Bioenergy for Europe: Which ones fit best?

- A comparative analysis for the Community -

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Final report – *External Annex*

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The Research Group

J. Calzoni[d], N. Caspersen[i], N. Dercas[c], G. Gaillard[e], G. Gosse[h], M. Hanegraaf[b], L. Heinzer[f], N. Jungk[g], A. Kool[b], G. Korsuize[g], M. Lechner[a], B. Leviel[h], R. Neumayr[a], A. M. Nielsen[i], P. H. Nielsen[i], A. Nikolaou[c], C. Panoutsou[c], A. Panvini[d], A. Patyk[g], J. Rathbauer[a], G. A. Reinhardt[g], G. Riva[d], E. Smedile[d], C. Stettler[f], B. Pedersen Weidema[i], M. Wörgetter[a], H. van Zeijts[b]

[a] BLT – Bundesanstalt für Landtechnik (Austria)

[b] CLM – Centrum voor Landbouw en Milieu (Netherlands)

[c] CRES – Centre for Renewable Energy Sources (Greece)

[d] CTI – Comitato Thermotecnico Italiano (Italy)

[e] FAL – Eidgenössische Forschungsanstalt für Agrarökologie und Landbau (Switzerland)

[f] FAT – Eidgenössische Forschungsanstalt für Agrarwirtschaft und Landtechnik (Switzerland)

[g] IFEU – Institut für Energie- und Umweltforschung Heidelberg (Germany); Project Co-ordinator

[h] INRA – Institut National de la Recherche Agronomique (France)

[i] TUD – Technical University of Denmark (Denmark)

Project co-ordinators

A. Patyk, G. A. Reinhardt
IFEU – Institut für Energie- und Umweltforschung Heidelberg GmbH
(Institute for Energy and Environmental Research Heidelberg)
Wilckensstrasse 3, D – 69120 Heidelberg, Germany
Tel: +49-6221-4767-0, Fax -19
E-Mail: andreas.patyk@ifeu.de, guido.reinhardt@ifeu.de

Content

Annex to Chapter 3

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1 Goals of the biofit study

Final version

1. Objectives stated in the Technical Annex

To produce at the European level an environment related decision base regarding the promotion of biofuels in the Community and

1. To show the environmental advantages and disadvantages of the different biofuels in the different countries compared to fossil fuels with help of the LCA
2. To make comparisons between countries for each biofuel
3. To make comparisons between biofuels in each country
4. To point out the most favourable biofuels in each country with help of the LCA and a socio-economic, political and legal analysis

2. Results of the discussion in chronological order

Minutes from Heidelberg

- Main objective: Establish an environment related decision base for the development of biofuels from agriculture and forestry
- Sub-objectives: To establish a clear methodology based on LCA

  To establish a co-ordinated data bank

  To show environmental advantages and disadvantages of selected life cycles of biofuels compared to life cycles of fossil fuels

  To carry out an overall assessment of the selected biofuels regarding social, economic, political and legal aspects

  To select the most suitable biofuels in each country

Questionnaire from IFEU (summarised)

According to the project group, following questions should be answered:

- How much fossil energy can be saved with biofuels?
- What are the environmental impacts of biofuels and fossil fuels?
- How much CO2 can be saved with biofuels and what are the costs?
- Is it better to cultivate biofuels or other non-food crops on agricultural land?
- Which biofuels shall be promoted?

The answers should be given for each biofuel and each country individually so that comparisons can be made.

Minutes from Copenhagen

Specification for the objective ''to show the environmental advantages and disadvantages of the biofuels compared to fossil fuels'':

- Focus on the comparisons of energy carriers
- Answer the question whether it makes sense to produce biofuels and if so, which ones are the best (considering also the impacts on the agricultural system) and what differences there are between the different countries in this respect, under the condition that the combustion of fossil fuels should be replaced.
- Assessment of the environmental benefits of replacing fossil fuels by combustion of residues from agriculture and forestry

3. State of the discussion

The discussion of the goals did not bring anything different compared to the objectives stated in the TA. All the points from the TA turn up again and differ only in the level of detail and in the wording. This implies that the objectives of the TA are chosen well and still valid. The only task in this draft now is to find an appropriate level of detail and wording.

4. Proposal

The objective of the project is to establish an environment related decision base for the promotion of biofuels from agriculture and forestry in the European Union and in each participating country. The target group consists of the European Commission Directorates and the national ministries for Environment, Energy and Agriculture. The study is designed to help this target group to decide about their future policy concerning biofuels.

This decision base for the target group consists of

i) An LCA-methodology and data for biofuels according to ISO 14040 - 14043. It allows to show the different environmental impacts from each biofuel compared to the corresponding fossil fuel (including the alternative land use or the alternative biomass use). The results will tell in each case if it makes sense from the environmental point of view to replace fossil fuels with biofuels or not and enables to select the most environmental friendly energy carrier for a given purpose. The impacts on biodiversity and physical soil quality shall be included in the LCA.

ii) The comparisons between the countries for each specific biofuel. They show which country is suited most for a specific biofuel from the environmental point of view. The results will also help to point out the most environmental friendly technology to produce a specific biofuel. From this result it can be seen if the promotion of a biofuel in the European Union shall depend on the country and on the technology or not.

iii) The comparisons between the biofuels in each country and in the EU. They allow the national ministries and the European directorates to find out the most ecological biofuel for either

 a) producing heat, electricity or fuel for Otto and Diesel engines in each country and in the EU; or

b) making most efficient use of the available land; or

c) saving the biggest amount of fossil fuels.

i) An analysis of economic, social, political and legal aspects of each biofuel including the impacts on landscape and land availability in comparison to fossil fuels. The analysis of the impacts of biofuels on these additional aspects is an important decision factor for the target group.

ii) The overall assessment. With help of the LCA-comparisons and the analysed aspects in iv) it will be possible to point out the most favourable biofuel for each purpose at European level and in each country .

FAT, 24 November 1999, Lena Heinzer

2 Functions of the product systems

Final version

1. Requirements of the ISO norms

The ISO-norms 14'040 and 14'041 set following requirements on defining the functions of an LCA and on their role in an LCA study:

Definition of a function: ”Performance of a product system in a life cycle assessment”.

Art. 5.1.2.1, ISO-norm 14’040: ”The scope of an LCA study shall clearly specify the functions of the system being studied”. [...] A system may have a number of possible functions and the one selected for a study is dependent on the goals and scope of the study”.

Art. 5.1.2.4, ISO-norm 14’040: ”In comparative studies, the equivalence of the systems being compared shall be evaluated before interpreting the results. Systems shall be compared using the same functional unit and equivalent methodological considerations such as performance [...].”

Art. 5.3.2, ISO-norm 14'041: ”The [function] shall be consistent with the goal and scope of the study.”

Art. 5.3.2, ISO-norm 14'041: ”If additional functions of any of the systems are not taken into account in the comparison of the [functions], these omissions shall be documented. For example, systems A and B perform functions x and y which are represented by the selected functional unit, but system A also performs function z, which is not represented in the functional unit. It shall be documented that function z is excluded from this functional unit. As an alternative, systems associated with the delivery of function z may be added to the boundary of system B to make the systems more comparable. In these cases, the processes selected shall be documented and justified”.

2. Background

Since agriculture is multi-purpose its products can fulfil several functions. Following criteria were considered in order to determine the functions relevant in this project:

- Goals and scope of the study
- Motivation of the target groups when promoting bioenergy chains
- Motivation of the direct actors when implementing bioenergy chains.

According to the technical annex and in confirmation with the paper ‘Life cycles under study’ from BLT (31-05-1999) the most important function of the investigated product systems is ‘providing useful energy’. This means that the product systems have to be analysed from the point of view of this use. This function implies the comparison with fossil fuels and is the main reason for the interest of the target groups coming from the field of energy and environment..

The function ‘treatment of agricultural and forestry residues’ is relevant because biofuel production not only provides energy but also makes significant changes to the considered biomass (combustion, fermentation). Moreover, a higher real net output for the farmer is possible in many cases or he has less problems with a residue. Due to this function we include the alternative way of handling the biomass in the comparison as well.

The functions ‘preservation of land under agricultural practice and maintaining rural income and regulating market prices for agricultural food products’ was chosen from the farmers and agricultural sectors view. Due to surpluses there is a high pressure on prices of food products. Farmers are looking for new income sources which have to be as ecological as possible to be accepted by society. The soil must remain able to produce food crops again if needed. Energy crops fulfil this function. That is why the target group ‘agricultural ministries’ are interested in our study.

3. State of the Discussion

After previous drafts and discussions the project team decided in Copenhagen to go back to the proposals made by FAT earlier on. The function of energy production shall be put in the foreground (functional unit), the aspects of agriculture are secondary.

4. Functions of the product systems

Main function: Provision of useful energy

Biofuels concerned: All

The product systems have a number of secondary functions. Some of these are dealt with under subtask 1.1 (Allocation), while the following three are dealt with by including the agricultural reference systems described in subtask 1.2:

- Treatment of agricultural and forestry residue
- Preservation of land under agricultural practice
- Maintaining rural income and regulating market prices for agricultural food products

The economic aspects of these secondary functions are dealt with by including the effects in task 3.

FAT, 24 November 1999, Lena Heinzer

3 Functional unit

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1 Requirements of the norms

- ISO 14040, definitions §3.5: ''Functional unit: Quantified performance of a product system for use as a reference unit in a life cycle assessment study.''
- ISO 14040, §5.1.2.1: [...] ''The primary purpose of a functional unit is to provide a reference to which the inputs and outputs are related. This reference is necessary to ensure comparability of LCA results.'' [...]
- ISO 14040 §5.1.2.4: [...] ''Systems shall be compared using the same functional unit and equivalent methodological considerations'' [...]
- ISO 14041 §5.3.2: [...]''The functional unit defines the quantification of these identified functions. [...] If additional functions of any of the systems are not taken into account in the comparison of the functional units, then these omissions shall be documented.''[...]

2 Functional unit for each bioenergy-chain

The chosen functional unit for all biofuels is '1 MJ useful energy' for following reasons:

- The main interest of the target groups in the biofuels is their energy production(see minutes from Copenhagen and final draft 'Functions of the product systems').
- An LCA according to ISO 14040 ff. covers the life cycle of a product system from cradle to grave.
- The description of the product systems (BLT-paper from July 1999) includes also the consumption (e.g. combustion) of the biofuels.
- Useful energy is available for the respective purpose for the end-user after the last conversion. This is the technical form of energy which the consumer requires for the respective purpose, heat, mechanical energy, light, useful electricity and electromagnetic radiation.(VDI-Richtlinien 4600)

Bioenergy-chain		**Functional unit**
Chain 1	Triticale, co-firing for electricity	1 MJ electricity
Chain 2	Rape for FAME	1 MJ mechanical work (Diesel engine)
Chain 3	Sunflower for FAME	1 MJ mechanical work (Diesel engine)
Chain 4	Sugar beet for ETBE	1 MJ mechanical work (Otto engine)
Chain 5	Miscanthus for district heating	1 MJ heat
Chain 6	SRF for district heating	1 MJ heat
Chain 7	Traditional firewood for residential heating	1 MJ heat

Chain 8	Swine excrements for CHP	MJ 1 electricity/heat
Chain 9	Wheat straw for district heating	1 MJ heat
Chain 10	Wood from forestry for electricity	1 MJ electricity
Chain 11	Lignocellulose for ETBE	1 MJ mechanical work (Otto engine)
Chain 12	Hemp for electricity	1 MJ electricity

3. Comparison of the selected functional unit with the norms

- ISO 14040 §3.5 and ISO 14041 §5.3.2:

  Per definition, the functional unit shall quantify the functions of the system. The functional unit chosen takes into account the energy production. The agricultural land and biomass related function is not considered in the functional unit.

- ISO 14040 §5.1.2.1

  The reference for all inputs and outputs is ensured.

- ISO 14040 §1.2.4

  With the chosen functional units following comparisons can be made:

  Between chain 1, 8, 10 and 12, between chain 2 and 3, between 4 and 11, between chain 5, 6, 7 and 9. Only comparisons between chains with the same end use are valid.

- ISO 14041 §5.3.2

  Although all systems have an additional function not taken into account by the chosen functional unit (namely ‘preservation of agricultural land and improvement of the economic situation on the arable food market’ and ‘recovery of biomass form coupled products and residues’, respectively), no special documentation is needed, because these secondary functions are considered in the calculations with the choice of the reference systems (‘fallow’ and ‘alternative use of biomass from coupled products and residues’, respectively).

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[1] The ratio between electricity and heat in the output depends on the installation/technique and can not be specified yet.

4 Allocation procedures

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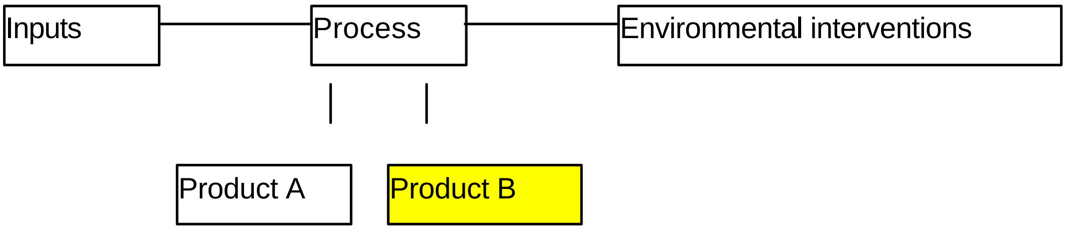
1 Allocation

The aim of allocation is to show to which extent a product of a multi-output process is responsible for the total of the environmental interventions of this process.



2 Requirements of the norms

- ISO 14041 § 5.3.3 [...] Resources need not be expended on the quantification of such inputs and outputs that will not significantly change the overall conclusions of the study. [...]
- ISO 14040 § 5.2.2: 'Allocation procedures are needed when dealing with systems involving multiple products [...]. The materials and flows as well as associated environmental releases shall be allocated to the different products according to clearly stated procedures, which shall be documented and justified.'
- ISO 14041 § 6.5.2 [...] 'The study shall identify the processes shared with other product systems [...]. The sum of allocated inputs and outputs of a unit process shall equal the unallocated inputs and outputs of the unit process. Whenever several alternative allocation procedures seem applicable, a sensitivity analyses shall be conducted to illustrate the consequences of the departure from the selected approach.'
- ISO 14041 § 6.5.3

  Step 1: 'Wherever possible, allocation should be avoided by:1) dividing the unit process to be allocated into two or more sub-processes and collecting the input and output data related to these sub-processes 2) expanding the product system to include the additional functions related to the co-products, taking into account the requirements of 5.3.2.

  Step 2: Where allocation cannot be avoided, the inputs and outputs of the system should be partitioned between its different products of functions in a way which reflects the underlying physical relationship between them; i.e. they shall reflect the way in which the inputs and outputs are changed by quantitative changes in the products or functions delivered by the system. [...]

Step 3: Where physical relationship alone cannot be established or used as the basis for allocation, the inputs should be allocated between the products and functions in a way which reflects other relationships between them. For example, input and output data might be allocated between co-products in proportion to the economic value of the products.'

- ISO 14041 § 6.5.4 [...] ' 6.5.2 and 6.5.3 also apply to reuse and recycling situations.

3 Task to perform

a) Identify the processes where allocation procedures are needed.

b) Avoid allocation.

c) If avoidance is not possible, perform system expansion.

d) If system expansion is not possible, allocation according to physical relation shall be made.

e) If allocation according physical relation is not possible, allocation according to other relationship shall be performed.

a) Unit processes where allocation procedures are needed

(based on the description of the life cycles from BLT from July 1999)

Coupled products not under study, respectively secondary functions of the biofuels not considered in the reference system:

- extracted rape meal (chain 2),
- P-fertiliser (chain 2, 3)
- glycerine (chain 2, 3),
- extracted sunflower meal (chain 3)
- sugar beet pulp (chain 5)
- vinasses from sugar beet (chain 5),

Coupled products under study:

- traditional firewood (chain 7)
- wheat straw (chain 9)

Special inputs from other systems:

- liquid swine manure for biogas (chain 8)

Inputs shared between several systems:

- machinery (all chains),
- buildings (all chains)

Notes:

- Waste disposal (e.g. landfilling of ash) is included in the product system (ISO 14041, Fig. 1)

- No allocation is needed for mineral fertilisers. This is due to the fact that only the actual nutrient requirement of the plant is considered. If the official recommendations in handbooks and consequently the applied amount of fertiliser are higher, the benefits (e.g. crop residues) for the next crop have to be taken into account.

Following plant available nutrient contents in percentages for fresh residues can be used (FAL, RAC, 1994):

Rape straw:	0 N	0.35 P2O5	1.6 K2O	0.15 Mg
Sunflower stalks:	0 N	0.26 P2O5	6.2 K2O	0.75 Mg
Sugar beet leaves with heads:	0.04 N	0.08 P2O5	5.4 K2O	0.07 Mg

b) Avoiding allocation

Further division into sub-processes than already done in the description from BLT (19 April and 28 May 1999) is not possible. Although ISO 14040 states that the whole life cycle shall be studied, it is however possible to avoid allocation by omitting certain stages of the life cycle if this is documented and if this does not change the outcome (ISO 14041 § 5.3.3). FAT suggests to leave out those unit processes that are exactly in the same quality and quantity in both the energy chain and the reference system. This allows us to avoid allocation.

