# The greenhouse gas calculation methodology for biomass-based electricity, heat and fuels

## Project Group
## "Sustainable Production of Biomass"

## Report from Working Group
## CO2 Methodology

# Preface

This description of a greenhouse gas calculation methodology for biofuels and bio-energy has been prepared by CE Delft and the University of Utrecht, in discussion with and following approval by the Cramer Commission, set up in the Netherlands to establish sustainability criteria for greenhouse gas calculations and other issues. In addition, the methodology has been discussed with the UK Ministry of Transport, LowCVP, IFEU, ISPRA and the German FNR.

We thank Commission members for their input and response to this difficult but important issue: Kees Kwant and John Neeft, SenterNovem; Eric Swartberg, Cargill; Hans Jager, SNM; Steven Wonink, VROM; Rob Remmers, Essent; Yves Ryckmans, Laborelec (Electrabel Belgium); Daan Dijk, Rabobank; Ronald Zwart, Productschap MVO; Mark Woldberg, Nedalco and Ronald Kalwij, Cosun.

# Publication Data

# Contents

# Summary

This report describes a methodology for calculating the greenhouse gas (GHG) reductions achieved in biomass-based electricity, heat and fuel chains. Proceeding from standard LCA methods in accordance with ISO 14040, the proposed methodology derives partly from a discussion meeting with representatives from the UK, the Netherlands, Germany and other countries. To engender international support, the methodology has also been embedded in the existing context established by IEA, IPCC, JI, CMD and other organisations. The report also contains a complete list of the biomass sources currently used and to be used in the future in the Netherlands.

To estimate the percentage GHG reduction achieved by a particular biomass production chain, or bio-chain, its performance must be properly compared with a reference, fossil chain. For biofuels for transport chain means a well to wheel approach. For bioelectricity this is the chain till the electricity consumer. The basic format for calculating the GHG reduction is thus:

GHG reduction = GHG emission, fossil chain – GHG emission, bio-chain

GHG emission, fossil chain

The bio-chain involves the following GHG emissions:
– Emissions associated with biomass production, specifically:
  • Emissions from use of agricultural machinery.
  • Emissions from fertilizer production.
  • Emissions from fertilizer use ($N_2O$).
  • Emissions embodied in changes in biomass carbon stocks.
  • Emissions embodied in changes in soil carbon balance.
– The GHG impact of residues from agricultural production.
– Emissions from biomass transport.
– Emissions from biomass pre-treatment.
– Emissions associated with the energy used for pre-treatment.
– The GHG impact of co-products from conversion.

The reference system has two elements: a fossil energy reference chain for delivery of fuel, electricity and/or heat and a reference situation for the area used for biomass cultivation.

The reference fossil energy chain involves the following GHG emissions:
– Emissions from mining.
– Emissions from transport of coal, gas, oil or electricity.
– Emissions from conversion to petrol, electricity or heat

The system is shown in Figure 1.

Figure 1    Bio-chain and fossil reference chain for GHG calculations
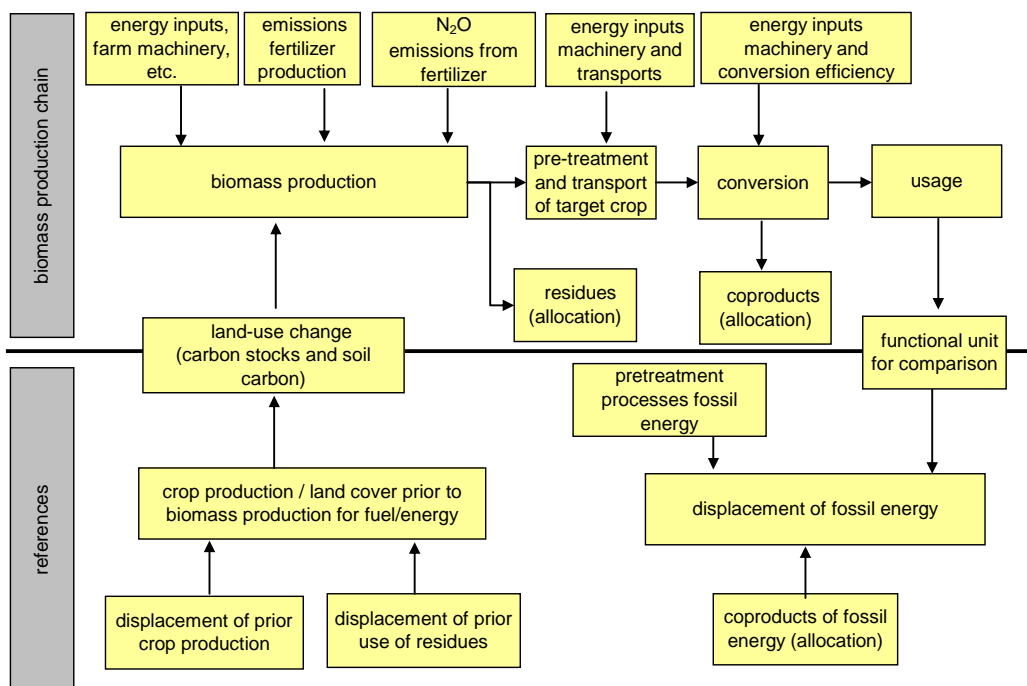


For bio-chains based on crops grown specifically for energy purposes, the reference consists of:
– A reference for land use, carbon stocks and soil carbon. Reference means how the land was used before the crops are cultivated.
– The reference production on this land (i.e. the GHG impact of displacement of prior production on the land). (But below it is concluded that this will not be used in the tool at present).
– The reference fossil energy chain.

To gain an accurate picture of GHG reductions, all these issues need to be investigated and included in a GHG calculation tool. Today most of this information is available, or can be estimated, although it may sometimes be hard to find. It is only the displacement of prior production on the land in question that is difficult to estimate for a concrete production chain according to the Commission Cramer[1]. For this reason the Cramer Commission has opted to omit this factor from the GHG calculation tool for the time being, recommending that a macro-monitoring scheme be started immediately to assess the impact of displaced production on net GHG emissions (as well as on biodiversity). As this impact may be substantial, results calculated with the GHG calculation tool must always be presented with a clear disclaimer that "the displacement effects of production have not been included in the calculation".

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[1]    Only Dutch NGO's do not agree with this temporally neglecting of GHG effects from displacement because this can be substantial and recommend to include displacement immediately

The conclusions from this monitoring scheme on displacement effects may well lead to changes in biofuel policies as well as in the GHG calculation tool itself.

The Cramer Commission recommends that the methodology and the tool be subjected to an evaluation in 1 to 2 years' time.

# 1 Introduction

This report describes a methodology for calculating the greenhouse gas (GHG) reductions achieved in biomass-based electricity, heat and fuel chains. The proposed methodology derives partly from a discussion meeting with representatives from the UK, the Netherlands, Germany and other countries.

In the summer of 2006 the Dutch Cramer Commission published its initial proposal for a GHG calculation methodology for bio-electricity, bio-heat and biofuels. This then formed the point of departure for a comparison with super-national systems and systems in use in the Walloon region of Belgium and the UK. These comparisons and subsequent discussions permitted identification of the most problematical issues in such a methodology. In a workshop on 30 October 2006 these issues were discussed with representatives of the Dutch Ministry of Environment, the British Ministry of Transport, LowCVP and experts from several other European countries.

