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*Ministry of Infrastructure and the Environment*

# Using the GBEP indicators in the Netherlands: The Outcomes of a desk study

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# Abbreviations

| | |
|---|---|
| CBS | Central Bureau of Statistics |
| EC | European Commission |
| EEA | European Environment Agency |
| ECN | Energy Centre of the Netherlands |
| ECOWAS | Economic Community Of West African States |
| EHS | Ecological Main Structure |
| EU-RED | Renewable Energy Directive 2009/28/EC of the European Parliament and Council |
| FAO | Food and Agricultural Organization |
| GBEP | Global Bioenergy Partnership |
| GHG | Greenhouse Gas |
| IEA | International Energy Agency |
| JRC | Joint Research Centre |
| LEI | Landbouw Economisch Instituut (Agricultural Economic Institute) |
| Meuro | Million euro |
| Mton | Million metric ton |
| NEA | Nederlandse Emissie Autoriteit (Netherlands Emissions Authority) |
| NREAP | National Renewable Energy Program |
| PJ | Peta (1015) joule |
| PBL | Planbureau voor de Leefomgeving (Netherlands Environmental Assessment Agency) |
| SRC | Short rotation coppice |
| TJ | Tera (1012) joule |
| TPES | Total Primary Energy Supply |
| UNEP | United Nations Environmental Programme |

# Guidance to the reader

In November 2011, the G20 and the GBEP Steering Committee endorsed the report “The Global Bioenergy Partnership Sustainability Indicators for Bioenergy”. This report presents 24 voluntary sustainability indicators. In 2012, various countries (including the Netherlands) are testing the practical applicability of these indicators. The findings will be reported to GBEP. This learning experience will support the capacity building efforts at GBEP.

The objective of this desk study is to make a results estimation of selected GBEP indicators applied to the Netherlands. The assessment of these indicators makes possible gaining insight into the practical applicability of GBEP indicators and the applicability of the methodology description in the Netherlands. This desk study also provides insights in the level of sustainability of the Dutch bioenergy sector.

In total, eighteen out of the twenty-four GBEP indicators are assessed in this study. This selection is based on the relevance of the indicators for the Dutch case. Care was taken that the selection of GBEP indicators represented well the three main pillars of GBEP: social, environmental and economic pillars.

Chapter 1 gives an introduction of GBEP, followed by the explanation of the objective of the study in chapter 2. Chapter 3 presents the key conclusions and recommendations of the findings of this study. The outcomes of the individual indicators are one by one explained in chapter 4. The next chapter 5 explains the general approach followed to estimate the indicators. This includes the selection of the indicators, the development of a template and the definition of the bioenergy sector. The methodological approaches for the individual indicators are further explained in chapter 6, followed by an explanation of the used data sources in chapter 7.

The information for this report was compiled with the utmost care. Comments or suggestions on the information presented in this report are highly welcomed: please contact the authors to share your views. The authors cannot be held responsible for the consequences of any errors or mistakes in the report.

This desk study has been carried out in the period from December 2011 to March 2012. This report expresses the opinion of the authors, and not necessarily NL Agency's views.

# 1 Introduction

The need to secure sustainability in a fast growing bioenergy market is widely acknowledged. Legislation and national policies are implemented or are for example under development in European countries, in the US or in Mozambique, Africa. Besides this, voluntary certification initiatives (such as RSB, NTA8080 or ISCC plus) are either developed or being developed to safeguard the sustainability of biomass for various end-uses. These initiatives intend to monitor performance on a project level. These initiatives, along with their differences in sustainability requirements, make their use difficult for the monitoring of the national sustainability performance of bioenergy over time, in relation to implemented policies.

## 1.1 Background GBEP

The Global Bioenergy Partnership (GBEP) is an international forum of governments, intergovernmental organizations and other partners. Members work towards consensus in the areas of the sustainable development of bioenergy. Around 45 government representatives and 22 international organizations are involved either as partners or observers. Members include large economies such as China, Brazil or the US.

In November 2011, the G20 and the GBEP Steering Committee endorsed the report "The Global Bioenergy Partnership Sustainability Indicators for Bioenergy" (GBEP, 2011). This report presented 24 voluntary sustainability indicators. The indicators intend to guide analysis of bioenergy development at a national level; they aim at supporting decision making on these issues. In addition, supporting information was provided in this report for each indicator on the data requirements and scientific basis. Suggested approaches for the measurement of indicators are presented as well in the enclosed methodology sheets.