- Allocation between traditional firewood and the products not under study (recreation, protection, conservation, forest residues and wood for construction) in chain 1 is not necessary. The products not under study as well as the unit processes 'forest establishment and maintenance' and 'felling and debranching' occur both in the bioenergy chain and in the reference system with decay in the forest. They can be subtracted from both systems without changing the results of the study and need not be analysed.
- Allocation between wheat straw and grain in chain 5 is not necessary. The product not under study 'grain' as well as the unit processes 'wheat growing'' and 'harvest' occur both in the bioenergy chain and in the reference system with incorporation of straw into the soil. They can be subtracted from both systems without changing the results of the study and need not be analysed.
- Allocation between liquid swine manure and the products from livestock keeping is not necessary. The unit process liquid manure occurs both in the bioenergy chain and in the reference system with spraying directly on the field. It can be subtracted from both systems without changing the results of the study and needs not be analysed. It is assumed that the module spraying can not be subtracted since biogas-treated slurry has changed its properties (less organic matter, less smell, less harm to plants) and produces therefore not the same emissions as the untreated liquid manure.
- For other unit processes allocation can not be avoided.

c) System expansion

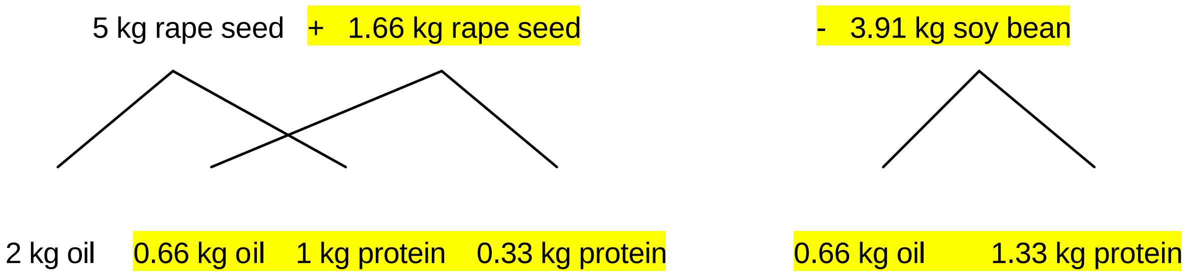
The fate of the coupled product in question must be considered. The same rules as for the selection of the reference system have to be applied (ISO 14041 §5.3.2) The amount of environmental interventions from the alternative product (which does not need to be produced due to the production of the coupled product) is assumed to be equivalent to those of the coupled product itself.

- Glycerine (chain 2 and 3) is sold to the industry. A system expansion with petrochemically produced glycerine is suggested (Reinhardt and Zemanek, 1998) on the basis of litre (with the same water content).
- For P-fertiliser, a co-product from the transesterification (chain 2, 3) we suggest to make a system expansion with mineral fertiliser on the basis of the plant available nutrient content.
- Extracted rape meal (chain 2) is used as protein component in livestock feed. Therefore, a system expansion with soy meal is realistic. In the procedure described below (Weidema, 1999) no more allocation between soy meal and its by-product soy oil is needed. The system expansion is based on the preconditions that

a) soy meal is the marginal protein fodder and rape oil is the marginal edible oil on the market

b) rape seed contains 40% oil and 20% raw protein in the dry matter and that soy bean contains 17% oil and 34% raw protein in the dry matter

c) the raw protein and the oil in both rape seed and soy bean are substitutable in the marginal application



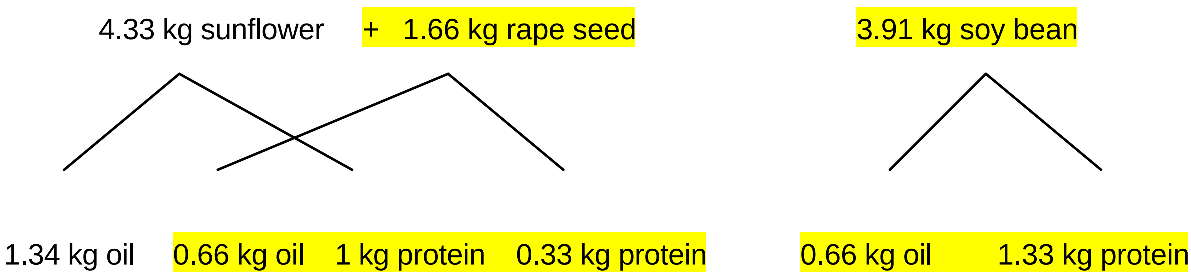
Per 5 kg rape seed produced in chain 2, there has to be accounted an additional production of 1.66 kg rape seed. Then a system expansion with 3.91 kg soy bean can be made in order to calculate the share of emissions from the original rape meal (1 kg protein) and the additional 1.66 kg rape seed. The soy oil and soy meal production has to be studied until the end with the inclusion of the transport of the soy meal to Europe. For more details please see also the attached text from TUD.

- Extracted sunflower meal (chain 2) is used as protein component in livestock feed. Therefore, a system expansion with soy meal and rape seed is realistic. In the procedure described below (Weidema, 1999) no more allocation between soy meal and its by-product soy oil is needed. The system expansion is based on the assumptions that

  a) soy meal is the marginal protein fodder and rape oil is the marginal edible oil on the market

  b) rape seed contains 40% oil and 20% raw protein in the dry matter, soy bean contains 17% oil and 34% raw protein in the dry matter, sunflower contains 31% oil and 23% raw protein in the dry matter

  c) the raw protein and the oil in rape seed, soy bean and sunflower are substitutable in the marginal application



Per 4.33 kg sunflower produced in chain 3, the production of 1.66 kg of rape seed has to be added. Then a system expansion with 3.91 kg soy bean can be made in order to calculate the emissions from the sunflower meal (1 kg protein) and the additional 1.66 kg rape seed. The soy oil and soy meal production has to be studied until the end with the inclusion of the transport of the soy meal to Europe. For details on the theory please see the attached text from TUD.

- Sugar beet pulp produced in chain 5 is used as energy component in livestock feed (either dried or silaged). System expansion with barley (the marginal energy feed) on the basis of the energy content is realistic. One kg of silaged sugar beet pulp silage with 7.1 MJ NEL and 101 g absorbable protein per kg dry matter substitutes 0.96 kg barley with 7.4 MJ NEL and 99 g absorbable protein per kg dry matter (RAP, 1994) The difference in the absorbable protein content and therefore the necessary adjustment of the protein in the whole diet is assumed to be neglectable and not taken into account.
- Vinasses (leftover of the fermentation of sugar beet, official names: vinasses obtained through fermentation, vinasses from sugar beet molasses) in chain 5 is dried and can be added to the sugar beet pulp or fed in feed mixtures or spread on the field as organic fertiliser (Hansa Melasse Handelsgesellschaft, 1999, E.V.A. GmbH, 1999). The first is rarely made, the second is well possible and the third is a good option especially for ecological farming because of the many trace elements, the nutrient circle and the stimulation of soil life (Debruck and Lewicki, 1997). These side effects can not be accounted for in the LCA. A completely other option is the utilisation of vinasses for biogas production.

  As the project is focused on energy production, the utilisation of vinasses for biogas is set as a standard procedure. A system expansion with natural gas on the basis of the heating value is suggested for this.

  A sensitivity analyses with field application of vinasses can be made. For this purpose, FAT suggests to perform a system expansion with nitrogen and potash fertiliser on the basis of the plant available nutrient content. Vinasse contains 4.4 % N and 11.8 % K_2O in the dry matter (Derbuck and Lewicki, 1997).
- For other unit processes system expansion is not appropriate.

d) Allocation according to physical relationship

- For tractors, allocation according to the hours of work compared to the total work hours of life is suggested. This is very practicable although it is slightly incorrect because different use results in different wear of the machine (Audsley et al., 1996; Wolfensberger und

Dinkel, 1997). But wear depends also on the operating person, which is not easy to assess. Other machines (ploughs etc.) can be allocated according to the units worked compared to units worked during the machines life (Gaillard et al., 1997).

- For agricultural buildings allocation according to the space of the machine occupied compared to the total space of the building on the basis of machine working hours is suggested.

Formula: $\frac{\text{gem/m3} * \text{X m3}}{\text{Y years} * \text{Z h/year}} = \text{A gem/h}$

gem/m3 = grams of emissions of the building per m3
X m3 = amount of space needed for the machine
Y years = life time of the building
Z h/year = total working hours of the machine per year
A gem/h = emissions per working hour of the machine originating from the building
A gem/h * b h/ha = c gem/ha
b = (machine working hours in the biofuel chain per hectare)
c = Emissions of biofuel chain originating from the building of the machine per hectare

- For industrial buildings allocation according to the biomass processed compared to the total amount of biomass processed during the life time of the building is suggested.

Formula: $\frac{\text{gem/m3} * \text{X m3}}{\text{Y years} * \text{Z tons/year}} = \text{A gem/ton}$

gem/m3 = emissions of the building per m3
X m3 = total amount of space of the building
Y years = life time of the building
Z tons/year = amount of biomass processed in the building during one year

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FAT, 24 November 1999, Lena Heinzer

5 System expansion for protein fodder by-products

Final version

Prepared by TUD

Summary

By-products, which are used for protein fodder concentrates, will need to be balanced by a system expansion producing the same amount of protein fodder from the marginal protein source, which is soy meal. Soy meal production has a by-product soy oil, which needs to be balanced by a system expansion producing the same amount of the marginal edible oil, which is rapeseed oil. Rapeseed oil production also yields protein fodder. This means that the net system expansion as a result of the original by-product protein fodder is a combination of soybean and rapeseed production, which can be calculated from the relations between oil and protein yield from the two crops:

Soy: 0.17 kg oil and 0.34 kg raw protein per kg soybean

Rape: 0.4 kg oil and 0.2 kg raw protein per kg rapeseed

Consequently, for 1 additional amount of soy protein, half (0.17/0.34) the amount of soy oil is produced, which is then balanced by a reduction in rape oil with half (0.2/0.4) the amount of protein. The sum relation is (0.17/0.34)*(0.2/0.4) = 0.25, meaning that every additional kg of soy protein results in a reduction of 0.25 kg rape protein, which then again needs to be balanced by an increased production of soy protein.

By iteration, a net output of 1 kg raw protein is obtained by:

- an increase in output of soybean protein of 1 + 0.25 + 0.252 +0.253 + …. = 1.33 kg raw protein, equivalent to 1.33/0.34 = 3.91 kg soy beans, and
- a decrease in rapeseed output of 0.25 + 0.252 +0.253 + …. = 0.33 kg raw protein, equivalent to 1.66 kg of rapeseed.

To balance the original protein fodder by-product, the described system expansion may be applied in one of two ways:

- by adding production of 1.66 kg of rapeseed to the system with the protein fodder by-product and adding production of 3.91 kg soybean production to all other systems, thus resulting in equivalent systems all producing 1.33 kg of raw protein in addition to their main product (this could be called a complete system expansion and may be the easiest to explain),
- by adding production of 1.66 kg of rapeseed and subtracting production of 3.91 kg soybean production in the system with the protein fodder by-product, thus 'neutralising' the output of this by-product, leaving all other systems unaffected, with the result that all systems only have the main product as their output (this is the model of avoided production, which directly reflects the consequences of the changes in amounts of by-product produced, and reduces the calculations to a minimum).

If rape oil is the main product studied, and rape meal therefore the original protein fodder by-product, using the model of avoided production allows the above calculations to be normalised to the original change in rape input by the normalisation factor (1/0.2)/((1/0.2)+1.66) = 0.75

implying that 25% of the additional rape oil production must be used to balance the decrease in soy production that is the consequence of the additional rape protein placed on the market.

The above calculated marginal changes in soybean and rapeseed output is achieved by changes in the marginal fertiliser application to the two crops. Although soybeans are largely self-sufficient in nitrogen from natural fixation, some nitrogen fertiliser is used, and does have an influence on the yield. Thus, a marginal reduction in nitrogen fertiliser applied to soybeans will reduce the yield. The consequent reduction in nitrogen fertiliser production will occur in the soybean producing countries, mainly Argentina, Brazil and USA. The affected rape seed production will be in Europe, thus affecting the marginal fertiliser production in Europe.

Documentation on the determination of marginal products/technologies

The marginal protein crop can be determined from the linear regression models used by enterprises producing mixed feeds[2]. By keeping all industrial fodder by-products constant except one protein component at a time, it can be shown that a change in this one protein component will be balanced by a change in soybean input. This can be explained by the fact that soybeans is the only protein crop (aside from grains) for which the protein is the main product. Some substitution between grain and protein concentrates is possible, as determined by their relative prices. However, within the time horizon studied, the price of soybeans is expected to be well below the price of grain crops.

The marginal edible oil component can be determined from the price relations between alternative oil crops. Different oil crops are grown to obtain different fatty acid compositions and thus cannot substitute each other completely. The more expensive oil crops will be grown to the extent that there is a market demand for their specific fatty acid composition, while the remaining demand will be met by the cheapest edible oil. Under the current market conditions, rape is the cheapest edible oil with a fatty acid composition that makes it substitutable with soy oil in most applications[3].

Uncertainties in the determination of marginal products/technologies

The determination of soybean and rape as the marginal crops for oil and protein fodder is not controversial. The developments in genetic engineering are likely to enhance the competitive position of these two crops versus their alternatives (CCP 1997).

The values used for protein and oil yields in the above calculations are average values that may deviate within a few percent. A coefficient of variance of 4% on the resulting values may be applied for sensitivity analysis.

References:

CCP. (1997). Biotechnology developments in the oilseeds sector. Item II.D of the provisional agenda. Committee on Commodity Problems. Intergovernmental Group on Oilseeds, Oils and Fats. 28th Session. Rome: FAO

[2] The advice and assistance of Mikkel Overvad of Dansk Landbrugs Grovvareselskab is acknowledged.

[3] The advice of J.C. Vis of Unilever is acknowledged.

6 Choice of reference-systems and technologies

Discussion paper

February 1999, TUD

The bio-energy-systems have some inputs and outputs, which will change the use of other resources. In the following arguments are made to identify these changes, called the „marginal technology“, as precisely as possible. The arguments follow a modified version of the method proposed in an e-mail from TUD „Comments to FAT“, 14/12/1998.

Some of these arguments may seem like common sense or too rigid economic assumptions about the way people behave. Still they are necessary in order to justify the choices of the system boundaries in the project, and to make it visible which assumption these choices are based upon. Please go through the arguments and examine the made assumptions.

Inputs (Functions: Energy recovery and preservation of agricultural land)	Reference-system
Residues from agriculture, forestry and wood industry	None (leaving the biomass to degrade in the ecosystem)
Land (for agricultural crops, incl. perennial crops)	Set-aside or barley (depending on scale of change)
Land (for forestry crops)	None (leaving the wood to degrade in the ecosystem)
Fuelwood	None or pulpwood (depending on scale of change)
Fertilizer	Fertilizer industry based upon imported ammonia, situated within the distance of 1000 km from the place of use.
Outputs: (Function: Provision of energy)	
Electricity	Coal-fired technology or natural gas. Lignite in Greece.
Residential heating	Local, natural gas and oil pumped in the Middle East and Venezuela and refined in EU
District heating	Local, natural gas and oil pumped in the Middle East and Venezuela and refined in EU
FAME for heavy vehicles	Diesel produced from oil pumped in the Middle East or Venezuela and refined in EU
Ethanol for passenger cars	Gasoline produced from oil pumped in the Middle East or Venezuela and refined in EU

One general assumptions: The data used in this project should be valid in the period 2003-2010. Within this timelimit new capital investments are possible and the present amount and type of capital equipment do not restrict the production.

Input: residues from agriculture, forestry and wood-industry

a) Will the energy-system under study only affect specific processes supplying this product/service, or will a market be affected?

The residues are pr definition produced no matter what they are used for. On the assumption that the residues have no other commercial use, the reference-system can therefore be identified from technical arguments alone: the reference-system for residues is their natural degradation in the respective ecosystem.

Input: land

a) Will the energy-system under study only affect specific processes supplying this product/service, or will a market be affected?

Land is traded on a market. Alternative uses of the land are production of housing, infrastructure, agricultural, horticultural or forestry products and recreation. The availability of land for growing energy-crops depends upon the supply and demand for these products.

b) What is the trend in the volume of the affected market?

The amount of land is limited by geography, and the demand for land for different purposes is steadily increasing. Therefore the land that can be assumed used for producing energy-crops will be the land with the lowest alternative costs, i.e. the area where the alternative crop has the lowest expected gross margin.

c) Identify the preferred, unconstrained technology to provide the desired adjustment.

The provision of land is constrained by planning legislation. Because of this planning, the areas available for housing and infrastructure cannot be assumed to be affected by the energy-systems under study. The demand for recreational areas may influence demands set for agricultural/forestry practises, but can also be assumed not to be affected by the energy-systems under study. The land available for growing of energy-crops must therefore be found within the area for agriculture, horticulture or forestry.

Within the areas used for agriculture, horticulture and forestry, the choice of crops is made by the farmer or forest owner. This choice depends strongly upon the flexibility of the crops, regulations concerning the land-use, and the expected gross margin from the different crops.

Cereals and most other agricultural crops have a production time of one year. Therefore these productions are much more flexible than perennial crops such as christmas-trees and berries, or forest-trees, which are grown in rotations from 50 to 150 years. Because of this difference, it is considered a structural, non-marginal change, when agricultural crops are replaced by perennial or forestry crops and vice versa. For an agricultural farmer choosing perennial or forestry crops is a structural change, which can only become attractive by a high certainty of a high expected income, e.g. by public regulations. Therefore it is assumed that the energy-systems under study do not affect the availability of land for forest productions (further arguments for the reference system of fuelwood production: see under fuelwood) .

The area available is regulated from the European Community with a set-aside rate, which is adapted each year in response to the situation at the market of agricultural crops. The main goal of this rate is to secure a stable and sufficient supply of food in the European Union, and prevent the building of intervention stocks. In spite of the reform of the intervention-system in

1992, the stocks continue to accumulate, because of general increase in productivity (FAOSTAT). The European Commission assesses that the cereals most affected by the set-aside reduction in cultivated area are barley and, to a lesser extent, wheat and maize (EC, 1997). These crops are therefore the most preferred for being substituted.