The results of these interesting and focussed discussions as well as the review of international approaches were then used to revise the Cramer Commission's original proposal in such a way that it can serve as a GHG calculation tool very similar to the planned British one and could set a direction for a tool in other European countries.

In Chapter 2 of this report we first summarise the most relevant biofuel and bio-energy sources in use in the Netherlands; the methodology must be suitable for all of them. In Chapter 3 we then provide a summary description of the GHG calculation methodology. In Chapter 4 we examine the principal methodologies in use today. Chapter 5 describes the proposed methodology in detail. Chapter 6, finally, presents a number of policy recommendations.

# 2      Biofuel and bio-energy chains

## 2.1     A methodology for two calculation tools: biofuels and bio-energy

The methodology described in this report has been developed with a view to implementing it in two calculation tools. First, under the responsibility of the Dutch Ministry of Environment, a calculator is to be developed specifically for transport biofuels and later, also under the responsibility of the Ministry of Economic Affairs, a calculator for bio-electricity and bio-heat (together, 'bio-energy'). These tools will enable companies to calculate their greenhouse gas (GHG) balances. The methodology must therefore be valid and useful for both biofuels and bio-energy.

## 2.2     Biofuel chains

After due discussion the following list of biofuel chains was drawn up for inclusion in the biofuel calculator next year (2007):
- Ethanol from sugar cane, sugar beet, wheat and corn.
- ETBE from ethanol from sugar cane, sugar beet, wheat and corn.
- Biodiesel (FAME) from tallow, used cooking oil and fats, palm oil, soy, rapeseed and sunflower oil.
- Pure plant oil (PPO) from tallow, used cooking oil and rapeseed.
- Bio-methanol from glycerine by-product of FAME.
- MTBE from bio-methanol from glycerine by-product of FAME.
- NExBTL from the Nesté Oil process.
- Bio-methane from anaerobic digestion.

ETBE has a better GHG performance than just adding ethanol if MTBE is replaced. For this reason the Netherlands favours inclusion of a separate ETBE chain.

Although the Nesté Oil NExBTL process has been included in the list, it is as yet unclear whether enough data will be available for it to be incorporated in the calculator.

Bio-methane from anaerobic digestion is not a chain as detailed as the others because "biomethane" does not define the feedstock. The feedstock for this chain will be municipal solid waste, or in other words landfill gas. If chains using waste as a feedstock are to be included, due allowance must be made for the waste acquiring an economic value over time.

Second-generation bio-ethanol and Fischer-Tropsch diesel can later be included to make the tool "second-generation-proof".

Biodiesel from the Jatropha crop and bio-butanol have not been included at this stage, for lack of data and because these fuels are not yet on the market. Some

experts also expect Jatropha to remain a locally cultivated crop. The calculator can readily be extended to include these chains at a later stage, however.

## 2.3 Bio-electricity and heat chains

No decision has yet been made as to which bio-electricity and bio-heat chains will be incorporated in the Dutch calculator. The list might be based on the list used in Belgium, or alternatively on the categorisation used by TNO to report bio-energy production in the Netherlands (TNO, 2005). The list should consist of the most relevant resources and not only depending on the resource but also on the technology applied.

The Wallonian list comprises the following sources (in brackets, the Wallonian default values for GHG emissions in kg $CO_2$ / $MWh_{prim}$):
- Organic industrial and household waste (0).
- Manure (0).
- Grass/straw (17).
- Corn (22).
- Rapeseed (65).
- Biodiesel from rapeseed (80).
- Wood from forests (40).
- Woodchips (30).
- Forest residues (20).
- Timber industry residues (20).

Table 1 shows the bio-electricity and bio-heat sources used in the Netherlands in 2004.

Table 1    Use of biomass in the Netherlands, 2004 (TNO, 2005) (Amounts including moisture)

| Type of biomass | Technology | Amount (thousand tonnes per year) | Of which imported (thousand tonnes per year) | Avoided use of fossil fuels (PJ per year) |
|---|---|---|---|---|
| Municipal waste | | 4,975 | 0 | 11.5 |
| Wood chunks | Stoves and open hearths | 600 | 0 | 5.4 |
| Wood pellets | Co-firing | 400 | 320 | 4.3 |
| Dried sewage sludge | | 2.3 PJ | 0 | 2.3 |
| Sawdust / wood chips | Industrial furnaces | 150 | 0 | 2.0 |
| Vegetable oils | Co-firing | 90 | 90 | 1.9 |
| Landfill gas | | 1.8 PJ | 0 | 1.8 |
| Wood chips | CHP | 175 | 0 | 1.8 |
| Bone meal | Co-firing | 100 | 10 | 1.3 |
| Biogas | | 1.1 PJ | 0 | 1.1 |
| Paper sludge | Co-firing | 500 | 9 | 0.4 |
| Waste wood (B-grade quality) | Co-firing | 45 | 0 | 0.4 |
| Wet organic residues | Co-firing | 112 | 6 | 0.2 |
| Chicken manure | Co-firing | 5 | 0 | 0 |
| **Total** | | **6,712** | **535** | **34.5** |

The conclusion for the Dutch situation is that the following sources are especially interesting, in that each represents more than 1 PJ savings on fossil fuel consumption:
− The biogenic fraction of municipal waste.
− Wood (chunks and pellets).
− Woody by-products.
− Vegetable oils: rape and palm.
− Bone meal.
− (Energy) corn.
− Dried sewage sludge.
− Landfill gas.
− Manure.

Biogas is not included because it is an intermediate and not a final product. If a support scheme for green gas is established it may become interesting to include biogas.

It is important, furthermore, that certain agricultural residues and co-products from the food industry are analysed, because of potential competition with other uses.

Conversion technologies
For the production of power and heat the following technologies are important:
− Co-firing in coal or gas fired power plants.
− CHP combustion with delivery of heat and power (e.g. waste incineration and wood.
− Anaerobic digestion of manure and organic residues for production of power.

## 2.4 Consequences for the methodology

These two lists of biomass chains encompass a wide range of crops, residues, by-products and waste and the GHG reduction methodology must therefore be sufficiently general to deal will all of them.

# 3 General methodology for biomass GHG calculations

## 3.1 Introduction

In this chapter we outline the approach adopted here for GHG calculations on biofuel, bio-electricity and bio-heat chains ("bio-chains"). In the chapter 5 the methodology will be described in more detail.

The overall approach adopted for these calculations is Life Cycle Analysis (CML, 2002) (CML, 2003), as described in the ISO 14040 series of standards (NNI, 1997-2000).

The 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006) provide a methodology to estimate national greenhouse gas emissions and some default data can be used for the calculation of bio-energy chains. Volume 4 on Agriculture, Forestry and Other Land use specifies the methodology and default values for the calculation of GHG emissions of land-use changes.[2] Moreover, vol. 3 provides default estimates for industrial processes such as fertilizer production and refineries.

To estimate the percentage GHG reduction achieved by a particular biomass production chain, or bio-chain, its performance must be properly compared with a reference, fossil chain. For biofuels for transport chain means a well to wheel approach. For bioelectricity this is the chain till the electricity consumer. The basic format for calculating the GHG reduction is thus:

GHG reduction  = GHG emission fossil chain – GHG emission bio chain
                              GHG emission fossil chain

Each of these chains needs to be broken down into constituent links, as shown in Figure 2.