The GBEP indicators cover together the 3Ps: People, Planet and Profit. The indicators do not intend to give a grading on performance. However, when measured over time, they can show progress regarding established national goals for sustainable development.

The objective of GBEP is that participating countries monitor indicators over longer periods of time. It is therefore important that indicators can be verified in practice within an acceptable time frame and costs. The latter is especially of relevance for those countries with small government budgets.

During the writing of this report, the Netherlands, Germany, Ghana, Indonesia and Colombia are testing the indicators on their practical applicability and report their findings to GBEP. Various other countries and organizations are intending to do so, such as Japan, the United States, Madagascar, FAO, UNEP the American Development Bank or the Economic Community Of West African States (ECOWAS)

# 2 Objective

The objective of this desk study is to make a result estimation of the selected GBEP indicators applied to the Netherlands. The assessment of these indicators makes possible gaining insight into the following aspects:

- The practical applicability of GBEP indicators;
- The applicability of the methodology description in the Netherlands;
- Feasibility (in terms of cost and time) of the yearly reporting of the GBEP indicators as a monitoring tool;
- The level of sustainability of the Dutch bioenergy sector; this without any judgment on the level of performance.

# 3 Key findings and recommendations

## 3.1 Key findings

This desk study has made a result estimation of the selected GBEP indicators applied to the Netherlands. The GBEP indicators cover environmental, social and economic pillars. Together, they provide insight in the level of sustainability of the Dutch bioenergy sector; this without any judgment on the level of performance.

The findings will be separately discussed for the three pillars of the GBEP indicators. Note that the outcomes have their uncertainties. Results should therefore be interpreted with care considering the limitations and uncertainties as discussed in chapters 4, 5 and 6. The practicality of the GBEP indicators (data availability, methodological constraints, usefulness, etc) of the GBEP indicators is discussed in the report 'Using GBEP indicators in the Netherlands, Practicality of the indicators' (SQ Consult, 2012).

### *3.1.1 Environmental pillar*

The maximum total area of land for bioenergy feedstock production in the Netherlands compared to the total national surface is only 0,3%. This is 2% of the total agricultural area. A very limited amount of fresh harvested wood and harvest residues are being used for energy purposes in the Netherlands. The estimated results show that forests in the Netherlands are being harvested sustainably.

Bioenergy has not directly contributed to yield increases. The contribution of bioenergy from degraded land is assumed to be zero. Residues contribute to 48% of the domestic bioenergy production; this is 50% for waste (see indicator 8).

The net annual conversion rates between land-use types caused directly by bioenergy feedstock production have been minimal in the last years. Limited changes have taken place between crop types within the agricultural area.

Results indicate that the area and percentage of nationally recognized areas of high biodiversity value or critical ecosystems converted to bioenergy production has been zero.

A change in crop cultivation in the agricultural area can result in a change in soil carbon stock change. Results indicate that energy crop production may lead most of the time to similar or slightly improved soil carbon stocks. There may be a decrease in soil carbon stocks when rapeseed replaces for example wheat or when SRC replaces grassland. The risk for lower soil quality due to lower soil carbon stocks is expected to be minimal. Care needs to be taken for crop or land use conversions on peatland areas.

Various studies indicate a decrease in peat areas in the Netherlands. Underlying reasons are the loss in organic matter for soil areas used for agriculture, in combination with drainage or not. Conversion of peat areas in the Netherlands cannot be attributed directly to bioenergy feedstock production though.