The set-aside areas have varied between 6 and 7.5 million hectares in the period 1993-1997 (EC, 1997). Assuming that the set-aside is still available and is not taken out of the production to meet demands for protection of ground water or extensive, agricultural production, and assuming that the increase in productivity on agricultural land will continue, set-aside areas can be used for the production of the energy-crops under study.

If it alternatively is assumed that the use of set-aside land is restricted because of e.g. environmental goals or that the flexibility loss of growing perennial energy-crops (willow and miscanthus) is not accepted, the area most likely being used for growing of energy-crops will be areas presently used for growing barley. The decreased production of barley will be met by the general increase in productivity of other cereals, which can substitute as fodder.

Therefore the reference system is set-aside or barley.

References:

Danish Institute of Agricultural Economics. (1993). Economics of Agricultural Enterprises. In Danish with English explanations.

EC, European Commision. (1997). GAP 2000. Situation and Outlook. Cereals, Oilseeds, Proteincrops. Working Document. Directorate-general for Agriculture. Available at:

http://europa.eu.int/comm/dg06/publi/cap2000/cereals/cerealen/cerealen.pdf

FAOSTAT. FAO’s on-line database available at http://apps.fao.org/cgi-bin/nph-db.pl

Input: fuelwood

a) Will the energy-system under study only affect specific processes supplying this product/service, or will a market be affected?

As already mentioned above, the supply and demand of wood is not as strongly connected as for many other materials, because of the long production time. Fuelwood is usually the by-product of construction wood, produced by premature thinning-operations of the wood-stands. Alternatively the wood can be sold for pulp and paperproduction.

Fuelwood can be produced from wood-diameters as small as 5-6 cm. The smallest parts are in this connection defined as wood residues, since they have no alternative, commercial use. Fuelwood is here defined as having diameters big enough for being sold for production of pulp (10-11 cm). Pulpwood is traded on a regional market.

However, since the demand for pulpwood as well as fuelwood has been rather stable over the past decade (FAOSTAT) and the supply of small dimensioned wood can be assumed to increase in the coming years (FAO, 1997), a surplus of small dimensioned wood may still exist. In this case the reference-system is none (leaving the wood in the ecosystem).

If the energy-system under study requires more energy than what can be provided by this surplus, the wood used as fuel will be taken from the pulpwood. Since pulp is has a low value-density, it is seldom exported over longer distances. Therefore the decrease in pulpwood production can be expected to be met by an increased paper import from countries with abundant pulpwood resources, such as Scandinavia (FAO, 1997).

References:

FAO. (1997). State of the World's Forests. Available at http://www.fao.org/WAICENT/FAOINFO/FORESTRY/SOFOTOC.htm

FAOSTAT. FAO's on-line database available at http://apps.fao.org/cgi-bin/nph-db.pl

Input: fertilizer

Will the energy-system under study only affect specific processes supplying this product/service, or will a market be affected?

Besides manure there exist a variety of different mineral N-fertilizers which can substitute each other. Examples are urea, ammonium sulphate and diammonium phosphate. Urea accounts for almost 50% of world nitrogen fertilizer production (in terms of N content, and including multi-nutrient products), compared with only 30% a decade previously. 99 % of them are based upon ammonia (NH3), which is extracted from the abundant resources in normal air (IFA, 1998).

Traditionally manure is consumed locally, on the same location where it is produced. Biogas technology and slurry separation may change this, because it makes the N-content more concentrated and easier to transport.

All mineral fertilizers are in principle sold on a global market. Traditionally USA and Western Europe have been supplying most of the world consumtion of fertilizer, but massive investments in other parts of the world have changed this situation (EFMA, 1997a). The tariffs on international trade are typically low, except for a few cases where specially high "dump-tariffs" have been introduced eg. in EU to avoid competition from the former USSR (Kemira, pers.com.). Transportation costs and traditions however limit the markets to smaller regions. The majority of the Danish mineral fertilizer consumption is for example produced in Denmark or the neighbouring countries such as Norway, Germany, Benelux, Poland and Russia (Kemira, pers.com.).

b) What is the trend in the volume of the affected market?

The global consumption of mineral fertilizer has shown a steady increase over the past decades (FAOSTAT), but the European market have experienced a decrease in the consumption of fertilizer due to economical crisis in Eastern Europe and general environmental restrictions. The European Fertilizer Manufacturers Association forecasts that these trends will continue (EFMA, 1997b). Reasons for this can be that many new plants are being constructed in the geographical regions which used to import fertilizer from Europe, eg. Asia (FAO, 1997), or reconstructed in regions which at present offers advantages for export to Northern Europe, eg. former USSR (RINACOplus, 1996).

Since the market is declining, plants can still be expected to be taken out of use. The marginal kg N-fertilizer can therefore be assumed to come from the plants about to close, which will be the least preferred, unconstrained technology.

c) Identify the preferred, unconstrained technology to provide the desired adjustment.

Manure is a waste product from the production of animal meat and is constrained to the amount linked to the optimal production of meat. This means that the consumption of fertilizer has no effect upon the production of manure.

Plants producing mineral N-fertilizer can be based upon a variety of different technological and chemical processes (IFA, 1998). However, roughly they can be divided into two categories: plants based on imported ammonia or plants with a combined production of ammonia and fertiliser. The combined plants are typically found where the resource of natural gas is abundant, eg. Norway. The combined plants have significant technical and economic advantage, since they avoid a process of transport and can use the CO2-emission as input in the production (Kemira, pers.com.).

It has not been possible to obtain data on the direct costs for the different production technologies. But since the cost for energy is one of the main costs for producing fertiliser, it can be assumed that the least economic efficient plants have the highest energy consumption. Worell et al (1994) estimates the national average energy consumption for the fertiliser industry in some European countries. Greece reaches with 43 MJ/kg the highest national average.

Therefore the least preferred plants can be defined from the following technical arguments:

They are based upon imported ammonia,

They have a energy consumption of more than 43 MJ/kg.

When using fertilizer in the production of energy-crops, it can be assumed that technology actually affected by this consumption fulfills these two criterias.

References:

EFMA European Fertilizer Manufacturers Association. (1997a). Industry Profile. http://www.efma.org/about/section02.asp

EFMA. (1997b). The Fertilizer Industry of the European Union - issues of today, the outlook for tomorrow. Available at http://www.efma.org/Publications/EUBook/Section08.asp

FAO. (1997). Fertilizers. Food Outlook 97/01. http://www.fao.org/WAICENT/faoinfo/economic/giews/english/fo/fo9701/fo970109.htm

FAOSTAT. FAO’s on-line database available at http://apps.fao.org/cgi-bin/nph-db.pl

Kemira Danmark, Kongensgade 107,7000, Fredericia, 79 22 33 66.Personal communication with Arne Engstrøm, 10/12/98.

IFA (International Fertilizer Industry Association. (1998). Mineral Fertilizers and the Environment - Part 1. The Fertilizer Industry's Manufacturing Processes and Environmental Issues. http://www.fertilizer.org/PUBLISH/PUBENV/part1.htm

RINACOplus. (1996). Russian Industry Analysis. Mineral Fertilizer Production. Vers. 1.0. http://lat-www.fe.msk.ru/infomarket/rinacoplus/research/fertl_10.html

Worrell E, Cuelenaere R F A, Blok K and Turkenburg WC. (1994). Energy Consumption by industrial processes in the European Union. In: Energy, 19(11), pp. 1113-1129.

Output: electricity

a) Will the energy-system under study only affect specific processes supplying this product/service, or will a market be affected?

Electricity is delivered through a market.

b) What is the trend in the volume of the affected market?

The production volume of electricity has been generally increasing for the last decade both in the EU and in each national sub-market (EUROSTAT,1997b, OECD 1997). Forecasts of the electricity demand do not suggest any decrease in the coming years, neither in the EU, nor in any of the national sub-markets (EC, 1996). Thus, the marginal technology that we are looking for is the most preferred technology (the unconstrained technology with the lowest, long-term production costs).

c) Identify the preferred, unconstrained technology to provide the desired adjustment.

Electricity derived from biogas derived from animal excrements will compete with other technologies involved for large scale electricity production such as nuclear, hydro, coal, oil, natural gas, biomass, waste and wind power, either as „pure" electricity production or in co-generation with heat.

Many of these technologies are currently constrained; i.e. their production capacity cannot be expanded to the extent desired, due to natural capacity constraints, political constraints, or the lack of a market for co-products:

For nuclear power plants it is not likely that new plants will be built within 10-15 years (EC 1995, 1996 and 1997). Some countries, e.g. Sweden, even plan a reduction. Hydropower is limited by the areas available for establishing new plants (EC, 1997), which may be regarded as a combination of political constraints and natural resource constraints. Even if nuclear and hydro capacity should increase, it will be a planned increase as a result of political decisions upon which small changes in market volume will have little influence.

Fossil fuels (coal, oil and natural gas) are not generally constrained, but may be constrained in individual countries by the emission quotas, especially the SO_2, NO_X and CO_2 targets. Biomass as an energy source may still expand its market share, but will eventually become limited by the availability of suitable land areas (in competition with other uses of land). Waste as an energy source is limited by the availability of the resource (waste).

Wind power is currently expanding its market share, but the development is still constrained by the availability of technical knowledge.

Co-generation of electricity and heat has a potential for expansion, both in new installations and in many existing power plants, which have a significant heat surplus. However, the decision to utilize the surplus heat is determined mainly by the availability of a local market for the co-product (heat) and is independent from the choice of technology for the general electricity market.

Thus, the technologies which presently have a potential to be the marginal electricity source are the fossil fuels, since they fulfill the condition of being unconstrained in potential production capacity. However, country specific constraints due to emission quotas may influence *which* fossil fuel is the marginal for each sub-market. In most of EU, lignite based power plants are no longer built. An exception may be Greece, where lignite power plants produce most of the electricity supply without indication of decline (EUROSTAT, 1997a). In the Nordic countries, the emission quotas do not leave room for much expansion of coal based power plants. At present, new power plants planned are natural gas fired (NORDEL, 1996).

In table 2 the production costs for the unconstrained technologies are estimated. The costs are composed of fuel costs, operation and maintenance costs, and depreciation of capital goods.

Table 2. Calculation of production cost per MWh for modern electricity production technologies (Weidema et al., 1999).

Fuel type	Plant type	Capital investment	Operation and maintenance	Fuel	Total cost
	MW	DKK/ MWh	DKK/ MWh	Cost in DKK/MWh	DKK/ MWh
Hard coal	400	110	59	84	250
Nat. gas	15	82	59	330	470
Nat. gas	250 CC*	68	34	220	320
Heavy fuel oil	15	99	100	140	340
Bio-mass	250* CFB	110	73	240	420
* CC: Combined Cycle in which a natural gas driven turbine and another turbine driven from steam produced from the exhaust gas of the gas turbine. CFB: Circulating Fluid Bed. Technology at experimental stage.					

Provided a deregulated electricity market with adequate transmission capacities – implying the same marginal technology all over EU – and provided that the EU emission targets do not generally limit the use of hard coal, coal condensing power will be the EU marginal power source, since it has the lowest cost of the unconstrained technologies.

However, as the emission targets are tightened, and the electricity consumption continues to rise, installation of new coal power plants will be constrained, as is currently the case in the Nordic countries. The current marginal technology in the Nordic electricity system is therefore natural gas power. Due to the lower capital costs required, gas fired plants may also be the marginal technology under periods of high interest rates. An exception at the other end of the spectrum is the present situation in Greece, where lignite may still be regarded as the marginal power source.

References:

EC. (1995). Nuclear Industries in the Community - The nuclear power station design and construction industry and completion of the European market. Information energy Europe sheet 23. Brussels: European Commission.

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Weidema B, Frees N and Nielsen A-M. (1999). Marginal production technologies for life cycle inventories. The International Journal of Life Cycle Assessment 4(1):48-56.

Output: residential heating

a) Will the energy-system under study only affect specific processes supplying this product/service, or will a market be affected?

Several types of fuel may meet the energy requirements for residential heating. Except some fuelwood produced in the household, most sources of energy for residential heating are distributed through a market.

b) What is the trend in the volume of the affected market?

The energymarket face two conflicting trends. One the one side, in OECD-countries energy intensity (i.e. energy consumption per unit of real GDP) is expected to continue to decline at an annual average rate of around 1 % following from technological advances (IEA, 1994). On the other side economic and population growth increases the demand for energy (WEC, 1993).

World electricity and heat demand is projected to grow at an average rate of 3.2 % per year in the time frame of this project (WEC, 1993). It is not possible in existing statistics (EUROSTAT, 1997) to see if Europe lies under this average. But since the replacement rate for capital investments in the energy-production to some extent is increased because of environmental demands for the fuels, the marginal technology can be expected to be the most preferred, unconstrained technology.

c) Identify the preferred, unconstrained technology to provide the desired adjustment.

Residential heating can be supplied from district heating plants or local, small scale combustion. District heating plants require substantial investments, since a pipe-system must be established. The plans for expanding the net for district heating is not assumed affected by the energy-systems studied here.

The available technologies for residential heating is therefore small scale combustion of fossil fuels or biomass, or heating from electricity. Coal is relatively much more expensive to use in small plants, because of big costs for storing and smoke-cleaning capacity in small scale combustion, the most preferred fuel will be fuel oil or natural gas. Electricity used for heating purposes is generally not economic, compared to alternative fuels.

Oil from the sources in the Middle East and Venezuela are expected to have the lowest extraction-costs (IEA, 1994). Since the OECD-countries are expected to increase the import within the time frame of this project, the International Energy Agency suggests that under any reasonable set of assumptions, the share of oil from the Middle East and Venezuela will rise from 30 % of total world oil supply in 1991 to between 45 % and 57 % in 2010. Therefore oil from these regions can be supposed to be the marginal.

Most oil extracted in the Middle East and Venezuela is transported to Europe as crude oil and refined within EU (Eurostat, 1997, UN, 1996).

Therefore the reference-system of residential heating based upon biomass is small scale combustion of fuel oil, pumped in the Middle East and Venezuela and refined in EU.

References:

EUROSTAT. (1997). Energiebilanzen.

IEA, International Energy Agency. (1994). World Energy Outlook.

UN. International trade statistics yearbook 1995. Vol. II. (1996). United Nations Department for economic and social information and policy analysis. Statistic division.

WEC, World Energy Council. (1993). Energy for Tomorrow's World - the realities, the real options and the agenca for achievement. St Martin's Press.

Output: district heating

a) Will the energy-system under study only affect specific processes supplying this product/service, or will a market be affected?

District heating is supplied from a market. District heating plants are not present in all EU-memberstates.

b) What is the trend in the volume of the affected market?

Statistics upon the production of district heating in the EU is only available for 1994 and 1995 (EUROSTAT, 1997). In these two years the production was stable, respectively 6896 and 6765 ton of oil equivalent. But since the replacement rate for capital investments in the energy-production to some extent is increased because of environmental demands for the fuels, the marginal technology can be expected to be the most preferred, unconstrained technology.

c) Identify the preferred, unconstrained technology to provide the desired adjustment.

District heating can be supplied from medium scale combustion plants, which can use oil, coal, natural gas or biomass such as whole crops, energy grass, miscanthus, willow and woody by-products from industry as fuel. Neither of these fuels is constrained at present. The most preferred fuel will be the one with the lowest costs. The costs can be estimated parallel to the total costs of electricity-production estimated in table 2, with one exception: coal-based energy have relatively high demands for investments in storing and smoke-cleaning facilities, which are mostly economic in large-scale combustion plants, such as electricity-production (Doms, 1993). Therefore coal will be less favourable to use than natural gas combusted in combined cycles and fuel oil. Since the costs of these two fuel-types are so close in size, it can be assumed that the marginal technology of supplying district heat will be a mixture of them. Natural gas has relatively high investment costs for distribution-pipes. Therefore it is most economically consumed on local or semi-regional level.

The reference system of district heating based upon biomass is therefore combustion of local, natural gas and fuel oil from the Middle East and Venezuela, refined in EU (see argument under „Residential heating“.

References:

Doms M E. (1993). Inter Fuel Substitution and Energy Technology Heterogeneity in U.S.Manufacturing.

EUROSTAT. (1997). Energiebilanzen.

Output: FAME for diesel powered heavy vehicles

a) Will the energy-system under study only affect specific processes supplying this product/service, or will a market be affected?

FAME will be able to substitute diesel for heavy vehicles, and is like other fuels provided by a market.

b) What is the trend in the volume of the affected market?

The amount of road transport is growing all over the world, leading to an increased demand for transport fuel (WEC, 1993). The world energy-supply of oil is increasing and the World Energy Council suggest that this trend will continue for the relevant time period, unless a very high degree of technology transfer and institutional improvements take place (WEC, 1993).

c) Identify the preferred, unconstrained technology to provide the desired adjustment.

Diesel based upon the marginal oil-production from the Middle East and Venezuela, refined in EU (see argument under „Residential heating“.

References:

WEC, World Energy Council. (1993). Energy for Tomorrow’s World - the realities, the real options and the agenca for achievement. St Martin’s Press.

Output: ethanol for passenger cars

a) Will the energy-system under study only affect specific processes supplying this product/service, or will a market be affected?

Ethanol will be able to substitute ethanol for passenger cars. Fuel for cars is provided by a market.

b) What is the trend in the volume of the affected market?

The amount of road transport is growing all over the world, leading to an increased demand for transport fuel (WEC, 1993).

c) Identify the preferred, unconstrained technology to provide the desired adjustment.

See arguments above: gasoline based upon oil from the Middle East or Venezuela, refined in EU.

References:

WEC, World Energy Council. (1993). Energy for Tomorrow's World - the realities, the real options and the agenca for achievement. St Martin's Press.