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[2]    In Vol. 4, Chapter 11 a methodology to estimate N2O emissions from fertiliser use is described.

Figure 2    Bio-chain and fossil reference chain for GHG calculations
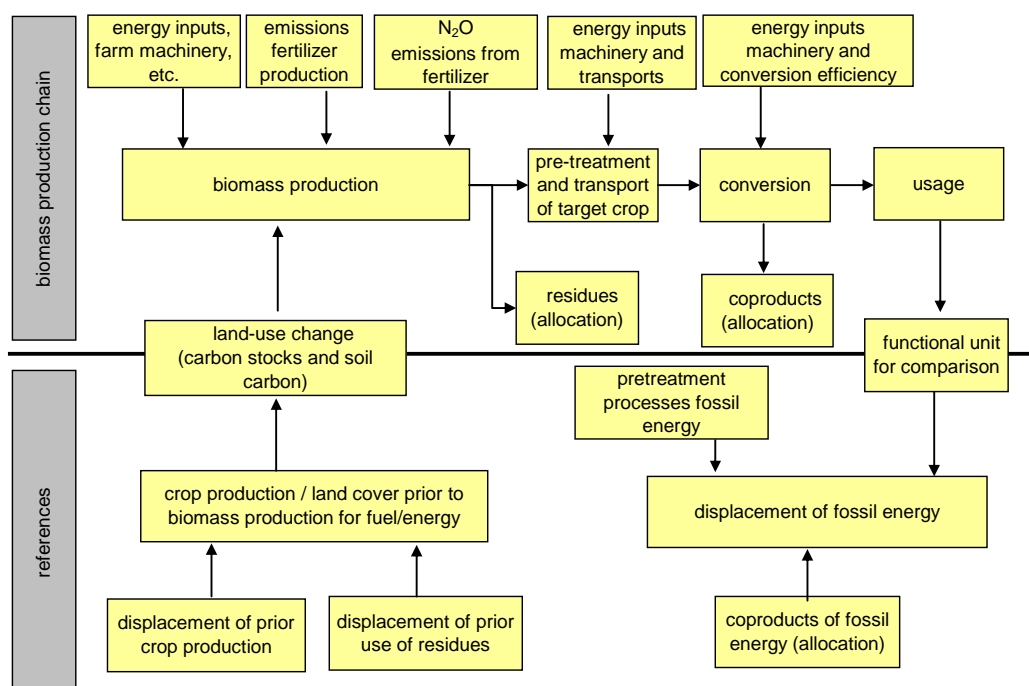


## 3.2    The bio-chain

The bio-chain involves the following GHG emissions:
–   Emissions associated with biomass production:
  •   Emissions from use of agricultural machinery.
  •   Emissions from fertilizer production.
  •   Emissions from fertilizer use ($N_2O$).
  •   Emissions embodied in changes in biomass carbon stocks.
  •   Emissions embodied in changes in soil carbon balance.
–   The GHG impact of residues from agricultural production.
–   Emissions from biomass transport.
–   Emissions from biomass pre-treatment.
–   Emissions associated with the energy used for pre-treatment.
–   The GHG impact of co-products from conversion.

The greenhouse impact of residues and co-products can be calculated by one of two methods, familiar from LCA practice: through suitable allocation of emissions, or by extending the system under analysis. The choice made here will be described in Chapter 5.

## 3.3    Reference chains

Two different types of reference chain can be distinguished:
–   For the bio-chains of crops grown specifically for energy purposes.
–   For the bio-chains of crop residues or co-products.

For bio-chains based on dedicated energy crops, the reference consists of:
− Displacement of crop production / land cover prior to biomass production for fuel/energy.
− Displacement of fossil energy.


For bio-chains based on residues or co-products the reference consists of:
− Displacement of prior application of the residue.
− Displacement of fossil energy.

The reference fossil energy chain involves the following GHG emissions:
− Emissions from mining.
− Emissions from transport of coal, gas, oil or electricity.
− Emissions from conversion to petrol, electricity or heat.

Estimates of these emissions are available from a variety of sources, and which of these will be used will be decided during further development of the calculators.

**Biodiversity**
Some of the data that need to be collected for these GHG calculations is also useful for determining biodiversity impacts, which are most likely to arise in connection with land-use changes and displacement of prior production. It is recommended to streamline efforts to retrieve information on these two aspects at a later stage.

# 4 Existing methodologies for biomass GHG calculations

## 4.1 Introduction

Under the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol, greenhouse gas emissions are currently calculated by individual countries for their National Greenhouse Gas Inventories as well as for emission mitigation measures implemented under the 'Clean Development Mechanism' (CDM) (Schlamadinger and Jürgens,2005) and 'Joint Implementation' (JI), the two so-called flexible mechanisms providing for emissions reduction in other countries.

Besides these international protocols, GHG balances for specific bio-energy projects have also been calculated by an array of agencies, consultancies and scientists. The IEA, for example, in its Bio-energy Task 38, aims to closely follow all methodological developments and advise on mechanisms to support biomass-based GHG mitigation in the international, national and commercial contexts. In Wallonia (South Belgium) a GHG balance calculation spreadsheettool with defaults is employed in the obligation (with penalty payments if not fulfilled) for electricity suppliers to produce a certain percentage of 'green' electricity, using parameters established by scientists in consultation with government and industry. Furthermore for the biofuels tender in Belgium a GHG calculation is also necessary and this is one of the criteria of the tender. In the UK a GHG calculator for bio-ethanol from wheat has been developed and is currently in the testing phase. And in the Netherlands a GHG calculation is now required of businesses applying for the 'Unique Chances' R&D support scheme.

In the following sections we review the methodologies adopted in these national and international systems, providing a brief description of each and indicating its relevance to the development of a calculation methodology for the Dutch context.

## 4.2 Existing GHG calculation methodologies

***IPCC: Good practice guidance*** (IPCC2006)
This is the methodology that is to be used for preparing the National Inventories for submission to the UNFCCC. This methodology was developed for estimating GHG emissions on a national basis, and there is no obligation to use it for individual bio-energy projects. Many of the values and methods provided in these guidelines can be applied for this purpose, e.g. information on energy production in Vol. 2, information on industrial processes in Vol. 3, information on agriculture and forestry in Vol. 4 and information on waste management in Vol. 5. The IPCC approach is 'tiered', with the level of detail depending on the information available and the importance of the emissions from the source in question. This kind of approach seems useful for a future calculation tool.

## UNFCCC: CDM and JI methodologies

For each type of CDM project a specific methodology has to be approved by the UNFCC. Examples of project types include grid-connected electricity generation from biomass residues, fuel switching from fossil fuels to biomass residues in boilers for heat generation and afforestation/reforestation.

The CDM methodologies include a detailed discussion of concepts of 'additionality' and 'baselines' (the reference case, i.e. a scenario providing a reasonable representation of the anthropogenic emissions from GHG sources that would occur in the absence of the proposed project activity). The same principles apply to JI methodologies, too.