**Table 1: Overview results of the environmental indicators (Ind = indicator)#**

| Ind | Sub-indicator | Result | Measured unit |
|---|---|---|---|
| 1 | GHG emitted per MJ biofuel produced | 29.7 | g $CO_{2eq}$/MJ biofuel |
| 2 | Percentage of improved or maintained soil carbon | 88 | % |
| | Risk on land with possible decrease soil carbon | Minimal | Qualitative |
| 3 | Annual harvest of wood resources by volume | 1200000 | $m^3$ |
| | Annual harvest of wood resources as % of net growth | 55 | % |
| | % Of the annual harvest used for bioenergy | 0,07 | % |
| 4.1 | Feedstock production emissions: PM2.5 | 202 | g/ha |
| | Feedstock production emissions: PM10 | 226 | g/ha |
| | Feedstock production emissions: $NO_x$ | 2486 | g/ha |
| | Feedstock production emissions: $SO_2$ | 29 | g/ha |
| 4.2 | Processing emissions: PM2.5 | 0.11 | mg / MJ |
| | Processing emissions: PM10 | 0.15 | mg / MJ |
| | Processing emissions: $NO_x$ | 9.12 | mg / MJ |
| | Processing emissions: $SO_2$ | 2.86 | mg / MJ |
| 4.3 | Transport emissions: PM2.5 | 0.01 | mg / MJ |
| | Transport emissions: PM10 | 0.01 | mg / MJ |
| | Transport emissions: $NO_x$ | 0.29 | mg / MJ |
| | Transport emissions: $SO_2$ | 0.03 | mg / MJ |
| 4.4 | End-use emissions: PM2.5 | 99 | mg / MJ |
| | End-use emissions: PM10 | 103 | mg / MJ |
| | End-use emissions: $NO_x$ | 237 | mg / MJ |
| | End-use emissions: $SO_2$ | 13 | mg / MJ |
| 5.1 | Water withdrawn from nationally-determined watersheds | 0.15% | % Of TARWR |
| | for the production and processing of bioenergy feedstock | 0.01% | % Of TAWW |
| | (only estimated for energy crops) | | |
| | # Renewable sources | $4.5*10^{-5}$ | % pf TAWW |
| | # Non-renewable sources | $8.8*10^{-5}$ | % of TAWW |
| 5.2 | Water withdrawn from nationally-determined watersheds | 0.48 | $M^3$/GJ |
| | for production and processing of bioenergy feedstock | Low | Qualitative |
| 6.1 | Pollutant loadings to waterways and bodies of water | 0.2-0.5 (N) | % Of total loadings |
| | attributable to fertilizer and pesticide application for | 0.3 (P) | |
| | bioenergy feedstock production | 0 – 0.1 (AI) | |
| 6.2 | Pollutant loadings to waterways and bodies of water | <1.4 | Mg/l |
| | attributable to bioenergy processing effluents | Low | % |
| 7.1 | Nationally recognized areas of high biodiversity value | 0 | Ha |
| | /critical ecosystems converted to bioenergy production; | 0 | % |
| 7.2 | Land used for bioenergy production where nationally | 0 | Ha |
| | recognized invasive species are cultivated | 0 | % |
| 7.3 | Land used for bioenergy production where nationally | 232 | Ha |
| | recognized conservation methods are used. | 5 | % |
| 8.1 | Total area of land for bioenergy production | 10723 | Ha (max) |
| | Land for bioenergy compared to national surface | 0.3 | % |
| | Land for bioenergy compared to agricultural area | 2.0 | % |
| | Land for bioenergy compared to managed forest area | 3.1 | % |
| 8.2 | Bioenergy from yield increases | 0 | % |
| | Bioenergy from residues | 47.8 | % |
| | Bioenergy from wastes | 50.2 | % |
| | Bioenergy from degraded / contaminated land | 0 | % |
| 8.3 | Net annual conversion rates land-use types (various) | 0 | Ha/yr |

# Check methodology chapter regarding uncertainties and robustness of the outcomes.

The Netherlands has a moderate water stress level. Water use by the agricultural sector is minimal compared to other economic sectors. The estimated proportional contribution of energy crops to the total actual renewable water resources (TARWR) is very small. The contribution of energy crop cultivation to pollutant loadings in the water is very minimal as well. Maize for energy represents for example respectively 0.4% and 0.6% of the total N and P fertilizer use (based on maximum allowed amounts) of the total agricultural land. The contribution of maize for energy and rapeseed to the use of chemical pesticides in agriculture is around 0% to 0.1% for all watersheds. The water use and processing loadings to the surface water by bioenergy processing facilities is expected to be limited. Information is highly uncertain and scarcely available though.

In the Netherlands, no invasive species are used for energy crop production. Based on national averages, around 9% of the bioenergy crop production applies nature conservation methods.