7 Characterisation of resource uses and environmental impacts

By Anne Merete Nielsen, Per H. Nielsen and Marianne S. Wesnæs

Technical University of Denmark, June 1999

1. Depletion of abiotic resources

Abiotic resources occur as inflows in the LCA. Different assessment methodologies exist. Heijungs et al. (1992) and Hauschild and Wenzel both suggest an assessment based upon the size of the presently known deposits (supply-horizon). Finnveden (1996) suggests aggregating and assessing consumption of abiotic resources according to their energy content or exergy consumption. Weidema (1993, 1996) and Müller-Wenk (1998) suggests to aggregate and assess consumption of abiotic resources based on the change in the environmental effects of the extraction as a result of having to use lower grade deposits in future. Since it is not the abiotic resources themselves, but their high-concentrated ores, which are scarce (Guinée, 1995a, table 5.15, p.108-112), the actual negative impact from consumption of abiotic resources is the increased use of energy and land for extraction.

Since these methodologies are still under development focus will be addressed to two abiotic resources with special relevance for energy-supply and agriculture, namely use of water and energy content of finite energy carriers.

Ground water consumption for irrigation and industrial use are included in the inventory in areas where water is depleted.

The theoretical energy contents of various energy sources are provided in Table 1. The energy contents of combustible fuels are given as lower calorific values as well as higher calorific value. The higher calorific values express the energy content if steam generated during the combustion process is condensed into water, whereas the lower calorific value expresses the energy content if the steam is not condensed.

For the BIOFIT-project TUD suggest that the higher calorific value is used, because it represents the maximum amount of energy that can be derived from the fuel with to days energy production methods.

Table 1: Energy content of various energy sources.

Energy source	Energy content MJ/kg		Reference
	Higher calorific value	Lower calorific value	
Uranium[1)]	451,000		Habersatter und Fecker (1996)
Crude oil[2)]	45.6	42.6	Habersatter und Fecker (1996)
Natural gas [2,3)]	48.8	43.8	Habersatter und Fecker (1996)
Lignite[4)]	9.5	8.0	Habersatter und Fecker (1996)
Coal[4)]	19.0	18.0	Habersatter und Fecker (1996)

1) As i occurs naturally in UF_6. 2) Directly from well site. 3) The calorific value for natural gas is 35.0 MJ/ Nm^3 (lower) and 39.0 MJ/Nm^3 (higher). Based on an average density of 0.8 kg/m^3 this has been converted to 43.8 respectively 48.8 MJ/kg. 4) Directly from mine (before treatment).

Large variation exists in the data for the energy contents of the resources when using different literature data. This is due to big differences of the quality and composition of the resources. For natural gas, the content of methane, ethane, propane vary from place to place. For lignite the content of carbon varies even within the same mine. Hence, the values given in Table 1 should only be regarded as quite rough estimates.

2. Global warming

The Intergovernmental Panel on Climate Change (IPCC) has developed an equivalence factor system, which can weight the various substances to one reference unit „kg CO2/kg substance“ according to their efficiencies as greenhouse gases (Houghton et al, 1992, 1994 and 1995). With the help of this system the emissions' total contribution to the global warming can be calculated as a Global Warming Potential (GWP). This procedure is based on expert judgements of scientists world wide and has gained international acceptance (Heijungs et al, 1992; Hauschild and Wenzel, 1998a).

IPCC provide GWP's for three different time horizons: 20, 100 and 500 years. The characterisation factors for the relevant compounds for the 100-year time horizon and the 500-year time horizon are presented in Table 2.

Table 2: Characterisation factors for global warming potential.

Substance name	Substance formula	Characterisation factors for global warming potential, g CO_2-eq / g substance		References
		100 year time horizon	500 year time horizon	
Carbon dioxide[1)]	CO_2	1	1	Wenzel et al. (1997)
Methane	CH_4	25	8	Wenzel et al. (1997)
Nitrous oxide	N_2O	320	180	Wenzel et al. (1997)
Carbon monoxide [2)]	CO	2	2	Wenzel et al. (1997)
Non-methane volatile organic compounds [2,3)]	NMVOC	3	3	Wenzel et al. (1997)

1) Include only CO_2 of petrochemical origin

2) Contributes indirectly to global warming due to conversion into CO_2 in the atmosphere.

3) The NMVOCs cover a range of substances, and the present characterisation factors only represent estimates of average values.

3. Ozone depletion

The Ozone Depletion Potential was introduced by Wuebbles (1988) and further developed by the World Meteorological Organisation (WMO), who has compiled an equivalence factor system, which can weight the various substances to the reference unit „g CFC11/g substance“ (WMO, 1995). With the help of this system the emissions’ total contribution to the stratospheric ozone depletion can be calculated as an Ozone Depletion Potential (ODP). This procedure is based on expert judgements of scientists world wide and has gained international acceptance (Heijungs et al, 1992; Hauschild and Wenzel, 1998).

Ozone depletion is not relevant for the BIOFIT-project and no characterisation factors for this impact category are provided.

4. Acidification

Heijungs et al. (1992) and Hauschild and Wenzel (1998) suggests an equivalence factor system, which can weight the various substances to one reference unit „kg SO2/kg substance“ according to their efficiencies reduce the regional ecosystem’s acid neutralising capacity. With the help of this system the emissions’ total contribution to the effect can be calculated as an Acidifying Potential (AP). This procedure is based upon simple assumptions about the chemical formations that the substances usually form.

Potting et al. (1998) proposes a set of characterisation factors that make more precise models of the fate of the substances and take the site of the emission into account. Through this system of site-dependent factors the size of the ecosystems which are potentially damaged by the emission can be calculated.

Site dependency will be included in the study if acidification based on a worst case study proves to be an important parameter for the environmental study of bio fuels. Table 3 shows the characterisation factors for the worst case of acidification.

Table 3: Characterisation factors for acidification potential.

Substance Name	Substance formula	Characterisation factors for acidification potential g SO_2-eq / g substance	References
Sulphur dioxide	SO_2	1	Wenzel et al. (1997)
Nitrogen oxides [1)]	NO_x	0.70	Wenzel et al. (1997)
Ammonia	NH_3	1.88	Wenzel et al. (1997)
Hydrochloric acid	HCl	0.88	Wenzel et al. (1997)

1) NO_X is calculated as NO_2.

5. Eutrophication

Heijungs (1992) and Hauschild and Wenzel (1998) suggest an equivalence factor system, where the nitrogen- and phosphorus-problems can be assessed individually and aggregated by either assessing the total emission of N, P or using a reference unit „g NO3/g substance“ according to the average N/P-relationship in biomass.

Nutrient enrichment is also site dependent. For the same reasons as mentioned above for acidification, characterisation factors for the worst case are selected for the initial phase of the study of bio fuels. Characterisation factors for the worst case of nutrient enrichment are shown Table 4. In addition to the reference units proposed by Heijungs (1992) and Wenzel and Hauschild (1998) PO_4^{3-} is also included as a reference unit in Table 4. The PO_4^{3-} -reference is equivalent with the NO_3-reference and only included to meet different traditions in different European countries.

Table 4: Characterisation factors for nutrient enrichment potential.

Substance Name	Substance formula	Characterisation factors for nutrient enrichment potential				References
		N g N-eq / g substance	P g P-eq / g substance	combined N and P g NO_3-eq / g substance	combined N and P 3) g PO_4-eq / g substance	
Nitrate	NO_3^-	0.23	0	1	0.096	Wenzel et al. (1997)
Nitrogen oxides 1)	NO_X	0.30	0	1.35	0.13	Wenzel et al. (1997)
Nitrous oxide	N_2O	0.64	0	2.82	0.27	Wenzel et al. (1997)
Ammonia	NH_3	0.82	0	3.64	0.35	Wenzel et al. (1997)
Ammonium	NH_4^+	0.78	0	3.44	0.33	Hauschild and Wenzel (1997e)2)
Phosphate	PO_4^{3-}	0	0.33	10.45	1	Wenzel et al. (1997)

1)NO_X is calculated as NO_2

2) The values for NH_4 are calculated based on principles provided by Hauschild and Wenzel (1997e).

3) The values for combined N and P in this column are calculated based on principles provided by Hauschild and Wenzel (1997e).

6. Photochemical ozone formation

The potential contribution to photo-chemical ozone creation from a substance is described by its Photochemical Ozone Creation Potential (POCP). This is calculated on the basis of knowledge about the types of reactions, which the substance undergoes with the other substances present in the troposphere, and the rate at which the various reactions proceed.

The POCP-value can vary considerably for different substances, but available data are often aggregated into one VOC-figure. The accuracy of such a calculation can be increased if it is specified from which source the VOC was released (see Hauschild and Wenzel, 1998c).

The POCP-values varies between regions with high or low concentrations of NO_x (see Hauschild and Wenzel, 1998c). Low NO_x is most relevant for Scandinavia, whereas high NO_x values are more relevant in the rest of Europe. Therefore, characterisation factors for high NO_x conditions are used as default, see Table 5.

Table 5: Characterisation factors for photochemical ozone formation potential.

Substance Name	Substance Formula	Characterisation factors (high NO_X) for photo chemical ozone formation potential g C_2H_4 -eq / g substance	References
Hexane[1)]	C_6H_{14}	0.4	Wenzel et al. (1997)
Non methane volatile organic comp. [2)]	NMVOC	0.5	Wenzel et al. (1997)
Carbon monoxide	CO	0.03	Wenzel et al. (1997)
Methane	CH_4	0.007	Wenzel et al. (1997)

1) This corresponds to the equivalency factor for n-hexane

2) This category covers a range of substances. The value should only be regarded as an estimate of an "average" value (see Hauschild and Wenzel (1998c).

7. Toxicological impacts

There are no internationally accepted standards for treating toxicity in life cycle assessments. The method proposed here is based on already established concepts and values from the toxicity classification and the risk assessment of chemicals under the auspice of international institutions such as the EU and the OECD. The method is further described in Hauschild and Wenzel (1998).

The toxic properties of each individual substance depend on a large number of different factors concerning the substance itself, the quantity emitted and the circumstances under which it is emitted and converted in the environment. In contrast to the situation pertaining to many of the other impact categories, there are no common internationally accepted equivalence factors for toxic substances. However, there is general agreement that the developed methodology shall be based on an integrated quantification of the environmental fate and the inherent toxicity potential of the substance (Udo de Haes, 1996).

Two different lines of approaches can be distinguished on the more detailed level: they could be termed „full fate“ and „some fate“. The „full fate-approach“ bases the impact assessment upon existing models of the dispersion and impacts of toxicological substances (Guinée et al., 1996, Hertwich et al., 1998). These models are typically developed for risk assessment at a screening level and have therefore a politically wanted tendency of overestimating the impacts through very high default values. The models are very complex and have high demands for detailed data. Therefore the default values will contribute significantly to the result of the assessment.

The „some fate-approach“ aims at developing a new methodology specifically for life cycle assessments based on an identification of the key parameters determining the environmental fate and effects of the substance and inclusion through individual modules (Jolliet and Crettaz, 1997, Hauschild and Wenzel, 1998). The reasoning behind the modular approaches is to ensure the accuracy, relevance and transparency of the resulting ecotoxicity and human toxicity assessment.

At this moment all characterisation methods make use of thresholds based upon NEC- (No Effect Concentrations) or ADI-measures (Acceptable Daily Intake) of the individual substances. This approach does not consider possible synergetic effects between the toxic substances and e.g. photo-chemical ozone creation.

Based upon the above discussion, the some-fate approach by Hauschild and Wenzel (1998) is chosen.

Hauschild and Wenzel (1998) differentiate between "ecotoxicity" and "human toxicity" and the relevant characterisation factors for the two types of toxicity will be provided in the coming two sections, followed by a short explanation. The reader should consult the original reference for more detailed explanations.

7.1 Ecotoxicity

Toxic substances emitted to the atmosphere, aquatic recipients or soil potentially contribute to ecotoxicity (Wenzel et al. 1997 and Hauschild and Wenzel, 1998). The characterisation factors for ecotoxicity from relevant substances emitted to air are listed in Table 6 and the factors for the same substances emitted to water and soil are listed in Table 7 and 8.

Emissions to air result in ecotoxicity in the water compartment as well as the soil compartment because the toxic substances are washed out of the atmosphere during rainfall into soil, lakes, rivers and seas. Some compounds emitted to air do not contribute to toxicity in water and soil. This is because the lifetime of the compound is short and the compound is assumed to be degraded in the atmosphere before the washout becomes significant (see Wenzel et al., 1997). Similar considerations explain the distribution of toxicity between the water and soil compartments for compounds emitted to water and soil in Table 7 and 8.

Table 6: Characterisation factors for potential ecotoxicity from substances emitted to air (Wenzel et al., 1997).

Substance	CAS no.	Water, chronic CF(etwc)[1)] m^3/g	Soil, Chronic CF(etsc)[2)] m^3/g
Atrazine	1912-24-9	0	0
Benzene	71-43-2	4.0	3.6
Benzo(a)pyrene	50-32-8	n.a.	n.a.
Cadmium	7440-46-9	$2.4 \cdot 10^4$	1.8
Chromium (VI)	7440-47-3	130	0.01
Copper	7440-50-8	$2.5 \cdot 10^3$	0.02
Tetrachlorodibenzo-p-dioxin[3)]	1746-01-6	$5.6 \cdot 10^8$	$12 \cdot 10^4$
Iron	7439-89-6	20	0.53
Lead	7439-92-1	400	0.01
Manganese	7439-96-5	71	1.9
Mercury	7439-97-6	$4.0 \cdot 10^3$	5.3
Nickel	7440-02-0	130	0.05
Selenium	7782-49-2	$4.0 \cdot 10^3$	106
Zinc	7440-66-6	200	0.005

1) CF (etwc): characterisation factor (ecotoxicity, water, chronic).

2) CF (etsc): characterisation factor (ecotoxicity, soil, chronic).

3) Represent dioxins.

Table 7: Characterisation factors for potential ecotoxicity from substances emitted to water (Wenzel et al., 1997).

Substance	CAS no.	Water, chronicCF (etwc)[1)] m^3/g	Water, AcuteCF (etwa)[2)] m^3/g	Soil, chronicCF (etsc)[3)] m^3/g
Atrazine	1912-24-9	$6.7{\cdot}10^3$	670	0
Cadmium	7440-46-9	$1.2{\cdot}10^5$	$1.2{\cdot}10^4$	0
Chromium	7440-47-3	670	67	0
Copper	7440-50-8	$1.3{\cdot}10^4$	$1.3{\cdot}10^3$	0
Iron	7439-89-6	100	10	0
Lead	7439-92-1	$2.0{\cdot}10^3$	200	0
Manganese	7439-96-5	360	36	0
Mercury	7439-97-6	$4.0{\cdot}10^3$	$2.0{\cdot}10^3$	0
Nickel	7440-02-0	670	67	5.3
Selenium	7782-49-2	$2.0{\cdot}10^4$	$1.4{\cdot}10^3$	0
Zinc	7440-66-6	$1.0{\cdot}10^3$	100	0

1) CF(etwc): characterisation factor (ecotoxicity, water, chronic).
2) CF(etwa): characterisation factor (ecotoxicity, water, acute).
3) CF(etsc): characterisation factor (ecotoxicity, soil, chronic).

Table 8: Characterisation factors for potential ecotoxicity from substances emitted to soil (Wenzel et al., 1997).

Substance	CAS no.	Water,chronicCF(etwc)[1)] m^3/g	Soil,ChronicCF(etsc)[2)] m^3/g
Atrazine	1912-24-9	0	530
Cadmium	7440-46-9	0	2.2
Chromium	7440-47-3	0	0.01
Copper	7440-50-8	0	0.02
Iron	7439-89-6	0	0.66
Lead	7439-92-1	0	0.01
Manganese	7439-96-5	0	2.4
Mercury	7439-97-6	$4.0{\cdot}10^3$	5.3
Nickel	7440-02-0	0	0.07
Selenium	7782-49-2	0	133
Zinc	7440-66-6	0	0.007

1) CF(etwc): characterisation factor (ecotoxicity, water, chronic).
2) CF(etsc): characterisation factor (ecotoxicity, soil, chronic).

***Example**:* Determination of environmental impact potentials for ecotoxicity (EP(et)) as a result of an emission of 100 g benzene to air and 10 g to water.

$EP(et) = Q \cdot CF(et)$

Emissions to air:

EP(etwc) = 100 g · 4.0 m^3/g = 400 m^3 (see Table 6)
EP(etsc) = 100 g · 3.6 m^3/g = 360 m^3 (see Table 6)

Emissions to water:

EP(etwc) = 10 g · 4.0 = 40 m^3 (see Table 7)
EP(etwa) = 10 g · 10 = 100 m^3 (see Table 7)
EP(etsc) = 10 g · 3.6 = 36 m^3 (see Table 7)

Total environmental impact potentials for ecotoxicity:

EP(etwc) = 400 m^3 + 40 m^3 = 440 m^3
EP(etwa) = 100 m^3
EP(etsc) = 360 m^3 + 36 m^3 = 396 m^3

7.2 Human Toxicity

Toxic substances emitted to the environment also contribute to human toxicity. The characterisation factors for relevant compounds are listed in Table 9 (emissions to air), Table 10 (emissions to water) and Table 11 (emissions to soil).

The distribution of human toxicity between air, water and soil follow the same principles as discussed briefly for ecotoxicity above, although extra parameters such as transfer factors and intake factors are included (see Wenzel et al., 1997).

Table 9: Characterisation factors for potential human toxicity from substances emitted to air (Wenzel et al., 1997).