In the case of JI methodologies, accounting principles are also set out for use in GHG calculations that cover such notions as "project-specific", the extent of GHG "sources" and "sinks", a "conservative" baseline, "leakage" (i.e. accounting for alternative biomass use) and "local energy systems". In some cases additional procedures, such as monitoring of project participants, may also be applicable.

## IEA Bio-energy Task 38 methodologies

Under its 'Task 38', IEA aims to demonstrate and promote the use of a standard greenhouse gas balance (GHG) methodology and has published a number of reports, articles and case studies (Gustavsson, 2000), (Wood and Cowie, 2004), (Schlamdinger and Jürgens, 2005), (van Dam, 2005), (Damen, 2005) and (Robertson, 2006).

The IEA Task 38 documentation describes the state-of-art use of LCA methodology for bio-energy systems and discusses critical issues. The BIOMITRE calculation tool has been designed to compare fossil fuel and bio-energy systems on a project basis. The flexible system boundary settings used in BIOMITRE and many LCA tools might be employed in the Dutch calculators as a means of optionally including certain aspects of the biomass chain like land-use change and reference production. The use of different 'tiers' (with a corresponding 'entry mask' on the data input form) might also be adopted.

## UK: GHG calculator (IC, 2005)

In the United Kingdom a methodology has been developed for calculating the GHG balance of using domestically produced wheat-based ethanol as a transport fuel. It comprise the following elements:
−   The GHG emissions of the production of the fertilizers, pesticides and seed used for growing the wheat; per-kg default values for the UK are used.
−   $N_2O$ emissions from the soil; default values for the UK are used.
−   Reference use of the land; in the UK calculator, this is set-aside with unfertilized, unharvested grass.
−   Fuel consumption of farm machinery (diesel) and transport; default values are used for both.
−   Avoided emissions from power generation; the reference is the average for the UK grid.

- Co-products: the 'Well to Wheels' report (Edwards, 2006) is strongly in favour of expanding system boundaries as opposed to using economic allocation. In the UK calculator one can choose between use of the co-product as animal feed or as co-fuel in a power plant, with default values set for each.

The (draft) calculator can be used by any of the stakeholders in the bio-ethanol fuel supply chain and is available at:

http://www.hgca.com/publications/documents/Bioethanol_calculator_tool.xls .

***Wallonia: Green certificates for bio electricity*** (Waals Gewest, 2004)

For the Green Certificate scheme in operation in the Walloon region of Belgium no specific system is used to calculate the GHG emissions of bio-electricity production. For some feedstocks, default values have been calculated based on existing Belgian LCA studies and these are used in a formula that calculates the GHG impact of substituting fossil by biomass fuel. The result determines the number of green certificates awarded. This (French-language) tool can be found at: http://www.cwape.be/servlet/Repository/?IDR=1711 .

**Belgium: Tender for biofuels including GHG calculation obligation**

In Belgium the governmental support, in the form of a tax exemption, for biofuels is divided with a tender procedure. One of the criteria of the tender is the GHG reduction of the biofuels. Included are also $CH_4$ and $N_2O$ emissions. Companies are obliged to report GHG information on farming, transport, production, and distribution and all fossil fuels necessary for this steps. This results in an amount of GHG emission per liter biodiesel of bio-ethanol. This number is used together with the costs of operation to grant the tender or not.

***The Netherlands: Calculations for the 'Unique Chances' support scheme***

Under the Netherlands' 'Unique Chances' support scheme for innovative energy investments, worth around 30 million euro annually, applicants are obliged to calculate and report the greenhouse gas balances of biomass projects. Use of the IEA calculation tool is recommended, with additional fossil energy reference values provided for 2020 and 2030 to account for ongoing technological development. Only a minority of applicants present a detailed calculation that includes all relevant aspects, and some even claim that biomass is always associated with zero GHG emissions. Experience with this support scheme shows that a more rigorous calculation tool with appropriate defaults is needed if better-quality information is to be obtained.

See:

http://www.senternovem.nl/mmfiles/UKR%20Modelprojectplan_tcm24-76313.doc

# 5   Key methodological issues

In this chapter the key methodical issues are described more in detail.
(*In italic also suggestion for concrete default values are given*).

As outlined earlier, there are two basic kinds of feedstocks for producing transport biofuels on the one hand and heat and power on the other: dedicated energy crops, grown specifically for that purpose, and crop residues and other forms of organic waste. Each has its own kind of production chain, as shown for dedicated energy crops in Figure 3 and for residues and so on in Figure 4. The various methodological issues of relevance to GHG emission calculations in the respective chains are immediately apparent. After discussion with experts from the UK and elsewhere, the main conclusion is that there is in principle substantial agreement on many of these issues. Although default values still need to be discussed for certain factors, these issues can be resolved during development of the actual calculators.

The numbered blocks in the two figures identify the key methodological issues, which will now each be examined in more detail, in the sections thus numbered.

Figure 3   Production chain of bio-energy from energy crops and fossil reference production chain (numbers refer to section where item is discussed)
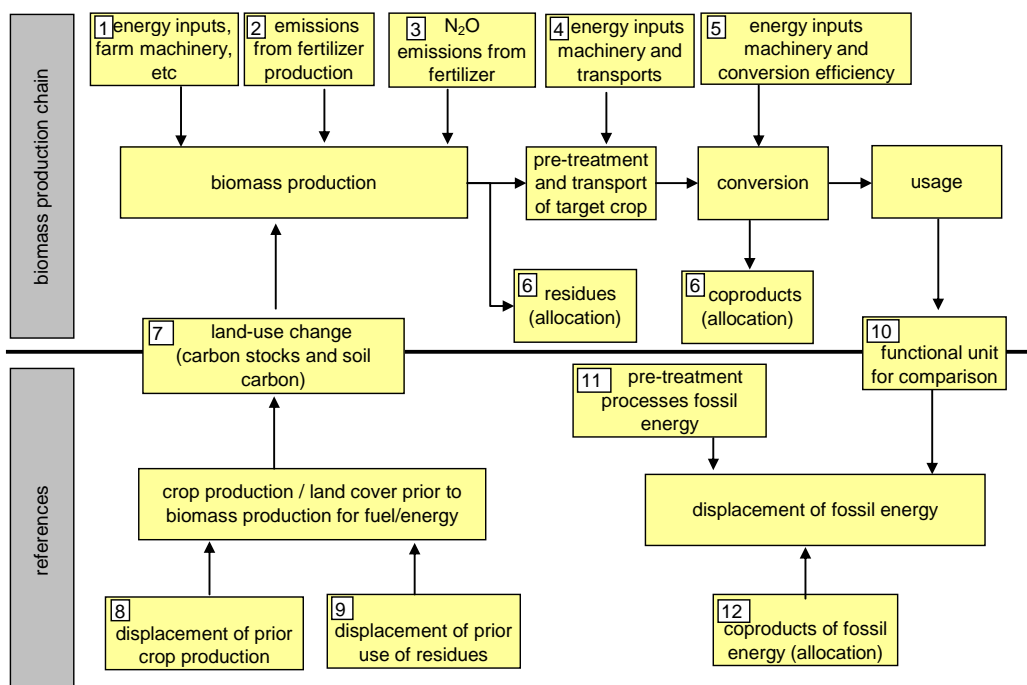


