion, simulating the effect on generation systems of the introduction of biomass systems is a very complex and sensitive matter, with a lot of assumptions linked to local conditions. 2 or 3 scenarios should be defined in order to keep awareness of this sensitivity.
Mr DELATTIN presents the work progress of Task 3.5 "Modelling of technology routes not yet considered" (see copy of the slides in annex) and Deliverable 12 "Additional conversion routes".
This deliverables aims at collecting data to assess the impact of new technology routes commercially available and introduce them in SPA. The 3 missing technology chains addressed are production of hydrogen, DME from biomass and biogas from biowaste.

#### 7.4.6. Next Follow-Up Committee meeting

The next Follow-Up Committee meeting will be held in September 2009, jointly with the TEXBIAG seminar.

### 7.5. 5TH FOLLOW-UP COMMITTEE MEETING (17 SEPTEMBER 2009)

Present: Igor STRUYF (Belspo), Jean-Marie Delincé (Elia), Leen GORISSEN (VITO), Carole PISULA (SPW-Département de l'Energie), Marie SCHIPPERS (SPW-Département de l'Energie), Olivier SQUILBIN (CWaPE), Chrystelle VERHOEST (Laborelec), Bart Vleeschouwers (Boerenbond), Gaëlle WARNANT (Agrobiopôle wallon), Hilde WUSTENBERGHS (ILVO), Isabelle BROSE (FUNDP), Svend BRAM (VUB), Yves SCHENKEL (CRAW), Florence VAN STAPPEN (CRAW).

Apologies for absence: Charles DEBOUCHE (FUSAGx), Michel DEGAILLIER (SPF Environment), Jean-Marc JOSSART (UCL), Luc Pelkmans (VITO), Nora PIERET (ValBiom), Yves Ryckmans (Laborelec), David BEKAERT (KUL), Annick CASTIAUX (FUNDP), Frank DELATTIN (VUB), Jacques DE RUYCK (VUB), Johan DRIESEN (KUL).

#### 1. Context

This Follow-Up Committee meeting follows the TEXBIAG seminar held in the morning and aims at answering two questions:

1. Does the Follow-up Committee think that the work achieved by TEXBIAG is progressing in the right direction?
2. What does the Follow-up Committee think of the TEXBIAG seminar and what remarks of the attendees do they think important to take into account?

#### 2. Reactions and comments

The Follow-up Committee approves the work progress of the project.
Mr SQUILBIN would like to know more about the practical use of the tools developed by TEXBIAG, in comparison with existing tools such as the Dutch '$CO_2$ tools' and with regards to the requirements of the Renewable Energy Directive.
Mr SCHENKEL confirms that the TEXBIAG tools need to be compatible with the RED but go beyond the sustainability requirements found in the Directive.
Besides, Mr SCHENKEL recalls the opportunity of validating bioenergy in the Belgian context in order to have them introduced and available in the EcoInvent database. Ms VERHOEST points out that the EcoInvent database does not always content accurate data regarding the geographic context.

She underlines the difficulty of translating data to specific cases, especially regarding consistency in data quality and uncertainty assessment. Furthermore as regards with the differences between global versus local impacts, she evokes the complexity to attribute global impacts to one's responsibility.
Mr VLEESCHOUWERS wonders whether SPA model takes into account price variations, such as prices of fossil energy, biomass or land. Mr BRAM replies that SPA does not include price effects because of the difficulty to model market prices. Mr VLEESCHOUWERS maintains that political decisions are also based on the market and a complete decision tool should include all factors. Since Mr BRAM reminds that TEXBIAG develops decision-making tools based on impacts (externalities), Mr VLEESCHOUWERS advises that final reports underline that other important aspects such as market prices are not included and should be accounted for.
Ms VERHOEST asks about the unit used for monetization. Is it in the form of a tax? Ms BROSE replies that no, monetary values are expressed in costs for damages e.g. per ton of $CO_2$eq and are not based on the $CO_2$ market.
Ms WUSTENBERGHS points out that there are costs from a lot of different sources. Ms BROSE agrees but she insists on the time constraint and recalls that existing studies or projects propose figures that can support our monetization effort.