Substance	CAS no.	Air CF(hta) m^3/g	Water CF(htw) m^3/g	Soil CF(hts) m^3/g
Atrazine	1912-24-9	$1.4 \cdot 10^5$	0	0
Benzene	71-43-2	$1.0 \cdot 10^7$	2.3	14
Benzo(a)pyrene	50-32-8	$5.0 \cdot 10^7$	0	0
Cadmium	7440-46-9	$1.1 \cdot 10^8$	$5.6 \cdot 10^2$	4.5
Chromium	7440-47-3	$1.0 \cdot 10^6$	3.6	1.1
Copper	7440-50-8	$5.7 \cdot 10^2$	3.4	$4.0 \cdot 10^{-3}$
Tetrachlorodibenzo-p-dioxin[1)]	1746-01-6	$2.9 \cdot 10^{10}$	$2.2 \cdot 10^8$	$1.4 \cdot 10^4$
Iron	7439-89-6	$3.7 \cdot 10^4$	$9.6 \cdot 10^{-3}$	0.77
Lead	7439-92-1	$1.0 \cdot 10^8$	53	$8.3 \cdot 10^{-2}$
Manganese	7439-96-5	$2.5 \cdot 10^6$	$5.3 \cdot 10^{-3}$	0.42
Mercury	7439-97-6	$6.7 \cdot 10^6$	$1.1 \cdot 10^5$	81
Nickel	7440-02-0	$6.7 \cdot 10^4$	$3.7 \cdot 10^{-3}$	0.12
Nitrous oxide	10024-97-2	$2.0 \cdot 10^3$	0	0
Selenium	7782-49-2	$1.5 \cdot 10^6$	28	$4.4 \cdot 10^{-2}$
Sulphur dioxide	7446-09-5	$1.3 \cdot 10^3$	0	0
Zinc (as dust)	7440-66-6	$8.1 \cdot 10^4$	4.1	$1.3 \cdot 10^{-2}$

1) Represent dioxins.

CF(hta): characterisation factor (human toxicity, exposure via air).

CF(htw): characterisation factor (human toxicity, exposure via surface water).

CF(hts): characterisation factor (human toxicity, exposure via soil.

Table 10: Characterisation factors for potential human toxicity from substances emitted to water (Wenzel et al., 1997).

Substance	CAS no.	Air CF(hta) m^3/g	Water CF(htw) m^3/g	Soil CF(hts) m^3/g
Atrazine	1912-24-9	0	1.1	0
Cadmium	7440-46-9	0	$2.8 \cdot 10^{3}$	0
Chromium	7440-47-3	0	18	0
Copper	7440-50-8	0	17	0
Iron	7439-89-6	0	$4.8 \cdot 10^{-2}$	0
Lead	7439-92-1	0	$2.6 \cdot 10^{2}$	0
Manganese	7439-96-5	0	$2.7 \cdot 10^{-2}$	0
Mercury	7439-97-6	$6.7 \cdot 10^{6}$	$1.1 \cdot 10^{5}$	81
Nickel	7440-02-0	0	$1.9 \cdot 10^{-2}$	0
Nitrous oxide	10024-97-2	$2.0 \cdot 10^{3}$	0	0
Selenium	7782-49-2	0	$1.4 \cdot 10^{2}$	0
Zinc (as dust)	7440-66-6	0	21	0

1) Represent dioxins.

CF(hta): characterisation factor (human toxicity, exposure via air).

CF(htw): characterisation factor (human toxicity, exposure via surface water).

CF(hts): characterisation factor (human toxicity, exposure via soil.

Table 11: Characterisation factors for potential human toxicity from substances emitted to soil (Wenzel et al., 1997).

Substance	CAS no.	Air CF(hta) m^3/g	Water CF(htw) m^3/g	Soil CF(hts) m^3/g
Atrazine	1912-24-9	0	0	$4.2 \cdot 10^{-2}$
Cadmium	7440-46-9	0	0	5.6
Chromium	7440-47-3	0	0	1.4
Copper	7440-50-8	0	0	$5.0 \cdot 10^{-3}$
Iron	7439-89-6	0	0	0.96
Lead	7439-92-1	0	0	0.10
Manganese	7439-96-5	0	0	0.53
Mercury	7439-97-6	$6.7 \cdot 10^{6}$	$1.1 \cdot 10^{5}$	81
Nickel	7440-02-0	0	0	0.15
Nitrous oxide	10024-97-2	$2.0 \cdot 10^{3}$	0	0
Selenium	7782-49-2	0	0	$5.5 \cdot 10^{-2}$
Sulphur dioxide	7446-09-5	$1.3 \cdot 10^{3}$	0	0
Zinc (as dust)	7440-66-6	0	0	$1.6 \cdot 10^{-2}$

1) Represent dioxins.

CF(hta): characterisation factor (human toxicity, exposure via air).

CF(htw): characterisation factor (human toxicity, exposure via surface water).

CF(hts): characterisation factor (human toxicity, exposure via soil.

8. Final remarks

Since EDIP (Wenzel et al, 1997 and Hauschild and Wenzel 1998) is used frequently as references in this paper, it should be noted that the term "characterisation factors, CF" used in the BIOFIT-project is equivalent with the term "equivalency factors, EF" used in EDIP.

Characterisation factors for active components in pesticides with respect to ecotoxicity and human toxicity will be available in Table 6-11 by the end of September. The names and CAS no.'s of active components that will be included in the study are extracted from CLM's report: "Proposal of Pesticides studied in the BIOFIT Project" and listed in Table 12. The CLM report is available on request.

Table 12: List of pesticides that will be included in the BIOFIT study.

Name of active component	Cas no.
Deltamethrin	52918-63-5
Metazachlor	067129-08-2
Napropamide	15299-99-7
Propyzamide	23950-58-5
Trifluralin	1582-09-8
Flusilazole	85509-19-9
Metamitron	41394-05-2
Glyphosate	1071-83-6

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Aggregation of toxicity indicators

Prepared by TUD

Carry out normalisation by dividing the impact potentials by the normalisation references. Then aggregate the normalised potentials for ecotoxicity and human toxicity into three impact categories by calculating the following averages:

Persistent toxicity

NEP(pt) = {NEP(etwc) + NEP(etsc) + NEP(htw) + NEP(hts)}/n, where n is the number of impact potentials entering into the numerators for which values have been calculated

Ecotoxicity

NEP(et) = {NEP (etwa) + NEP (etp)}/n

Human toxicity

NEP (ht) = NEP (hta)

Pt: persistent toxicity

Etwc: Chronic ecotoxicity in water

Etsc: Chronic ecotoxicity in soil

Etwa: Acute ecotoxicity in water

Etp: Ecotoxicity to microorganisms in sewage treatment plants

Hta: toxicity to humans via air

Htw: toxicity to humans via surface water

Hts: toxicity to humans via soil

8 Methodology task 1.4 ‘Land Use’

Final version

Prepared by CLM

Contents

1 Introduction

The objective of this subtask is the description of the ecological impact of production of biofuels on 'land use'. For this purpose, indicators have to be developed and methods chosen. According to the Technical Annex, at least indicators for *biodiversity* and for the physical aspects of *soil quality* as erosion and soil compaction should be included. Landscape will be treated as a part of task 3, the socio-economic and political assessment.

Only few quantitative methodological approaches for the assessment of biodiversity and soil quality and quantity are available. Still it is important to determine the impact for the categories biodiversity and soil quality and quantity in the overall evaluation of chains and crops for bioenergy, if we want sustainable agricultural production. A negative score of bioenergy production on biodiversity and soil quality and quantity is not very acceptable. Therefore these factors have to be taken into account, even in the case they appear to be not quantifiable. At present some methodologies for “land use” are in discussion but none of them are widely accepted neither by the scientific nor the LCA community. For this reason, we have to be (very) pragmatic.

The impact of the introduction of bioenergy production on biodiversity and soil quality and quantity should of course be compared with the impact of the reference system. It is assumed that management of the fields is done by Good Agricultural Practice.

2 Definitions

We use the following definitions of biodiversity and soil quality.

Biodiversity, or *biological diversity*, according to UNEP (1998) means the variability among living organisms from all sources including, inter alia*,* terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part. This includes diversity:

- *within species*; the diversity within species is the genetic diversity between organisms within a species;
- *between species*; the diversity between species is a level between within species and ecosystems. Data and indicators on the level of diversity between species are best available, relative to the other levels;
- *between ecosystems*; ecosystem means a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit (UNEP 1998). When we compare the energy crop and the reference crop, we replace one ecosystem by another. Habitats for wild species can change.

This definition is not fully tailored to biodiversity in agricultural systems. Using the above definition and information from FAO and the Rathenau Institute (1998) Oerlemans & Guldemond (1999) come up with a description of agrobiodiversity in three levels:

1. Variation within crops (genetic diversity) and between crops (diversity in agricultural crops).
2. Life support functions, which includes soil fauna that support agricultural production, insects for pollination of crops etcetera. This can also be called functional biodiversity.
3. Wild life species which live or grow on agricultural land, alongside agricultural crops. These species are not necessarily functional for the farming system.

The methodology in this project looks at number of species (level 3) and life support functions (level 2). We concentrate on the impact *in the field*. The effect of bioenergy production on biodiversity in the neighbouring area is not looked at.

Soil quality is an important element of life support functions. We give the following definition of a good soil: 'A soil with a good quality is able on one hand to maintain a diversified and active biological activity and a typical soil structure for the site, on the other hand to guarantee sufficient, good and safe products for man and animals in high crop yields for its type and climate'. In this definition we used some elements in the definition of soil fertility given by FAT (Wolfensberger & Dinkel 1997).

This sub-task will concentrate on *physical* aspects of soil quality, including soil quantity. The Technical Annex mentions erosion and soil compaction as examples. The chemical aspects are being viewed in sub-task 1.3. Biological aspects will be described in the paragraph on biodiversity.

3 Evaluation of methods

Proposals for methods to assess biodiversity and soil quality and quantity can be found in literature on bioenergy or literature on LCA methodology.

3.1 Biodiversity

Relevant literature on environmental assessment of bioenergy crops concern Van der Bijl & Biewinga (1997), Biewinga & van der Bijl (1996), Wolfensberger & Dinkel (1997) and Kaltschmitt & Reinhardt (1997). These studies focus on number of species (diversity), threatened species and characteristic species. Quantitative data have been used, but often expert judgements were needed to estimate the number of species. A drawback of these methods is that they are not attuned for being used within LCA. We therefore better look at the more general LCA literature.

From the LCA literature, we see that there is no standard method yet for implementation of land use indicators in the LCA methodology. So far, in most studies these incators only concern the area of land used. Some studies added changes of land use between five classes, ranging from natural systems to systems degraded by pollution and loss of soil and vegetation (Heijungs et al. 1992). This is also not very suitable for our study, as drastical changes do not occur through the introduction of energy crops; the land use remains within one system (agriculture or forest). Below two studies will be discussed, that have attempted to integrate biodiversity and soil quality into LCA. The two studies have been carried out by Cowell (1998) and Lindeijer et al. (1998).

Physical Habitat Factor

Cowell (1998) presents a so-called Physical Habitat Factor (PHF). The formula is:

PHF = 1/6 [(Ae/Amax) + 2 * (1-Re/Rmax) + 2 * (1-Se/Smax) + (1-Pe/Pmax)], where:

- Ae = area of ecosystem e in world
- Amax = largest area of any one ecosystem in the world
- Re = number of rare species in ecosystem e
- Rmax = greatest number of rare species in any one ecosystem in the world
- Se = number of species in ecosystem e
- Smax = highest number of species in any one ecosystem in the world
- Pe = Net Primary Productivity (NPP) of ecosystem e
- P = highest NPP of any one physical habitat in the world

When applying this formula to energy crops “ecosystem e” can be considered to be the energy crop. So, for our energy crops we need data on area, rare species, species and NPP.

Cowell has shown how to operationalize the method. She states that effort is needed to find good data on the number of rare species and species of “any one ecosystem in the world”. Also, further development of appropriate indicators for management practices (e.g. timing of sowing of crops) is needed. Other drawbacks are the uncertainty of the data (expert opions are needed), the low transparency of these uncertainties for the LCA user, and the disputable assumption that different ecosystems are exchangable at a certain rate.

Loss of biodiversity due to occupation

The method of Lindeijer et al (1998) is more ‘simple’. Their formula for local loss of biodiversity due to ecosystem occupation is:

$E_O = A * t * (\alpha_{nat} - \alpha_{act}) / \alpha_{nat}$, where:

- A = area (e.g. 1 ha energy crop)
- t = occupation time (e.g. 1 year)
- α_{nat} = species richness for a given area in the natural system
- α_{act} = species richness for a given area in the in actual system

α is to be calculated with the following formula:

$\alpha = (S_{mapping\ cell} - 10) / LOG10(A_{mapping\ cell} / 1\ m2)$, where:

- $S_{mapping\ cell}$ = number of species counted in a certain area (mapping cell)
- $A_{mapping\ cell}$ = area (m2) of mapping cell in which the species are counted

(The ratio behind this extra formula is that the number of species depend on the area in which you count, and the relationship between number of species and area is not linear.)

The number of vascular plants has a good link with biodiversity, also for other plants and animals. (Note however that this is not always the case, in particular not for agricultural systems.) The advantage of using this indicator is its good data availability. The method is applicable for all kinds of cases and it can be used in existing databases.

With regard to bioenergy, it shows the difference in biodiversity between energy crops and the reference system, but usually not between energy crops (as the number of species is normally one, the energy crop itself, and perhaps some weeds). Anyhow differences in land use per unity of energy produced will be shown.

Proposal: to use the method of Lindeijer et al. (1998), as this method seems applicable given the time constraint in the BIOFIT project. Default values will be used for α_{nat} (no data collection needed by the BIOFIT project team members).

As far as the method of Cowell is concerned we propose at least to collect data of rare (Red Lists) species, in order to have some indication of differences between energy crops. The general LCA discussion more and more moves towards the use of indicators that include the number of rare plant and animal species. It is not only used by Cowell but also for example in the Eco-indicator 1999. National Red Lists are available in national legislation. The number of Red List species should follow from literature or -if literature data is not available- should be estimated by experts on nature conservation. Data fields must be left blank in the case these two sources do not lead to a satisfactory result (later, default values may be used). Make explicit for which region in your country you do the assessment of rare species.

In case the area in which species are counted or estimated is not known, use 1 ha as a default value.

3.2 Life support functions of the soil

Van der Bijl & Biewinga (1997), Biewinga & van der Bijl (1996), Wolfensberger & Dinkel (1997) and Kaltschmitt & Reinhardt (1997) applied various methods to assess soil quality and quantity. Examples of these methods are: weight average load, amount of earth worms, metabolic quotient and C biomass / C dead organic matter, enzym activity of micro organisms, and the Universal Soil Loss Equation. Again, we first look at the more general LCA literature.

Cowell (1998) has defined a restricted number of factors concerning soil that could be added to LCA:

- organic matter (OM): changes in the OM level of the soil may be assessed by direct measurement, modelling or use of indicators;
- quantity of soil: generally measured as the actual or predicted mass of eroded soil during the time period under analysis, and assessed as part of the existing abiotic resource depletion impact category;
- soil compaction: assessed using a Soil Compaction Indicator.

Organic matter / free net primary biomass productivity

Organic matter (OM) in soil supports soil fauna. It has an important effect on soil productivity and on biodiversity. Changes in quantity of organic matter in soil through changes in cropping can be 1) actually measured, 2) modelled, 3) inputs of OM could be measured. Method 1 is most preferable, followed by method 2. However, these methods have their problems. Method 1 requires extra data, which should be very precise in order to see changes in OM. Method 2 requires an extra modelling step and also requires large datasets. For the BIOFIT project, method 3 seems most advisable as it is rather simple and data are easily available.

An indicator close to organic matter added to the soil is the free net primary biomass productivity (fNPP). This is simply the total biomass dry matter grown on a ha in a year (NPP), minus the biomass removed from the field in harvest. Lindeijer et al. (1998) have proposed to use fNPP as an indicator for the potential of nature development, as it expresses the amount of biomass free for development of higher species. The formula for ecosystem occupation as a measure for life support functionality is:

$EO = A * t * (NPP_{nat} - (NPP_{act} - Y))$, where:

- A = area (e.g. 1 ha energy crop)
- t = occupation time (e.g. 1 year)
- NPP_{nat} = net primary productivity in natural system (Mg/ha.yr)
- NPP_{act} = net primary productivity in the actual system (Mg/ha.yr)
- Y = yielded biomass (Mg/ha.yr)

Production data concern the dry matter. Most data is available on above ground biomass. Lindeijer et al. propose to use what they call the ‘UNEP project’ method:

NPP = sum {change in aboveground biomass + change in aboveground total dead matter + (relative rate of decomposition * aboveground total dead matter)}

Proposal: to use the method of Lindeijer et al. Default values will be used for NPP_{nat} (no data collection needed by project team members). Proposal is also to use data on the NPP over a time period of 1 year.

Quantity of soil

Specially in areas with mountains the risk of erosion is high. The quantity of eroded soil can be measured, but should in most cases (due to lack of data) be calculated with the (revised) Universial Soil Loss Equation (USLE). The formula for USLE is (e.g. Stroosnijder & Eppink 1993):

A = K * L * S * R * C * P), where:

- A = estimated soil loss (in tons)
- K = soil susceptibility to erosion
- L = slope length factor
- S = slope gradient factor
- R = rainfall factor
- C = crop and management factor
- P = erosion control factor

For our purpose we do not have to use all these factors. The first three abiotic factors (K, L and S) are fixed for a certain place, at least on a short term basis, and in principle determine the potential soil loss. We can assume on fixed figure for these factors per region. Of the remaining factors (R, C and P), the last two may change in the course of time due to land use and tillage and can influence the soil loss considerably. These three factors are most relevant for our assessment. We assume that the erosion control is carried out according to good agricultural practice, so P can be considered as a fixed factor too.

This leaves R and C as important variables. Here we propose to follow the method of Biewinga & van der Bijl (1996). They calculate a value for R * C per crop as follows:

1. The crop growth is divided into four stages:

   A-B = between start of growth and closure of the crop

   B-C = between crop closure and start of dropping leaves / dying (not applicable to all crops)

   C-D = between start of dropping leaves / dying and harvest

   D-A = between harvest and start of growth

2. For each crop stage a value for C is determined. Per definition, for a full covered and rooted soil, the C-value is 0.0. For a soil without a crop this is 1.0. Biewinga & van der Bijl

(1997) give C-values for various energy crops in the various crop stages (see Appendix 7 of their report ‘Sustainability of Energy Crops in Europe’).