If residues or coproducts are also used for biofuels production the GHG allocated to them has to be used in the GHG calculation of the residue/coproduct chain. For biofuel production from residues and coproducts which do not come from

biofuel chains, an alternative or prior application of the residue or coproducts has to be included in the calculation (see figure 4)

Figure 4    Production chain of bio-energy from crop residues and other wastes and fossil reference production chain (numbers refer to section where item is discussed)
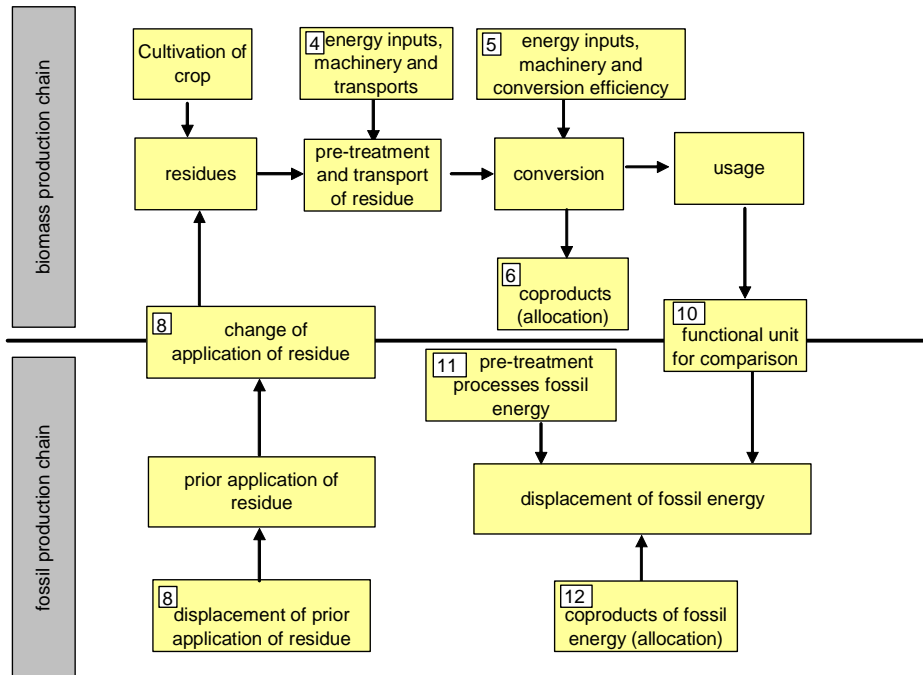


## 5.1    Energy inputs, farm machinery

In the case of a crop cultivated specifically for biofuel production, the energy inputs of the farm machinery used in biomass production comprise:
–   The fossil fuel and oil consumed in ploughing and sowing.
–   The fossil fuel and oil consumed by the agricultural machinery used for fertilizer application and other forms of crop management.
–   The fossil fuel and oil consumed in the harvesting process.

The emissions associated with the manufacture of this machinery and with production of their constituent materials have not been taken into account in the Dutch calculator, as these are generally negligible compared with those due to energy consumption during machinery lifetime.

*Calculated thus, fuel and oil consumption for the cultivation of oilseed rape in the Netherlands is an estimated 130 litres per ha of rape (CE, 2005).*

In the case of a crop residue being used for energy production (in the form of pelletized rice residue, for instance) the energy inputs of the agricultural machinery used for biomass production are taken to be zero. The basic principle, in other words, is that all the fuel and oil used in crop handling is attributed to the target crop and not to the residue. On the other hand, emissions due to a prior user now having to use another crop *are* taken into account in the calculations on

crop residues, including emissions from farm machinery. If the prior usage of the residue was land filling this emission reduction because of stopping land filling has also to be included if this does not lead to double accounting. This can be the case because many EU countries support avoiding land filling and have policies for this.

In the UK pesticides are also included in the methodology (IC, 2005). However, as pesticide production contributes very little to the overall greenhouse impact of a biofuel: less than 0.5% (IC, 2005), in the Dutch methodology this has been omitted.

## 5.2 Emissions during fertilizer production

To calculate the GHG emissions associated with nitrogen fertilizer production, the fertilizer application rate per hectare and the GHG emissions occurring during fertilizer production need to be known. Typical application rates for nitrogen fertilizer are 195 kg/ha for oilseed rape (CE, 2005) and 185 kg/ha for wheat (IC, 2005), although the exact rate will depend on the targeted yield and the amount of mineral nitrogen in the soil (depending in turn on whether the straw from the previous crop is ploughed in, for example). Due allowance must therefore be made for farming practice for the particular crop being investigated.

*The LowCVP model uses a default value of 6.69 kg $CO_2$-eq./kg for nitrogen fertilizer production (IC, 2005).* The default value to be used will be discussed with experts.

The use of phosphate and potash fertilizers has not been taken into account in the calculations, because the $CO_2$ emissions associated with production of these fertilizers are much lower than for nitrogen fertilizer *(0.71 kg $CO_2$/kg for P-fertilizer, 0.46 kg $CO_2$/kg for K-fertilizer)* and application rates are also lower *(41 kg/ha for P-fertilizer, 46 kg/ha for K-fertilizer) (IC, 2005).* Overall, this means the $CO_2$ emissions of P- and K-fertilizers are about 40 times less than those of N-fertilizer.

## 5.3 Soil emissions due to N-fertilizer application

Crop residues and fertilizer in soils give rise to emissions of $N_2O$, a greenhouse gas 296 times as potent as $CO_2$. Although IPPC emission factors are available for calculating these emissions, these have a broad range[3]. Since the publication of the IPPC emission factors and calculation formula, more research has been done on the issue and today more tightly defined default values are available. For crop production in Europe, values between 4 and 8 kg $N_2O$/ha.yr (CE, 2005) and 4.4 kg/ha.yr (IC, 2005) are cited. During development of the calculation tool, default values will be discussed with experts and will be in accordance with ranges that derive from the IPCC emission factors together with LCA information on fertiliser application.

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[3]   In (IPCC, 2006), these default factors are summarised in Vol. 4, Table 11.1 These emission factors have to be combined with data from LCA on the amount of fertiliser used per crop per ha.

## 5.4 Energy inputs, pre-treatment and transport

Post-harvest, the first emissions to be take into account are those associated with energy inputs to biomass pre-treatment processes: natural gas or electrical power used for drying the crop, for example. This means all the GHG arising during both production and use of this gas and power must be factored in. Default values are available for both (see 5.11). When natural drying is applied this contribution is obvious zero. Use of waste heat is in general free of GHG emission. Only when the normal reference for waste heat would be selling to others a reference for heat production would be necessary but in most cases the alternative for waste heat use is no use at all.

The second set of emissions to be included here are those associated with transportation of the pre-treated biomass, for which purpose the transport distance and the type of truck or vessel used (i.e. its emissions) must be known. Fuel usage default values will be used for each type of truck and ship, allowing $CO_2$ emissions to be determined for each. Furthermore, if important, a factor for pipeline transport can be added.