3. For each crop stage the amount of rainfall (R) is determined. Data can be derived from monthly rainfall statistics.
4. Values for C and R per crop stage are multiplied (R*C) which gives the amount of harmfull rainfall. Then, the harmfull rainfall data per crop stage are summed up to give one result per energy crop.

When R * C is known, the eroded soil can be calculated if regional data are available on K, L, S and P; we could also decide to use e.g. two sets of default values. Once the figure for mass of eroded soil is obtained, resource depletion can be assessed using the formula of Lindfors et al. (1995):

soil static reserve life = R / E, where:

- R = global reserves of agricultural soil (i.e. total topsoil in world)
- E = current annual global net loss of soil mas by erosion

Cowell (1998) calculates a static reserve life of between 94 and 114 years. Of course this method is crude, because soil is not globally available.

Proposal: as USLE requires a lot of special data, we propose to focus only on the aspects that really differ between crops. We therefore propose to gather data on R (rainfall factor) and C (crop factor).

Soil compaction

Soil compaction by the use of machines is an important problem for agriculture. Compaction is related to the weight of tractors and machinery, tyre width + tyre pressure, and the soil humidity. For soil compaction two methods have been mentioned. Cowell (1998) mentions a study of Kuipers & van de Zande (1994) who have compared various methods for extimating soil compaction. They conclude that the Field Load Index “is likely to be an effective criterion for quantifying the compaction risk from field traffic on the scale of a farmer’s field”. From this Cowell derives a Soil Compaction Indicator (SCI):

SCI = A * [· W_i * T_i], where:

- A = area (ha)
- i = operation i
- W = weight of vehicle plus implement (tonnes)
- T = field time of the vehicle (hours/ha)

A more complete formula (including tyre width) comes from Wolfensberger & Dinkel (1997):

$SP = \cdot [(2ai / b) * \sigma i_{(20\ cm)} * Fi]$, where:

- SP = soil pressure (bar)
- ai = tyre width of axle i (cm)
- b = working width (cm)
- $\sigma i_{(20\ cm)}$ = pressure of axle i at a depth of 20 cm (bar)
- Fi = factor to correct for more axles that use the same path (the axle with the highest $\sigma i_{(20\ cm)}$ gets factor 1, the 2nd axle factor 0.5, the 3rd 0.25 etc.)

Both formulas do not include the clay and water content of the soil which are important too. Site-dependent aspects may have a greater influence on the actual compaction than the chosen technology. As for the water content, a link could be made with data collected for the calculation of erosion on monthly rainfall. However, there is no formula available to make this link.

Proposal: to use the most complete method (Wolfenberger & Dinkel 1997). This however requires a lot of additional data acquisition, which most probably cannot be generated in the given time by all project team members. Only FAT has good data available, at least for part of the machinery used in energy crops. We propose to include fields in the SPOLD format where the result of the soil compaction formula can be put in, in case project team members have the opportunity to do the soil compaction calculation. Note that in practice much of the fields will remain blank; in the final database estimates / default values could be used to fill these fields.

The SP formula does not contain area and time. Implicitly, the formula is about 1 ha and 1 yr.

4. Data to be collected

Bioenergy crops

The following schedule shows the qualitative and quantitative indicators and data to be collected for the bioenergy crops. The data should be collected for the reference scenarios (without bioenergy) as well as for the scenario with bioenergy. A description of the items is given in the previous paragraph.

symbol	item	data	dimension
General			
A	area	1	ha
t	time	1	yr
L	longevity (crop life) - in whole years	.....	yr
Biodiversity			
S mc	number of species of vascular plants monitored in a mapping cell	.....	-
A_S mc	size of mapping cell in which the species have been monitored	.....	ha
RP mc	number of red list plant species in a mapping cell	.....	-
A-_RP mc	size of the mapping cell of the red list plant species	.....	ha
RA mc	number of red list animal species in a mapping cell	.....	-
A_ RA mc	size of the area in which the red list animal species are found	.....	ha
Life support functions of the soil			
NPP	net primary biomass production (dry matter)	.....	Mg/ha.yr
Y	yielded biomass (dry matter)	.....	Mg/ha.yr
SP	soil pressure (of machinery) in 1 ha and 1 yr	.....	bar
TA-B	time from start of crop growth (A) to crop closure (B)	.....	months/yr
TB-C	time from crop closure (B) to start of crop dying (C)	.....	months/yr
TC-D	time from start of crop dying (C) to harvest (D)	.....	months/yr
TD-A	time from harvest (D) to new start of crop growth	.....	months/yr
CA-B	cropping factor between A and B	.....	
CB-C	cropping factor between A and B	.....	
CC-D	cropping factor between A and B	.....	
CD-A	cropping factor between A and B	.....	
RA-B	rainfall between A and B	.....	mm
RB-C	rainfall between B and C	.....	mm
RC-D	rainfall between C and D	.....	mm
RD-A	rainfall between D and A	.....	mm

By-products

There are three special cases with by-products: wood logs, straw and swine manure. In these cases, the area component is not looked at, as the activities are the same in both the reference and the bioenergy scenario. As the biodiversity and soil themes relate to land use, these cases will not have a (negative) score on these themes. This means that in principle no data have to be collected for these three cases.

However, this would not be justified for the ecosystem occupation as a measure for life support functionality (formula with NPP), as the three cases clearly remove organic matter from the forrest (wood logs), agricultural land (straw) or prohibit part of the organic matter to be returned to the agricultural field (biogas from manure). We assume the last flux can be ignored, but this will not be the case for wood logs and straw.

Data on NPP and Y should be collected for reference forrest (without extra wood log harvest), forrest with (extra) wood log harvest, reference wheat (with straw incorporation in soil) and wheat with straw harvest. Other data collection for by-products can be ignored.

symbol	item	data	dimension
General			
A	area	1	ha
t	time	1	yr
Life support functions of the soil			
NPP	net primary biomass production (dry matter)	....	Mg/ha.yr
Y	yielded biomass (dry matter)	....	Mg/ha.yr

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9 Data collection guidelines

1 Agriculture (without Land use)

Pesticide application

According to good agricultural practice (if possible including assessments of future developments)

Fertiliser application

The amounts of fertilisers should be assessed from the nutrient removed from the field with the harvested crop covering the whole crop rotation. They depends on the assumptions concerning the yields (see below).

Yields

In general the definition of future yields in agriculture can only be experts assessments in a more or less direct way. For each chain under study one of the following two procedures should be used:

The yield in 2010 is *guessed* from contemporary yields. The guess implies quantitative assumptions concerning the development. The contemporary yields best case are based on statistics, but in some cases there will be only few data of limited quality. Therefore, already the base is more or less guessed.

The yield in 2010 is *calculated* from the yields of the last years. The procedure needs a sound statistic basis and implies the assumption the developments of the past can be prolonged into the future.

IFEU should be informed on the applied procedure from all partners and concerning all chains.

Mechanical work (time expenditure)

The time consumption separately for different types of tractors and self propelled agricultural machines can be fixed directly based on practical experience or calculated by models.

Field emissions

All emissions under concern in this section are strongly influenced by soil type, climatic conditions, and agricultural practice. Since actual measurements of emissions are neither practical nor appropriate for LCA purposes, estimates or models to calculate average emission factors are required.

Please note:

- All emission factors are given now in g.
- For all substances in the **New Input Files** emissions have to be given in mass of the substance (not of the N- or P-content of N_2O, NO_3^-, PO_4^{3-} etc.).

The data as they should be used now (unit and reference, see above) are collected in Table 1-1. For avoiding discussions the data which are calculated from sources with other references are given **without** round off.

Table 1-1 List of field emissions

Substance	**Emission factors**			**Unit / Reference**
	Min	Max	**Mean**	
to Air				
NH3	0	70	40	g NH3 / kg fertiliser-N
N2O	0	47,1	19,6	g N2O / kg fertiliser-N
to Water				
NO3(-) tillage	22.143	243.571	132.857	g NO3(-) / (ha*a)
NO3(-) fallow	22.143	66.429	44.286	g NO3(-) / (ha*a)
PO4(3-)			13,4	g PO4(3-) / kg fertiliser-P2O5
sources: see text				

NH3 emissions into air due to the application of mineral fertiliser: From /ECETOC 1994/ (list of emission factors for different N-fertilisers; range: from close to zero up to about 100 g NH3-N/kg fertiliser-N) min, max and mean values are guessed. The mean was derived in /IFEU 1997/99/ as average value of mineral N-fertilisers used in Germany. /UBA_Strogies 1997/ suggested this value for the EC. For min and max values some very extreme data are neglected. Proposed data: Table 1-1.

N2O emissions into air due to the application of mineral fertiliser:

From /Bouwman 1995/ min, max and mean values are derived (min, max) or adopted (mean, 12,5 g N2O-N/kg fertiliser-N). The mean was applied in /IPCC 1997/, /Bentrup & Küsters 1999/, /IFEU 1999/ and formed the basis in /FAT 1997/ (used 9,5 g/kg). The values includes 75 per cent for direct emission and 25 per cent for indirect emissions (not taking into account emissions via airborne emissions of NH3 and NOx, which seem to be an order of magnitude smaller than the others /IPCC 1997/). Proposed data: Table 1-1.

NOx emissions into air due to the application of mineral fertiliser: NOT considered. Justification: The whole range of possible NOx emissions due to the application of fertilisers is about 20 to 100 times smaller than burning the biomass, related to the same functional unit. As the error for estimating NOx emissions due to the use of biomass is very likely bigger than 5 % the NOx emissions due to the application of fertilisers are neglected.

Nitrate into (ground) water: The procedure of CLM should be applied:

- **Calculation of the "nitrogen (N) load to soil":** This calculation is done by the following equation: N load to soil = N fertiliser input + N-deposition - N output in harvested parts of the crop - ammonia emission. The units are all "kg N per ha".

- **Calculation of the "nitrogen leaching to water":** X% * N load to soil is emitted to water (surface water and ground water). For The Netherlands a rough estimate of X% is 43%, which is the country's average from national statistics. You could also try to find more region or even field specific data for the estimation of X%. Note however that field data must be representative for a certain region.

The CLM approach requires a good literature source, which will not be available in all countries (NL: "Background document agriculture of the National Environmental progress report" of the governments institute for people's health and environment).

In the case the CLM method is not applicable defaults related to the area are suggested (basis: /Audsley 1996/; range: 5.000 to 60.000 g N/(ha*a), compared to other sources omitting extreme values). Proposed data: Table 1-1.

Phosphate into water: Based on /FAT 1997/ (10 g Phosphate-P/kg fertiliser-P) the value which should be used is calculated (p-emissions due to erosion might be negligible). Proposed value: Table 1-1.

Heavy metals: The procedure according to /FAT 1997/ is applied. Data for HM content of fertiliser, HM content of agricultural products and HM losses by drainage water are provided by FAT (European averages applied for all countries). Country specific data have to be collected for the following parameter: deposition of HM (mg/(ha*a), HM content of agricultural soil (mg/kg), soil losses (kg soil/ha).

Pesticides: Amount of pesticide ingredients applied should be used.

2 Conversion and use

Data for energy consumption should be adopted or assessed from actual plants. The principles for determination of emissions are given by the following tables. Concerning the methane emissions of the biogas chain some default values are given below.

Table 2-1a List of units, possible sources and principles for determination of emissions for various substances emitted to the environment

Substance / recipient	**Unit**	**Possible source**	**Principles for determination of emissions**
Emissions to air			
CO_2	g	Combustion of fossil fuels	See average emission factors for different fuels in Table 3. Only emissions from fossil fuels are relevant.
CO	g	Combustion processes	Emissions are specific for combustion processes. Use specific emission factors representative for the actual fuel as well as the actual combustion process.
NO_x	g	Combustion processes, fertilizer production	Emissions are specific for combustion processes. Use specific emission factors representative for the actual fuel as well as the actual combustion proces. Fertilizer prod.: specific for fertilizer plants and production methods. Use emission factors representaive for the actual technology. Emissions vary significantly among plants.
SO_2	g	Combustion of fossil fuels containing sulfur	Emissions are only relevant for fuels containing sulfur. Use mass balance investigations based on 100% of the the sulfur content of the specific fuel or emission factors for the specific fuel.
N_2O	g	combustion processes, fertilizer prod.	Fertilizer prod.: specific for fertilizer plants and production methods. Use emission factors representaive for the actual technology. Emissions vary significantly among plants. Emissions are specific for combustion processes. Use specific emission factors representative for the actual fuel as well as the actual combustion process.
NH_3	g	combustion proc., fertilizer prod.	Fertilizer prod.: specific for fertilizer plants and production methods. Use emission factors representaive for the actual technology. Emissions vary significantly among plants. Emissions are specific for combustion processes. Use specific emission factors representative for the actual fuel as well as the actual combustion process.

Table 2-1b List of units, possible sources and principles for determination of emissions for various substances emitted to the environment

Substance / recipient	**Unit**	**Possible source**	**Principles for determination of emissions**
Emissions to air			
CH_4	g	combustion processes, specific industrial processes	Emissions vary significantly among plants. Emissions are specific for combustion processes. Use specific emission factors representative for the actual fuel as well as the actual combustion process. For industrial processes: Use specific emission factors for each process.
HCl	g	Combustion processes	Only relevant when Cl is present (e.g. waste incineration). Emissions vary between plants due to processvariations and variations in environmental protection units installed. Average emission factors can represent groups of plants.
NMVOC	g	Combustion processes and specific industrial processes	NMVOC = Non Methane Volatile Organic Compounds. Emissions are specific for combustion processes and fuels. Use specific emission factors representative for the actual fuel as well as the actual combustion process. For industrial processes: Use specific emission factor for each process
Benzene	g	Specific industrial proc. and comb. processes.	Use specific emission factors for each process. Emissions are specific for combustion processes and fuels. Use specific emission factors representative for the actual fuel as well as the actual combustion process.
Benzo-A-pyrene	g	Combust. proc. in general.	Use specific emission factors for each process.
Dioxines	g	Combustion processes	Only relevant when Cl is present (e.g. waste incineration). Use specific emission factors representative for the actual combustion proces. Note that some incineration plants are equipped with dioxin removal facilities.
Heavy metals cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), mercury (Hg), manganese (Mn) , lead (Pb), selenium (Se) and zinc (Zn)	g	Combustion processes	Specific for fuels. Can be determined by massbalance investigationsor emission factors. Note that some plants are equipped with fly ash removal facilities which reduces air emissions of heavy metals. Masses of heavy metals should refer metal itself (do not include mass of eventual ligands). If possible, please provide information about the actual chemical form of the metal in the inventory,

Table 2-1c List of units, possible sources and principles for determination of emissions for various substances emitted to the environment

Substance / recipient	**Unit**	**Possible source**	**Principles for determination of emissions**
Emissions to water			
NH_3	g	Fertilizer prod.	Fertilizer production: specific for plants and production methods. Use specific emission factors. Emissions can vary significantly among plants.
NH_4^+	g	Fertilizer prod.	Fertilizer production: specific for plants and production methods. Use specific emission factors. Emissions can vary significantly among plants.

Table 2-2 List of units, possible uses of various resources and of heating values currently used by FEU for common data sets

Ressource	**Unit**	**Heating value MJ/kg**	**Possible uses**	**References / Comment**
Crude oil	kg	42,68	Energy production	AGE
Natural gas	kg	44,0	Energy prod./fertilizer prod.	AGE/DGMK
Coal	kg	29,79	Energy production	AGE
Lignite	kg	8,86	Energy production	AGE
Uranium	kg	(4E+06)	Energy production	based on /Ecoinvent 1996/
Water	kg	-	Irrigation + industrial use	Water consumption (of ground water). Differences in infiltration are to be included only for areas where water is depleted.

AGE: Work group „Energy Balances“

DGMK: German Society for Oil and Coal Research

The present data are approximate because composition and quality of each energy sources varies.

Table 2-3 Approximate carbondioxide emission factors for various fossil fuels currently used by FEU for common data sets

Fuel	Emission factor g CO_2 / kg fuel	Reference
Light oil / diesel	3172	AGE/UBA
Heavy fuel oil	3186	AGE/UBA
Gasoline	3172	AGE/UBA
Natural gas	2411	AGE/UBA
Coal	2740	AGE/UBA
Lignite[2)]	975,4	AGE/UBA
Uranium	0	-

AGE: Work group „Energy Balances“
UBA: German Federal Environmental Agency
1) The present data are approximate because composition and quality of each energy sources varies.
2) The coal content of lignite varies significantly and the present emissions factor is only a rough average value.

Methane emission from swine manure

Methane emission (kg CH4/ton manure) from (not fermented) swine manure is calculated as 0,095 * organic matter content of manure (kg/ton) (source: Zeeman 1994 and 1999).

Methane emission from fermented swine manure is supposed to be 0 because all the CH4 emitted will be collected by the biogas installation and combusted to produce energy.

Defaults: If the organic matter content of the manure is not known we could use 60 kg/ton manure as a default for org. matter content. That results in a default for CH4 emission for (not fermented) swine manure of 5,7 kg/t manure.

3 Land use

General

Area and time: • we agreed to use a standard for area and time of 1 ha and 1 year, respectively. In case your figures are measured for other areas and time periods, recalculate them to fir our standards.

Longevity: • minimum crop life is one year.

Life support functions of the soil

3.1 Ecosystem occupation (CLM)

NPP is built up of components from 3 fractions, i.e. living material, dead material, and decomposed material. We interpret the formula for NPP (called the UNEP project method) as follows:

NPP = sum {change in living matter + change in aboveground dead matter + {relative rate of decomposition * aboveground dead matter)}

Note that we include the whole plant to assess living matter, in order to make up for the harvested roots.

For annual crops, we assume that there is no plant material present at the beginning and at the end of the time period of a year. For perennials, it is needed to assess on a yearly base, how much new plant material is grown, and how much is lost to the soil.

example: sugarbeet

At harvest, sugar beet consists of three parts: leaves, heads, and roots. The latter is harvested, thus only leaves and heads are available for decomposition. For our calculations, we use data on the dry matter weight of leaves, heads, and roots (Smit, 1990) and we assume that dead material is included in the dry matter weights. Data on decomposition come from Handboek voor de Akkerbouw (1989).

• leaves: 5.7 Mg/yr dry matter, rate of decomposition: 80%, remaining after one year for the life support function of the soil: 1,14

• heads: 1.5 Mg/yr dry matter, decomposition rate 65%, remaining 0,525

• roots: 17.9 Mg dry matter

NPPact = 5.7 + 1.5 + 17.9 + 1.14 + 0,525 = 26.765

For NPPnat we use a standard figure from Lindeijer (1998): 8. Now we can calculate the ecosystem occupation by sugarbeet is calculated using the formula:

EO = A * t * (NPPnat - (NPPact - Y))

EO = 1 * 1 * (8 - (26.765 - 17.9)) = 0.865

The meaning of this figure will become clear after calculation of EO for the reference, i.e. grass fallow.

3.2 Soil Pressure (FAT)

The calculations were made according to the method described in Wolfensberger and Dinkel (1997) which was derived from empirical studies. Yet only worst case scenarios with fully loaded harvest machines were looked at. For the parameter ‘weighted soil pressure’ the average pressure on the whole field is calculated. Together with the parameter ‘area driven on’ it indicates the danger of deformation of soil particles or smearing and is especially important on clay soils. The parameter ‘maximal pressure in a depth of 20 cm’ on the other hand is more important for loamy and sandy soils and indicates the risk of soil compaction. Depending on the soil type the one or the other two indicators are more relevant.

SPweighted = Σ [(2ai / b) * σi(20 cm) * Fi], where:
- SP = weighted soil pressure (bar)
- ai = tyre width of axle i (cm)
- b = working width (cm)
- σi(20 cm) = maximal pressure of axle i at a depth of 20 cm (bar)
- Fi = factor to correct for more axles that use the same path (the axle with the highest σi(20 cm) gets factor 1, the 2nd axle factor 0.5, the 3rd 0.25 etc.)

$$\sigma(20\ cm) = \frac{r}{c} * \left[1 - \left\{ \frac{20}{\left(20^2 + \frac{c}{3.1416}\right)^{0.5}} \right\}^{kv} \right] \qquad \text{with } c = a * d * 0.2697$$

- $\sigma i(20\ cm)$ = maximal pressure of a tyre at a depth of 20 cm (bar)
- r = load on tyre
- c = contact area between tyre and soil
- a = tyre width
- d = tyre diameter
- kv = factor for soil situation

3.3 Quantity of soil (CLM)

TA-B etc.: • obtain these figures from agricultural research in your country.

CA-B etc.: • use the relevant figures in Table 1 (see below).

RA-B etc.: • obtain these figures from rainfall data in your country.

For values of K, L, S and P we will make use of standard figures, to be gathered by CLM, with possibly help from some of the partners.

Crop and crop management factor (source: Biewinga & Van der Bijl, 1996).

Per definition, for a fully covered and rooted soil, the C-value is 0.0. For a soil without a crop (no cover, no roots), the C-value is 1.0 (Stroosnijder & Eppink 1993). For intermediate situations, we make some assumptions, using figures from Wischmeijer as stated by Stroosnijder & Eppink (1993):

- during the closed crop stage, a full leaf cover reduces the C-value to 0.4; depending on row and plant distances and root intensity, the value is reduced further to a minimum of 0.0;
- before crop growth, for most crops no leaf cover is present; then roots and stems can reduce the C-value to a minimum of 0.3; for winter crops, where some leaves and small roots are present, we assume a reduction to 0.6 (for grass fallow, sown in September, to 0.3);
- during early crop growth, the C-value gradually declines from the level before crop growth to the level during closed crop; therefore, for this stage we take the average of those two levels;
- during the stage of dying crop, leaves gradually disappear, but stems and roots stay behind; then the C-value rises from the level during closed crop to 0.3 to 0.5; therefore, for this stage we take the average of those two; for grass fallow we assume ploughing under in September again.

Table 3-1 gives resulting assumptions for C-values which we can use in our calculations. For perennial crops these are averages of the values during early and later years.

Table 3-1 Values used for the crop and crop management factor (C-values)

	D-A	A-B	B-C	C-D
crop	(before growth)	(early growth)	(closed crop)	(dying)
rape seed	0.60	0.38	0.15	0.23
sugar beet	1.00	0.60	0.20	0.25
winter wheat	0.60	0.35	0.10	0.20
sweet sorghum	1.00	0.63	0.25	0.33
maize	1.00	0.63	0.25	0.33
hemp	1.00	0.58	0.15	0.23
miscanthus	0.48	0.31	0.13	0.22
poplar	0.53	0.37	0.21	0.31
willow	0.44	0.28	0.12	0.21
eucalyptus	0.52	0.37	0.21	0.31
grass fallow	0.30	0.18	0.05	0.18

Example for sugar beets in the Netherlands

symbol	**item**	**data**	**dimension**
General			
A	area	1	ha
t	time	1	yr
L	longevity (crop life) - in whole years	1	yr
Life support functions of the soil			
NPP	net primary biomass production (dry matter)	26.765	Mg/ha.yr
Y	yielded biomass (dry matter)	17,9	Mg/ha.yr
SP	soil pressure (of machinery) in 1 ha and 1 yr	....	bar
TA-B	time from start of crop growth (A) to crop closure (B)	2	months/yr
TB-C	time from crop closure (B) to start of crop dying (C)	4	months/yr
TC-D	time from start of crop dying (C) to harvest (D)	0	months/yr
TD-A	time from harvest (D) to new start of crop growth	6	months/yr
CA-B	cropping factor between A and B	0.60	
CB-C	cropping factor between A and B	0.20	
CC-D	cropping factor between A and B	0.25	
CD-A	cropping factor between A and B	1.00	
RA-B	rainfall between A and B	128	mm
RB-C	rainfall between B and C	286	mm
RC-D	rainfall between C and D	0	mm
RD-A	rainfall between D and A	339	mm

4 Normalisation

The results of the Life cycle inventory analysis (LCI) and Life cycle impact assessment (LCIA) respectively are expressed in terms “average impact per inhabitant” for each country. These values are produced in the following way:

> For each country, the energy and emission balances are calculated for every sector and all LCIA parameters. These sums are divided by the number of inhabitants.

For the balance parameters and number of inhabitants the reference year 2010 shall be used. The values for CO_2-equivalents and SO_2-equivalents are calculated in the same way as for individual product life cycles, unless they are directly available from the respective data source.

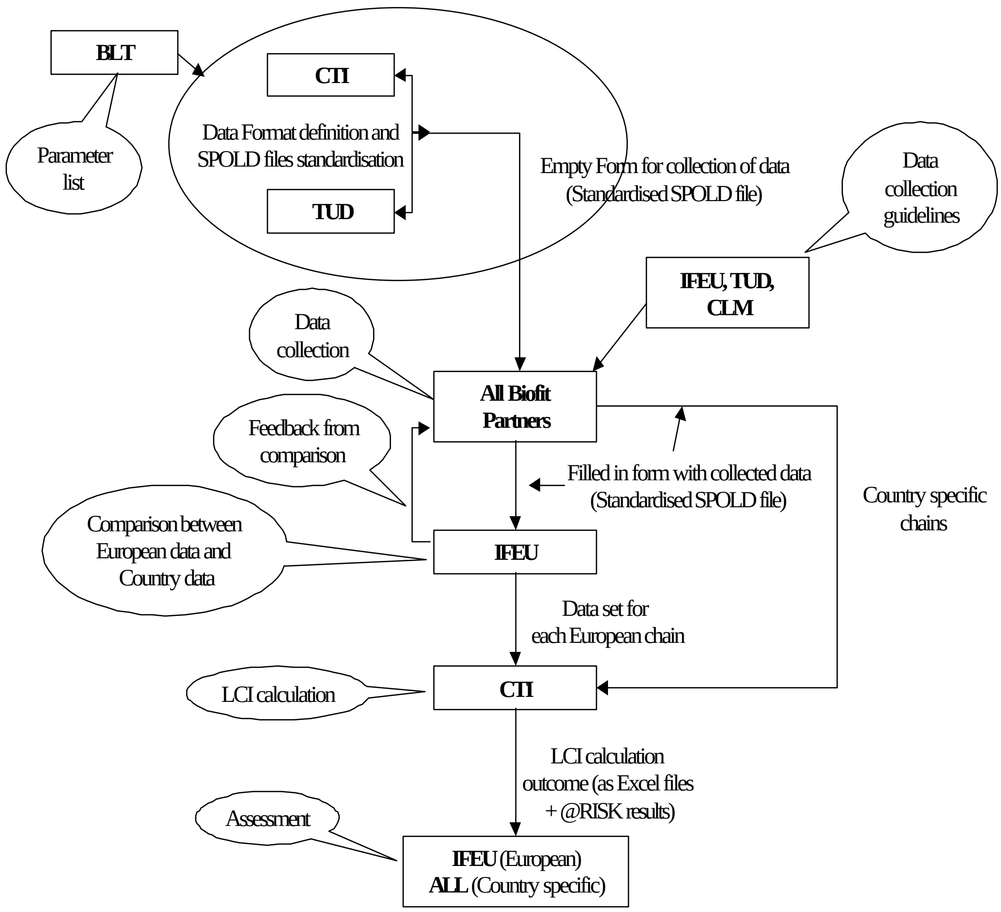
For individual parameters other reference units might also be sensible:

- With regard to land area, the area of a whole country could be used as an alternative to agricultural area only.
- Besides the pesticides listed in the LCIA, alternatively the total amount of all pesticides used in each respective country could be used.

In any case all countries, i. e. partners, have to follow the same procedure (decision to be reached in Athens).

Andreas Patyk, Guido Reinhardt, Ulrich Höpfner, IFEU, Heidelberg, 29.03.2000

10 Flow scheme “data collection”



Annex to Chapter 4

11 Results 'Land Use and Biodiversity'

Prepared by CLM

Results on Ecosystem occupation

Ecosystem occupation (EO) has been calculated using the formula of Lindeijer et al. (1998). In short, the value of ecosystem occupation by a crop is calculated by subtracting its free net primary production (fNPP) from the fNPP of the natural system, with fNPP calculated as the difference between primary production and yield. This means that, in general, harvest of only seeds results in a higher fNPP than the case in which whole plants are harvested. Thus, a value for fNPP higher than that of the natural system results in a negative value for EO, indicating a larger contribution to the availability of biomass for the development of biodiversity than supplied by the natural system. Likewise, an fNPP-value lower than that of the natural system results in a positive value for EO, indicating that less biomass is available for life support than with the natural system. When EO is zero, agricultural and natural system are equal in their life support.

Table 1 gives the results obtained for ecosystem occupation per country. For natural conditions, a default value of 8 for the fNPP is assumed (Lindeijer et al.). Ecosystem occupation for the reference systems grass fallow and wood is zero.

Observations

- For a number of crops the fNPP values are difficult to assess, due to a lack of data for aboveground production, root production and corresponding decomposition rates. In many cases only a mean value could be given, while in other cases values are estimates rather than hard figures. Hence the results should be interpreted with care. No sensitivity analysis could be made.
- fNPP values and yield data for the same crop differ between countries. Examples for FNPP:
  - triticale: from 12 (Denmark) to 24 (France);
  - wheat straw: from 5 (Greece) to 22.2 (France);
  - sugar beet: from 11.7 (France to 26.8 (Netherlands).

  Examples for yield:
  - rape: from 2.7 (Austria) to 6.4 (Germany);
  - miscanthus: from 7.5 (Denmark) to 16.8 (Netherlands).

  These differences may be partly explained by differences in the interpretation of the calculation method. For example, for assessment of yield (dry weight), no clear procedure was followed.

  Apart from methodological errors, the differences may well depend on differences in management practises between regions and countries, e.g. method of harvest. In addition, climate and soil differences may play have a substantial influence.
- The ordering of crops according to their result on ecosystem occupation differs between countries. For instance, sugar beet has the highest ecosystem occupation in Germany,

and the lowest in the Netherlands. Similarly, triticale has the highest score in Denmark, whereas in France it has the lowest value. These differences need to be explored further in order to understand them.

- In some countries, EO values for rape, triticale and wheat turn out to be negative. This implies that these crops in these soils are better in providing FNPP than the average FNPP in Mid-Europe. Maybe information on soil structure could explain the differences, perhaps in combination with the yearly addition of organic matter.
- In some countries rape is followed by a grass filler crop in the same year. Hence in our comparison with grass fallow as a reference crop we would have to sum up the figures for EO by rape and grass filler crop, if they were available.
- In Austria, rape may substitute cattle fodder on the fields; in doing so, more cattle feed needs to be imported, e.g. soybean from Brazil. The cultivation of soybean takes place at the expense of tropical rainforest. Therefore, we might use values for the ecosystem occupation from the tropical rainforest and soybean as reference values for rape.

Conclusions

Concerning the impact of energy crops on land use as assessed by the method for Ecosystem occupation by Lindeijer et al. (1998) the following conclusions can be drawn:

- The assessment of the impact of land use by energy crops could only partly be carried out due to a lack of data. Most gaps were found in data concerning the weight and the rate of decomposition of the fractions of plant material.
- No data are available to validate the results obtained so far with this method. Hence the value of using Lindeijer method could not be ascertained.
- The method does not take into account the scarcity of ecosystems and their reproducibility. Therefore, results obtained with this method should be interpreted with care.
- There appears to be a difference in the impact on land-use between cereals, perennials, and other crops. More research is needed to verify and explain this result.

References: Lindeijer et al., 1998.

Tabel 1 Ecosystem occupation

	NPP mean	**NPP min**	**NPP max**	**Y mean**	**Y min**	**Y max**	**EO mean**	**EO min**	**EO max**	**Sources**
Austria										
triticale	10,1	8,1	12,1	8,7	7,0	10,4	6,6	6,9	6,3	
wheat straw	8,7	8,6	12,8	9,3	7,4	11,1	8,6	6,8	6,3	
rape	8,9	7,1	10,7	2,7	2,2	3,3	1,8	3,1	0,6	
ref: soybean Brazil		16,0	22,0							
ref: trop. rainforest	12,0									
Denmark										
triticale	12,5	6,2	16,1	11,6	3,6	16,2	7,1	5,4	8,1	NPP: estimate, Y: Nielsen & Kristensen, 1998
willow	8,5	6,6	10,5	7,5	5,6	9,5	7,0	7,0	7,0	NPP: est., Y: Gamborg, 1996
miscanthus	8,5	7,0	10,0	7,5	6,0	9,0	7,0	7,0	7,0	NPP: est., Y:Parsby & Rosenqvist, 1999
rape	16,0	14,0	18,0	2,8	2,3	3,2	-5,2	-3,7	-6,8	NPP: est., Y:Parsby & Rosenqvist, 1999
wheat straw incorp.	12,5	6,2	16,1	7,5	6,7	8,3	3,0	8,5	0,2	NPP: est., Y: DAAC
wheat straw harv.	12,5	6,2	16,1	11,6	5,5	15,0	7,1	7,3	6,9	NPP: est., Y: DAAC
France										
triticale	24,0			12,0			-4,0			
rape	11,7			3,5			-0,2			
sugar beet	11,7			14,1			10,4			
sunflower	9,6			3,0			1,4			NPP: CRES
miscanthus										
wheatstraw	22,2			12,0			-2,2			Inra: input not correct
wheat	22,2			12,0			-2,2			
Germany										
miscanthus	10,7			10,1			7,4			
rape	7,4			6,4			7,0			
sugar beet	13,5			13,2			7,7			
triticale	12,1			9,0			4,9			
wheat straw	14,4			11,3			4,9			
willow	8,7			6,9			6,2			
Greece										
sunflower	9,6			0,1			-1,5			NPP: CRES
wheat straw incorp.	5,0			2,5			5,5			
wheat straw harv.	5,0			5,0			8,0			

Tabel 1 Ecosystem occupation (continuation)

	NPP mean	NPP min	NPP max	Y mean	Y min	Y max	EO mean	EO min	EO max	Sources
Italy										
sunflower	9,6	4,1	15,0	2,9	1,4	3,8	1,3	5,3	-3,2	
References										
grass fallow	4,0	3,0	5,0	0,0	0,0	0,0	4,0	5,0	3,0	NPP: est., Y: Djurhuus, 1986
fossil fuel	2,0	1,0	8,0							Lindeijer et al., 1998
Netherlands										
sugarbeet	26,8			11,8			-7,0			NPP: Smit, 1990, Handboek voor de Akkerbouw, 1989, Y: B&B, 1996
hemp	14,9			13,0			6,1			NPP: Coelman, 1996,Y: B&B, 1996
miscanthus	10,7			16,8			14,1			NPP: est., Y: B&B, 1996
willow	8,7			15,4			14,7			NPP: est., Y: B&B, 1996
Switzerland										
rape seed				2,8	2,4	3,2				
wood logs for energy	12,0			10,7			10,7			NPP: Lindeijer et al., 1998
ref: forest	12,0			0,0						NPP: Lindeijer et al., 1998

Results on Erosion

An indication of the erosion hazard during a calendar year is obtained using data, per cropping stage, for the cropping factor (C) and rainfall (mm). The amount of harmful rainfall is calculated as the sum of C*R per cropping stage. Generally speaking, the higher C*Rtotal, the higher erosion hazard exists.

Following the method from Nonhebel (1995), the following cropping stages are identified: A: start of leaf development, B: a full vegetation cover has developed, C: start of leaf degeneration, D: leaves have disappeared or crop is harvested. For perennials, we use these data as assessed in full growth.