*In the Dutch-language report 'Biomassa: de groene motor in transitie' (Schoof, 2003) the following default values are cited for transport fuels:*
*Petrol: 88.9 kg $CO_2$-eq,/MJ and 2.6 MJ/km (cars in 2002).*
*Diesel: 84.7 kg $CO_2$-eq./MJ and 2.1 MJ/km (2002).*


## 5.5 Conversion

The next emissions to be factored in are those associated with energy inputs to conversion processes, i.e. such steps as:
–   Crushing the oil out of the crop.
–   Refining the oil.

As in the case of pre-treatment, it is natural gas and electrical power that will be used for these processes and the $CO_2$ emissions due to both production and use of that gas and power therefore need to be included. For both, default values are available (see 5.11). An alternative source of energy can be on site biomass or residues (E.G. bagasse for production of bioethanol or straw in the Netherlands). In this case the effects in the chain of this biomass or residues have also to be included. For residues this means that also a reference residue use has to be determined and if there is a reference residue use system extension with this use is recommended.

The efficiency of conversion determines how much end-product is produced from the crop. *To produce 1 tonne of PPO, for example, requires 3.5 ± 0.5 tonne of oilseed rape (small-scale production), which means the yield of oil is 1.42 tonne per ha (CE, 2005). Using these figures, the $CO_2$ emissions associated with all the previous steps in the process can be ascribed to 1 tonne or 1 kg of oil.* For each biomass chain this efficiency has to be established.

## 5.6    Allocation of residues and co-products[4]

In cases where there is a need to distribute emissions over several products, strong preference is given in the LCA methodology according to the ISO series of standards to extending system boundaries. System extension represents best the causality of actions in the market. Also the leading European research projects on biofuels use system extension like the Well to Wheel analyses of JRC [Edwards, 2006]. Furthermore system extension is used for more than 10 years in very many LCA studies for all kinds of products. In the earlier report of the Cramer Commission, however, allocation using market prices is cited as the preferred option, because of its simplicity, although it is realised that this too may be problematical. Market prices fluctuate and are also influenced by subsidies in agriculture, energy, fuels, etc. Especially in the biofuels and agricultural markets subsidies are rather big and prices are fluctuating because of governmental targets. Some NGOs, such as the Netherlands Society for Nature and Environment (SNM; prof. Lucas Reijnders), are against allocation using traditional prices, instead advocating allocation by means of corrected, green prices (i.e. including compensation for environmental impacts). Economic allocation is a recurrent issue in many LCA debates and should in general be avoided. Only if system allocation raises real problems economic or energy allocation is an alternative.

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**Economic allocation**

Biodiesel Plant    -> biodiesel with value 80

                        -> glycerine with value 20

If economic allocation is used, 80% of the emissions of the biodiesel plant and upstream chains are allocated to the biodiesel and 20% to the glycerine.

**Or system extension**

Biodiesel Plant    ->biodiesel

                        ->glycerine, replacing production of fossil glycerine with a GHG emission of 25

If system extension is used and the biodiesel and upstream chain has a GHG emission of 100, 25 can be subtracted for the glycerine, which leads to a GHG emission for biodiesel of 75.

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Given these considerations, in contrast to the recommendations of the earlier Cramer Commission report, **system extension** will be used to calculate default GHG values for the main residues and co-products. This will be based on an economic evaluation of the relevant market. If possible, the **marginal** effect of an extra kg of residue or co-product will be calculated. If such calculation is too difficult or unfeasible, **average** usage of the residue or co-product will be used for the purposes of calculation. In this way over 80% of biofuels will be able to be covered. Because of the importance of by-product usage for net GHG emissions,

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[4]    We use the term 'residues' to refer to primary residues from agriculture and forestry, e.g. logging residues and straw, while 'co-products' refers to secondary processing residues, e.g. dried distillers' grain and heat.

the calculation tool must be designed such as to encourage due reporting of the by-products actually used.

*Minority wishes more information before choosing for system extension*
A minority (especially commodity board MVO) wishes more actual information on system extension for specific chains before supporting this method.

In cases were system extension raises problems (such as isobutylene and co-production of biofuels) other allocation methods can be used, such as market-based allocation, which reflects value to society. In that case, attention needs to be paid to the possibly distorting effect of subsidies on the agricultural market. In some cases there may also be good reason to allocate on an energy basis. The actuals cases have to be discussed with experts and stakeholders.

*Double accounting when production of biofuels and bio energy are combined*
If both the crop and residues of co-products from a certain production ha are used for biofuels or bio energy the allocation method for these must be equal to prevent shopping. Furthermore attention for allocation is necessary if a biomass chain produces both bio energy and biofuels. In European countries were both bio energy and biofuels are stimulated and subsidized the risk of double accounting of GHG reduction has to be avoided. In the UK this risk will be avoided by allocation by energy content in this cases. This seems a practical approach for the Netherlands also . For countries with only a biofuels stimulation policy and no bioenergy policy this allocation by energy content is not necessary. This may give a difficult to explain differentiation of figures. During the further development of the GHG tool for biofuels must be evaluated which approach is best in this cases. The choice is between the following options:
− energy allocation for countries with both bioenergy and biofuels policies and system extenstion for countries without bioenergy policies
− energy allocation for all biomass chains which produce both bioenergy and biofuels all over the world

*Byproducts which can also be a source*
Some byproducts of biofuel chain A can be a source for biofuels chain B. (EG glycerine) In this case it is important that the $CO_2$ burden which is allocated from chain A to the byproduct is also used as input for the calculation of chain B.

## 5.7 Emissions due to land-use changes

Land-use changes are deemed especially important, because the impacts of such changes may offset GHG benefits entirely, depending on the nature of the changes and the period of time over which their impact is to be spread. Even moderate effects on GHG balances should be included, though. JI and CDM methodologies include this factor in their baseline definition. Deforestation to create space for biofuel plantations should lead to a net GHG reduction of zero (in practice it may even be negative). Although the calculator should deal with some of the land-use changes that are to be avoided, it is widely agreed there

should also be other (certification) measures in place to deal with land-use changes.

Land-use changes may have either a positive or negative effect on bio-energy GHG balances, as exemplified respectively by a change from annual crops to short-rotation forestry and by deforestation. Our calculation methodology takes into account the direct impact of land-use changes on the area used for biomass production.

Our methodology is based on the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4 (IPPC, 2006). These guidelines take into account changes in the carbon stocks of (1) biomass, (2) dead organic matter and (3) soils. 'Tier 1' of the IPCC methodology (the calculation method with the least detail) has been used in the first instance, as equations as well as default parameters are provided for this level. This methodology is based on standard parameters for the change from one land use category to another, viz. forestland, cropland, grassland, wetland, settlements and other lands. Furthermore, the default factors in the guidelines are based on climatic zones, e.g. tropical or temperate. (In some cases involving very large biomass streams from a specific country, 'Tier 2' of the IPCC methodology, using country-specific data but the same methodological approach, can be implemented in the calculation tool.)

In order to apply this methodology, the following information is required from bio-energy producers: where the biomass is produced, whether and when any change in land use has occurred for the purpose of producing this biomass, and the category into which prior and current land use falls. If no such information is available, a default value based on typical assumptions for the type of biomass and region of origin will have to be used.