Per definition, for a fully covered and rooted soil, the C-value is 0.0. For a soil without a crop (no cover, no roots), the C-value is 1.0 (Stroosnijder and Epink, 1993). For intermediate situations, we use figures from Biewinga and Van der Bijl (1996), as well as for perennial crops, for which the data are averages of the values during early and later years.

Data and results of the calculations are presented in Table 2. Regarding the energy crops, the amount of harmful rainfall varies from 138 (willow in Germany) to 695 (sunflower in Italy). In contrast, the amount for grass fallow varies from 56 (Austria) to 143 (Netherlands).

Observations

- Rape seed appears to results in high values for harmful rainfall and thus erosion. However this crop is generally followed by grass fallow as a soil cover. This reduces the risk for erosion.
- As shown in Germany and the Netherlands, perennial crops cause lower erosion risks than annual crops. This may well be explained by the provision of winter cover.
- From the annuals, wheat and triticale appear to result in lower erosion risks than sugar beet and rape. This is possibly due to the wider row distances with the latter.
- Top 3 in erosion hazard is: sunflower, hemp, and sugar beet.

Conclusions

Concerning the impact of energy crops on erosion as assessed by the method of harmful rainfall, we conclude the following:

- The method uses readily available data and can easily be carried out. However, factors not included in this method may play a large role in the occurrence of erosion. Therefore, the method needs validation with actual data on erosion.
- For perennial crops, the method does not include the starting years in which erosion risks are higher than in subsequent years. Therefore, results for perennials may be overestimated.
- The method may be improved by including factors to assess the effect of management practises on erosion risk.
- Following this method, soil cover is the best way of reducing the harmful effect of rainfall. This is demonstrated by the lower erosion risks from perennial crops and cereals with a close row distances.

References

Biewinga & Van der Bijl, 1996 / Nonhebel, 1995 / Stroosnijder & Eppink, 1993

Table 2 Erosion

	cropping factor				**rainfall**				**C*R**				**Total C*R**	**Year rainfall**	**Sources**
	AB	**BC**	**CD**	**DA**	**AB**	**BC**	**CD**	**DA**	**AB**	**BC**	**CD**	**DA**			
Austria															
triticale	0,35	0,1	0,2	0,6	226	259	0	64	79	26	0	38	143	1990	?
rape	0,38	0,15	0,23	0,6	468	281	0	215	178	42	0	129	349	1990	?
wheat straw	0,35	0,1	0,2	0,6	226	259	0	64	79	26	0	38	143	1990	?
grass fallow	0,18	0,05	0,18	0,3	173	0	0	82	31	0	0	25	56	1990	?
Denmark															
triticale	0,35	0,1	0,2	0,6	67	508	0	141	23	51	0	85	159	?	DAAC, DMI
rape	0,38	0,15	0,23	0,6	487	155	0	64	185	23	0	38	247	?	DAAC, DMI
willow	0,28	0,12	0,21	0,44	141	136	222	205	39	16	47	90	193	?	DAAC, DMI
miscanthus	0,31	0,13	0,22	0,48	141	136	222	205	44	18	49	98	209	?	DAAC, DMI
grass fallow	0,18	0,05	0,18	0,3	70	505	0	129	13	25	0	39	77	?	DAAC, DMI
France															
triticale	0,35	0,1	0,2	0,6	309	167	0	163	108	17	0	98	223		
rape	0,38	0,15	0,23	0,6	361	167	0	111	137	25	0	67	229		
sugar beet	0,6	0,2	0,25	1	98	223	0	318	59	45	0	318	421		
sunflower	0,63	0,25	0,33	1	75	97	0	546	47	24	0	546	618		
miscanthus	0,31	0,13	0,22	0,48											
wheatstraw	0,35	0,1	0,2	0,6	309	167	0	163	108	17	0	98	223		
grass fallow	0,18	0,05	0,18	0,3											
Germany															
wheat	0,35	0,1	0,2	0,6	310	223	0	129	109	22	0	77	208		
rape	0,38	0,15	0,23	0,6	415	176	0	71	158	26	0	43	227		
sugar beet	0,6	0,2	0,25	1	176	250	0	236	106	50	0	236	392		
triticale	0,35	0,1	0,2	0,6	310	223	0	129	109	22	0	77	208		
miscanthus	0,31	0,13	0,22	0,48	269	271	88	34	83	35	19	16	154		
willow	0,28	0,12	0,21	0,44	46	183	379	54	13	22	80	24	138		

grass fallow	0,18	0,05	0,18	0,3	130	307	128	87	23	15	23	26	88		

Table 2 Erosion (continuation)

	cropping factor				rainfall				C*R				Total C*R	Year rainfall	Sources
	AB	**BC**	**CD**	**DA**	**AB**	**BC**	**CD**	**DA**	**AB**	**BC**	**CD**	**DA**			
Greece															
sunflower	0,63	0,25	0,33	1	86	45	0	326	54	11	0	326	391		
grass fallow	0,18	0,05	0,18	0,3											
Italy															
sunflower	0,63	0,25	0,33	1	124	64	80	574	78	16	26	574	695	1960-1990	?
Netherlands															
sugarbeet	0,6	0,2	0,25	1	138	286	0	339	83	57	0	339	479	1990	B&B, 1996
hemp	0,58	0,15	0,23	1	69	186	67	441	40	28	15	441	524	1990	B&B, 1996
miscanthus	0,31	0,13	0,22	0,48	95	260	0	408	29	34	0	196	259	1990	B&B, 1996
willow	0,28	0,12	0,21	0,44	128	138	117	379	36	17	25	167	244	1990	B&B, 1996
grass fallow	0,18	0,05	0,18	0,3	106	293	0	364	19	15	0	109	143	1990	B&B, 1996
Switzerland															
rape seed	0,38	0,15	0,23	0,6	278	512	260	112	106	77	60	67	309	1970-1998	
grass fallow	0,18	0,05	0,13	0,3	288	1485	0	570	52	74	0	171	297	1970-1998	

Annex to Chapter 5

12 Methodology for task 3 'Socio-economic and political analyses (SEPA)'

Final version

Prepared by CLM

Objectives

According to the technical annex this task has "to give an overview on probable social effects of an extended production of biofuels in the Community and the effect of current legislature to the production of biofuels". Ultimate goal of this task is (as we agreed during the KOM):

- to combine the environmental results from tasks 1 and 2 with socio-economic and political information;
- to indicate the chances for the best environmental chains for biofuels from an socio-economic and political point of view.

In essence, we propose to make an inventory of the issues involved, aiming at a description of events and developments and presenting hard figures only if these are readily available. For the inventory the project team members should try to make efficient use of *existing literature on bioenergy* and *expert knowledge*. If you find out during your study that these sources are not sufficiently available, contact CLM or IFEU to discuss on which issues you should concentrate.

Methodology

The methodology falls into three parts. The first part on socio-economic effects is quantitative. For the cost calculation the results from task 2 can be used, supplemented with price data. The second and third part are qualitative and contain effects on landscape and the policy and political arguments per country in favour or against certain biofuel chains.

<u>Socio-economic effects</u> (fill in per energy chain)

Nr./Action by ...	Description
1.1 / ALL	*Costs per ha yr*. Costs should be provided for the reference system (fossil energy and - in most cases - fallow land) and for the various biofuel systems. The costs should include farm activities, transport, preconversion, conversion, logistics and end-use. (See the Appendix for more information; here you also find information on how to deal with energy from by-products). The costs per ha yr can be easily related to the costs of avoided CO2 (EURO per ton CO2) or to the costs of bioenergy produced (e.g. EURO per GJ, litre or kWh) in the participating countries.
1.2 / ALL	*Gap between the production costs of biofuels as compared to fossil fuel*. This gap clearly follows from the calculation above. (This information may

form the basis for an inventory of possible economic instruments to stimulate the production of biofuels at a national level as well as at the level of the EU.)

1.3 /ALL *Employment*. Here, an valuation is asked of the effects of introducing biofuels on employment. Provide an estimate of labour requirement, if posible for the whole chain. This also includes the employment effects in the reference system (effects for the fossil fuel industry), of which data may be derived from national statistics.

1.4 / CLM Effect on income distribution between regions. Does the implementation of energy crops in the various EU regions influence the competitiveness between the regions? And if so, do the ‘poor’ regions benefit or loose? These questions will be answered qualitatively by CLM. Three sources of information are needed. First the ‘gap between the production costs of biofuels as compared to fossil fuel’. This shows the potential benefits for a region; if the gap is large (in a negative sense) the potential benefits are smaller than in a region where the gap is small. Second, the possible area for growing bioenergy is of importance. Regions with a large possible area benefit more than regions with no available area. Information on this will follow from ‘future land claims’ (see ‘political factors’). The possible area largely depend on the opportunity costs (difference with existing agricultural crops). Third, information is needed on the relative importance of fossil fuel production and refinery in the various EU countries. These data can be extracted from general statistics, e.g. Eurostat. Note that the Biofit project team members do not need to provide additional information with regard to ‘effect on income distribution’.

<u>Landscape</u> (fill in per energy chain)

Nr./Action by ... Description

2 / ALL *Effects on landscape*. We propose to concentrate on the effect of bioenergy production on the aesthetic, visual ‘perceptive value’ (or ‘quality’ or ‘identity’) of the landscape, with special attention to the variation of elements in the landscape. The perception of landscape partly depends on individual taste and varies from region to region. Full ‘scientific’ assessments take years, therefore we propose a simple procedure (no field trials) which can largely be carried out by the project team itself. Every partner should be able to evaluate the impact of bioenergy production on landscape in their region with this method. We ask you to follow a two-step procedure:

2.1 • Look at the existing variation in the region. Start with a description of the visual structure (pattern) and dominating colours of the landscape in the regions where the production of bioenergy is most likely introduced. This is an indication of the current identity of the landscape. Describe then the colour and texture (e.g. height and density) of the reference and the new crops (Biewinga & Van der Bijl 1996). Also describe area sizes and border lenghts. Then, compare the descriptions of the landscape with reference crops and with new crops and determine if there is a change in variation of the landscape.

2.2 • If the introduction of bioenergy production changes the variation of the landscape, this can have a positive or negative effect on the quality (identity) of the landscape. The actual score depends on the perceptive value in the specific region. Try to find out whether the change is perceived as positive, neutral of negative by the public (literature, expert opinions).

Political factors (general for bioenergy)

Nr./Action by ... Description

3.1 / ALL *Future land claims*. One condition for growing energy crops is that in 2010 part of the agricultural area is not needed for food production anymore. There are many land use potentials other than energy crops. In some European areas there is a large pressure on land, in others land abandonment may occur. In some areas there is a large increase in land for non-agricultural purposes. Demand for agricultural products and yield per ha determine the amount of land used for agriculture. Agricultural policy is one of the main factors.

We propose to include a short qualitative study containing:

1) Which are the most important trends/tendencies you see in politics/policies with regard to the utilization of land?

2) What are the consequences of political choices and claims on the future availability of land for growing energy crops?

3.2 / ALL *Alternative energy sources*. Bioenergy is one of the possible alternatives for fossil energy sources. Here the idea is to describe qualitatively the forces and policies that promote the use of the biofuels from our study, and those which promote the use of other alternative energy sources (e.g. wind, solar, nuclear). The idea is that there is a fixed budget for promoting alternative energy sources, so the lobby of interest groups will be on the division of this budget between the various types of alternative energy. Each project team member is asked to focus on his own country. First, summarize the main policies that exist or will come into force, which influence alternative energy sources. Second, give a short overview of the viewpoints of the authorities with regard to bioenergy in relation to other alternative sources, at least the national and/or regional ministries of agriculture, environment and economic affairs. Give also the viewpoints of interest groups: farmers organisations, environmental organisations, fosil fuel companies and potential bioenergy processors. You may add more viewpoints if you think important actors are missing.

3.3 / ALL *Legislation*. Do legal aspects exist at national levels and at the EU-level which may prevent or promote the production of biofuels?

3.4 /CLM *Summary of political arguments* (pros and cons) to stimulate specific biofuels and chains at regional, national and/or EU-level. This summary will be drawn by CLM from the three items mentioned above, and may be supplemented with other political arguments which not have been mentioned yet.

Expected contribution of partners

From each partner a contribution is expected relevant for its country, which consists of:

- collecting of information from literature and experts (economists), filling in the cost format;
- analysing of the information;
- writing of a summary for their own country, for the socio-economic, landscape and the political part, using the numbering that is indicated above;
- participation in discussions on this task during a workshop;
- commenting on the synthesis of the contributions from all partners, and on the conclusions and recommendations.

Procedure and time schedule

In order to fulfil this task we propose the following activities and timing:

- All partners collect information relevant to their country, data collection may start end of July 1999. Preliminary data for the two 'test' chains triticale and swine excrements are to be collected and delivered before the end of September.
- All partners write a national report according to the CLM-format (November-December 1999). (The format will follow from this text.)
- CLM and IFEU are responsible for a synthesis of the work contributed by the partners, extrapolating it to EU-level; this will result in a draft report (January-February 2000).
- Conclusions and recommendations in the draft will be discussed with all partners during a workshop (March 2000) and possibly with external experts, and will be used as an input for subtask 2.5 'Assessment'.
- CLM and IFEU write the final report, which will be used for the milestone report and for the compilation of recommendations in task 4 'Final conclusions and recommendations' (May 2000).
- CLM and IFEU are responsible for the inclusion of a chapter on this task in the progress report (September 1999) and in the 4th milestone report (April 2000).

Appendix: Cost assessment

The project budget does not give much time for the socio-economic assessment. Therefore this assessment is mainly qualitative, using existing literature. Nevertheless, for the cost assessment unspecified results (e.g. EURO per KWh) do not suffice. To explain differences between the different biofuels, with fossil fuels and between regions, we need information about the underlying assumptions of the literature on bioenergy you use.

Given the time constraint, we propose to use existing literature. However we propose not to give the final results from this literature, but to provide the underlying information. Everyone is at least asked to fill in **Table 1** and the farm data **Table 2**, as this part of the chain differs between EU regions. The tables can be used for the energy crops but also for the 'crops' in het reference system.

Note that the required data are *per ha and per year*. This does not directly correspond with the functional unit GJ, but it is the best way to avoid misstakes. In literature you will very often find ha as a unit. (It can easily be recalculated in GJ, if necessary.)

In the case of perennial crops, you can use the following formulas for calculating the annual costs:

- annualised establishment costs
  = establishment costs * rate * (1 + rate)L / ((1 + rate)L - 1);
- annualised harvest costs = harvest costs * rate / ((1 + rate)Hi - 1);
- annualised grubbing up costs = grubbing up costs * rate / ((1 + rate)L - 1).

(These formulas are from Biewinga & van der Bijl 1996. In these formulas is:

rate = interest rate;

L = Longevity (crop life);

Hi - harvest interval.)

When filling in **Table 2**, assume machine operations are carried out by contractors, with operation at a standard rate. This includes the labour costs - a standard wage in agreement with generic labour agreements - and the machine costs. Of course we know that this is normally not the case, but it is the easiest way to do. Besides, when the farmer carries out the activities by himself, he also has costs: the hours he spends and the deppreciation of machinery.

Table 3 requires data for the rest of the chain, expressed per GJ or in another unit. Fill in the data which you can find from national literature. In case you do not have data, we could use default (mean European) values. For fossil fuels we propose to use default values anyhow.

Do not forget to clearly administer the references used for every figure you put in the table!

Note that no data are required about the market price of biofuels or about the amount of subsidies. These data will not be an input of the study, but will be the result from it. When we know all costs ,we can calculated at which price of biofuels it becomes attractive for the farmer.

The format can be filled in for all the crops where area is concerned.

There are two special cases with by-products: wood logs and straw. In these cases, the area-component is not looked at, as the activities are the same in both the reference and the bioenergy scenario. For these cases only the *extra* costs that coincide with the harvest of the by-product (like baling the straw, etc.) should be recorded, expressed per tonne dry matter.

Biogas from swine manure is another special case, also without an area component. In this case you are asked to collect data about the *extra* costs of the biogas production (compared to manure production without biogas production). The following data are needed:

- establishment costs of the biogas plant (ECU);
- capacity (tonne liquid manure per year, with .. dry matter %);
- writing off period (years);
- annual operation costs or operation costs per tonne manure.

With regared to by-products like rape meal and vinasse you are asked to provide additional data in **Table 4**.

Table 1 General information on the crops

crop			
region			
yield		kg fresh weight/ha	
dry matter content		%	
harvest interval		yr	for calculation perennials
longevity (crop life)		yr	for calculation perennials
interest rate		%	a.o. for calculation land costs

Table 2 Data assembly on costs of farm activities, all data per ha year

description cost	input (from task 2)	unit	price EURO per unit (literature)	costs [ha yr] (calculation)
seeds or plants		(number)		
soil prepation		(times)		
sowing		(times)		
N-fertiliser		kg		
P-fertiliser		kg		
K-fertiliser		kg		
pesticides		kg		
application of fertilisers		(times)		
spraying of pesticides		(times)		
mechanical clearing weeds		(times)		
soil prepation / sowing		(times)		
irrigation costs		(times)		
harvesting		(times)		
cleaning costs		(times)		
grubbing up (perennials)		(times)		
storage on the farm		months		
land costs	1	(ha yr)		
			use interest rate	
Total costs				....

Table 3 Data assembly on costs of activities behind the farm gate

description cost	costs EURO	per unit (fill in the unit used in literature)	costs EURO per ha yr	remarks
TRANSPORT				
transport costs				
PRECONVERSION				
chipping costs				
drying costs				
CONVERSION				
investment costs				
variable costs				
DISTRIBUTION				
distribution costs				
END-USE				
(for transport fuels only)				
investment costs vehicle				
yearly costs				

Table 4 Data assembly on financial returns of by-products from activities behind the farm gate

description by-products	market price EURO	per unit (fill in the unit used in literature)	amount per unit of main product (see table A3)	remarks
...				
...				