For changes in soil carbon stocks, i.e. dead organic matter and some fraction of the biomass, the IPCC Guidelines provide default timelines. The annual changes in these carbon stocks will be used in the calculation of $CO_2$ balances. However, the IPCC Guidelines do not provide a methodology to account for GHG emissions on a project basis over several years and, thus, no method to account for changes in biomass occurring in the first year of the land-use change. These changes should be accounted for over the full lifetime of biomass production and, therefore, changes are distributed over the lifetime of the plantation. To this end, typical lifetimes of different biomass production system will be established and used in the calculation tool. This lifetimes will be based on the lifetimes used in the general approach of the Dutch Ministry for Environment for environmental investments in support schemes (Milieukostenmethodiek, 1998) and will discussed with stakeholders. The base year for land-use changes will be 2005, in line with the first report of the Cramer Commission.

This methodology for land use change will be further discussed with stakeholders and tested in practice because this use of IPCC land use data in a GHG tool is new.

### 5.8 Emissions due to displacement of prior production

One complex but important issue in the GHG calculation methodology is how to factor in the reference production of biomass used for different purposes, e.g. food, timber, biofuels. In the Cramer Commission's earlier report this is cited as a topic to be investigated after 2011. Land-use changes may be direct as well as indirect (i.e. due to dislocation of other production) and including a reference production system in the analysis means indirect land use changes will, in principle, be duly accounted for.

Including a factor for the reference production system might encourage the use of set-aside land and marginal land over good agricultural land. With such a factor, set-aside and marginal land would get no penalty for reference production, leading to improved GHG reduction performance, as generally desired by biofuel policy-makers. It would also mean preference for agricultural intensification and avoidance of competition with food crops. Another important argument for including this aspect is the fact that CDM and JI explicitly include this factor in their GHG calculations by determining 'baselines'. If such a factor is not included in a calculator for bio-energy use in the EU, European biomass usage might be at an unfair advantage compared to CDM biomass projects in non-EU countries.

Land use change and reference production as an indicator of displacement (leakage) effects is another important aspect. Although in the longer term this might also be included in the GHG calculator, it is too complex, according to the Commission Cramer, to do so at the moment. As this impact may be substantial, results calculated with the GHG calculation tool must always be presented with a clear disclaimer that "the displacement effects of production have not been included in the calculation"

Displacement effects in the relevant markets can more readily be monitored on a larger scale and the Dutch and British governments therefore intend to monitor them at the national and/or European level. The results of these monitoring efforts will be used to adjust biofuels policies, possibly being incorporated in a GHG index at a later stage.

*NGO's suggests to include displacement*
Dutch NGO's find this neglecting of the displacement effect unacceptable. They do not support the general opinion of the commission that inclusion in the methodology is one step to far and that macro monitoring is a good alternative.

*Monitoring macro (displacement) effects of national and European biofuel policies*
In broad brush-strokes, the monitoring scheme for displacement effects could take the following form:
1 Determine the relevant markets/areas delivering biofuels to the country/EU.
2 Determine the expansion of each of these markets due to biofuels, due to food/feed and in total.
3 Determine how the additional demand is being met (e.g. by intensifying current agricultural production, extending farmland acreage, etc.)

4   Determine the GHG and biodiversity impacts of expansion of these markets (varying from almost no effect if yields are improved to large effects if deforestation is occurring).
5   Distribute the impacts of market expansion over biofuels and food/feed.
6   Divide these effects by the amount of biofuels per market.

To this end market statistics and satellite photographs can be used, as well as the model built by MNP and others for the Biodiversity convention (MNP, 2006).

This displacement monitoring scheme could examine developments and effects in 2004, 2005 and 2006, for example, publishing its results in 2007. This could lead to:
−   Excluding some sources of biofuels because of major negative displacement effects.
−   Introducing a displacement GHG penalty for some biofuel sources with moderately negative displacement effects.
−   Neglecting displacement in the GHG calculator for sources with only a minor displacement effect.
This monitoring scheme should ideally be integrated by the EU into a Strategic Environmental Impact Assessment for the Biofuel Directive.


## 5.9   Emissions due to reference residue use

A factor important for bio-electricity, for certain of today's biofuels and, in the future, for second-generation biofuels is the reference residue use. This factor accounts for whether the residue used was formerly used in other economic activities (mainly as animal feed and fertilizer or as a soil improver). For all the main residues, default values can be calculated.

What we are concerned with here is how to avoid competition with existing useful biomass applications, an issue brought up by NGOs. As research from the University of Utrecht and CE Delft has shown, factoring in a reference residue use can lead to a 50% decrease in GHG reduction in the case of bio-electricity generation

Example 1: DDGS (Distillers' Dried Grains and Solubles) is a co-product of wheat-ethanol production that is of value as an animal feed but can also be burned in a coal-fired power plant. The animal feed displaces soy-bean meal (Edwards, 2006), which means the emissions associated with soy-bean production and transport are displaced.

Example 2: Straw is an agricultural residue originating from a wide range of crops. When oilseed rape is planted instead of wheat, the ensuing straw is not very suitable for use as animal feed and is generally ploughed in, in contrast to wheat straw, which provides better animal feed. This difference has two effects:
1   Ploughing in the rape straw means less fertilizer usage compared with not ploughing in the wheat straw but sometimes also extra methane emission due to anaerobic digestion.
2   Another residue or product must be used as animal feed, to substitute for the wheat straw.

*Reference agricultural production or reference residue use*
In GHG calculations "reference agricultural production" or "reference residue use" are accounted for in different ways, depending on the type of input: crop or residue. Some biomass can be regarded as a crop as well as a residue. In such cases the company using the calculator will be free to choose, and the calculator should yield the same results in each case. This will have to be duly checked during actual development of the calculator.

Reference residue use should in principle be included in the GHG calculation. This factor is especially important for bio-electricity and heat, but also for certain biofuel chains. The only issue to be wary of is double counting of GHG reductions due to avoided methane emissions from landfill. This will be discussed during further development of the calculator. If biofuels produced from residues (e.g. second-generation fuels) become more important, this factor should be included. If possible, the **marginal** effect of an extra kg of residue use will be calculated.

*Residues from other biofuels chains*
Some resicidues or byproducts of biofuel chain A can be a source for biofuels chain B. (EG glycerine) In this case it is logical that the $CO_2$ burden which is allocated from chain A to the byproduct is used as input for the calculation of chain B.

## 5.10 The functional unit for comparing fossil and bio-energy

The basis for comparing bio electricity and fossil electricity is 1 kWhe delivered to the customer.
The basis for comparing biofuels for transport with conventional fuels is 1 km driving of a standard car on gasoline or diesel. Bioethanol wil be compared with gasoline, biodiesel with diesel. This way efficiency differences between ethanol and gasoline which are claimed can be included. Furthermore differences in de base gasoline (RBOB) because of addition of ethanol or ETBE can also be included.

## 5.11 Fossil energy references

The fossil energy reference must also account for the production and transport of these fossil fuels. In most databases, production process emissions are included in fuel emission data. The report 'To shift or not to shift' (CE, 2003) provides emission data per litre diesel and per tonne.km transport per ship. For emission data on electricity production in the Netherlands, the environmental report of EnergieNed (Dutch electricity producers association)  can be used.

For biofuels it has to be considered if differences in the base gasoline (RBOB) for mixes with ETBE and ethanol and conventional fuel are important enough to include in the calculation tool.

*A very good European source for fossil fuel references for the transport sector is the Well to Wheels study (Edwards, 2006).*

A more difficult question with respect to the production bio-electricity and heat is how the fossil energy reference is to be determined in the case of combined heat and power production (CHP). In most existing reports, separate production of heat and electricity is taken as the reference. In some cases this would appear to be too positive, as CHP from natural gas is a possible or even preferable choice of reference.

In all cases, the entire fossil energy chain needs to be included, as is the case in the Walloon GHG calculator for bio-electricity. This means data is also required on gas production, distribution and so on. For CHP, and especially for small-scale CHP, it is recommended not to assume automatically that the reference is separate production but to ask for proof of this. The following issues still need to be discussed and resolved:
−   Should calculations on fossil electricity be based on best available technology (Combined Cycle Gas Turbine (CCGT), 55% gas efficiency, as in Belgium), average European production, average national production or estimated marginal production?

Leading principal for answering this question is the causality question: If 1 kWhe bioelectricity is added which other source is not used because of that.

In the recent updated Dutch Protocol Monitoring Renewable Energy a mix of commonly used electricity production is used for stand alone bio electricity. For co-firing in existing installations direct replacement of coal or natural gaz is used.
*Table 3.3 in this report [Monitoring RE, 2006} gives 0,592 kg/kWhe produced in 2005 and 0,425 kg/kWhe in 2010)*
The commission suggests to follow this Monitoring protocol for electricity and heat references.

For fossil transport fuels, too, data on the entire chain are required. Again, there are a number of issues that need to be discussed:
−   Does the marginal production swing of fossil transport fuel differ from the average? (This might be affected by production from Canadian tar sands, for example, but on the other hand Saudi Arabia might also produce more).
−   Is there a need for regional differentiation of fossil default values, and can such information be found?

## 5.12    Default values and freedom to use actual values

An issue of a different kind is how default values are to be established for the calculator.

**Conservative, typical and best practice values**
For most parameters used in the calculator it is possible to calculate:
−   A conservative value, i.e. the worst case in the market.

- A typical value, i.e. the market average.
- A best practice value, i.e. the best in the market.

It is recommended to derive all three values and include them all in the calculator, to provide companies data with which to assess their performance compared with the rest of the market.

**Conservative default values for readily obtainable, important data**

The British approach of linking the amount of effort required to obtain an up-to-date default value to the degree of conservatism of the value is interesting. This means conservative defaults will incentivise the gathering of important data that is readily obtainable.

Table 2     Setting of default values

| Effort to obtain data | Important factor | Less important factor |
|---|---|---|
| Easy | conservative | conservative |
| Possible | conservative | typical |
| Difficult | between cons. and typical | typical |

**Prevention of optimisation through strategic use of actual and default values**

A GHG emission reduction calculator for bio-energy generally has around 5 to 25 parameters, covering any number of steps from production, conversion and transport through to bioproducts, fossil references and so on, depending on the level of detail desired.[5] While seeking agreement on default values for these parameters, the Cramer Commission also wants to allow companies to use their own values (in combination with some default values). To encourage the latter, conservative default values will be set.

Although this seems to be a logical approach, it also involves certain dilemmas. Small companies may not be able to calculate their own values (due to the relatively high cost) and will have to use the defaults. If all the parameters are chosen conservatively, it is very likely that this will result in a very low $CO_2$ emission reduction for these companies. There is a risk, furthermore, that journalists (or NGOs) experimenting with the calculator might publish this very conservative estimate as 'the truth'. If, alternatively, more mid-range default values are chosen and companies are free to choose between defaults and own values, very high $CO_2$ emission reduction figures will result that may be too optimistic.

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**Example: Biofuel Z and the effects of opportunistic usage of actual and default values**

For Biofuel Z, GHG emissions comprise the emissions of production (PrZ), Transport (TrZ), Conversion (CoZ), N2O (N2OZ), minus the emissions allocated to by-product Y (BiY):

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[5]   Working with very detailed tier levels, the number of parameters may well exceed 25. Many of these data will have to be provided by the producer, however. The most important default values to agree on are those representing emissions aggregated from a more detailed level.

GHG Z = PrZ + TrZ + CoZ+ N2OZ - BiY
         reference fossil fuel


Assume the following average defaults in the calculator and the following actual values for Z:
            av. default    actual value
Pr Z          10              15
Tr Z          10              8
COZ           10              12
N2O           20              5
BiY           30              15
Ref           100             100


GHG emissions (emissions reduction) can now be calculated in the following ways:
GHG = 3% (97% reduction) if all best values are taken, or
GHG = 20% (80% reduction) if all default values are taken, or
GHG = 25% (75% reduction) if all actual values are taken, or
GHG = 42% (58% reduction) if all worst values are taken and made the conservative default.

As the example in the box illustrates, complete freedom of choice between defaults and actual values will lead either to very optimistic results, because of opportunistic choices, or very conservative default values that make it impossible for small firms with insufficient data.

### Correlation between factors

Some parameters are obviously correlated. For example, in any given region there will be high degree of correlation between crop yield and fertilizer input. It is therefore recommended to organise correlated parameters in a coupled group. For these kinds of parameters, it is only possible to use actual values if all the values are available.

The British idea to set conservative default values for key data that are relatively easy to obtain is supported. The Dutch idea to prevent opportunistic optimisation through selective use of actual and default values by not allowing complete freedom in the mix of actual and default data is also supported. Furthermore, the idea of also providing typical values to encourage parties to improve their results and help journalists wishing to use the tool for other purposes is also supported.

### 5.13    Procedure for setting default values for in a calculation tool

Based on the earlier discussions in this chapter the following procedure could be used to set default values for a calculation tool for bio fuels, electricity and heat:

1   Gather all relevant independent sources with values for default values for the separate chains (see for suggestions the different paragraphs in this report).
2   Determine which values are correlated (eg yield and fertilizer use) and which values are not correlated. Make combinations of values for values which are correlated and treat them further as a combination of values.
3   Discuss this values and combinations of values with an international expert group and determine with this expert group typical (combination of) values, best available (combination of) values and conservative worst case (combination of) values.

4   Check for the different (combination of) values (best available, typical, worst case) the difference between the results in %GHG reduction. This indicates the different levels of importance of the values.
5   Estimate the effort which is necessary to collect actual values.
6   Make a proposal for a mix of default values (typical and conservative) based on importance and effort needed to get the actual value (see Table 2).
7   Discuss the chosen default values with stakeholders.
8   Determine the default values based on the above process.

# 6 Further recommendations

Besides spawning the greenhouse gas calculation methodology described here, which in itself contains several recommendations on points of detail, discussions with the Cramer Commission and the British government led to several additional recommendations:

1 It is recommended to evaluate the methodology and its practical use in 1 to 2 years' time.

2 It is recommended to streamline the process of gathering information for greenhouse gas emission calculations and biodiversity impact calculations, because many of the land use issues affect both. This will reduce the overall effort required.

3 It is recommended to start immediately with monitoring and analysing the macro-effects on greenhouse gas emissions, biodiversity and competition with food caused by national and EU biofuel and bio-energy policies. The results of this macro-monitoring of developments in production regions can help improve both biofuel policies and the GHG methodology presented here.

4 It is recommended to work together with other European Countries and the European Commission towards a European GHG tool.

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