The average greenhouse gas emissions that can be attributed to a MJ of biofuel in the Netherlands is 29.7 g of $CO_{2eq}$/MJ. Compared with the standard fossil transport fuel emission according to ER-RED (2009), this constitutes a GHG emission savings of about 65%. Insufficient data are available about the GHG emissions from bioenergy for heat and electricity. The estimations on non-GHG gas emissions to air caused by bioenergy production have significant uncertainties. The outcomes suggest that on average per MJ bioenergy, the emission of pollutants like $NO_x$, $SO_2$, PM2.5 and PM10 are often higher than per MJ conventional energy. However, non-GHG emissions are highly dependent on the technical system in which combustion takes place, and on physical characteristics of the fuel. Typically, the formation of these pollutants is less controlled in smaller systems, which therefore have significantly higher emissions per MJ. A primary consideration of GBEP is the impact of bioenergy on the local air quality. No indication of elevated risk has been found for the Netherlands.

The use of energy crops for bioenergy production in the Netherlands is limited and its impact on land-use related environmental impacts is therefore inherently minimal as well. The cultivated energy crops show differences in water use, fertilizer needs or soil carbon stocks. Selecting a suitable energy crop for the local conditions in the Netherlands is key for further improving the sustainability performance of domestic biomass production. This will also be true for residues and waste for biomass production although specific information on these resources is too scattered at this moment to give this a definite conclusion.

### *3.1.2 Social pillar*

The average growth of employment in the total renewable energy sector in the Netherlands is 189% from 2007 to 2010. This was 200% for the bioenergy sector and 160% for the wind energy sector. Employment growth of the bioenergy sector has thus been positive, also in comparison to other renewable energy sectors. Income levels and risk of injuries of the bioenergy sector are comparable to other economic sectors with similar activities.

Results indicate that the bioenergy sector is increasingly contributing to the employment and income generation for people in the Netherlands. Contributions are, however, still limited in comparison to other traditional economic sectors.

**Table 2: Overview results of the social indicators (Ind = indicator) #**

| Ind | Sub-indicator | Result | Measured unit |
|---|---|---|---|
| 11.1 | Average income paid per year | 19810 to 54010 | € / year, depending on sector |
| | Change in income | 0 | % |
| 11.2 | Annual savings by households | 134 to 235 | € / Year saved, max. |
| | Savings as % of share of total income | 0.43 to 0.76 | % of average total income, max |
| 12.1 | Net job creation | 6517 | Number (2009 to 2010) |
| | Net job creation per MJ bioenergy | $5.12 \times 10^{-8}$ | Number / MJ |
| 12.2 | Net job creation – number of skilled jobs | 4344.70 | Number (2009 to 2010) |
| | Net creation skilled jobs per MJ bioenergy | $3.41 \times 10^{-8}$ | Number / MJ |
| | Net job creation – number of unskilled jobs | 2172.35 | Number (2009 to 2010) |
| | Net creation unskilled jobs per MJ bioenergy | $1.71 \times 10^{-8}$ | Number / MJ |
| 12.3 | Net job creation – number of definite jobs | n.a. | Number (2009 to 2010) |
| | Net creation definite jobs per MJ bioenergy | n.a. | Number / MJ |
| | Net job creation – number of temporary jobs | n.a. | Number (2009 to 2010) |
| | Net creation temporary jobs per MJ bioenergy | n.a. | Number / MJ |
| 12.4 | Total number of jobs | 11920.45 | Number |
| | Number of jobs in relation to total working population | 0.19 | % |
| 12.5 | Number of jobs in compliance with ILO | 100 | % |
| | Number of jobs other sectors in compliance with ILO | 100 | % |
| 16 | Number of sick days per MJ bioenergy | $4.4 \times 10^{-9}$ | Number / MJ |
| | Number of sick days per ha of biomass produced | n.a. | Number / ha |

# Check methodology chapter regarding uncertainties and robustness of the outcomes.

### 3.1.3 *Economic pillar*

The results show that bioenergy in the Netherlands contributes to the total primary energy supply and diversity in the Netherlands, though to limited extent (2.4% in 2010).

Total annual savings of convertible foreign currencies are positive for most bioenergy systems, but negative for biofuels. Underlying reasons are that biofuels are typically more expensive than conventional fuels for road transport and that most of the biofuels, or the crops they are made from, are imported. It should be noted that bioenergy production and use in the Netherlands is largely policy driven, and the costs are generally higher compared to fossil systems (excluding externalities and carbon credits).

Accurate data about the suitability of the use of existing infrastructure for bioenergy were not available. It can, however, be concluded that major disruptions that endanger the energy supply in the Netherlands are unlikely. The country has a good transport infrastructure for energy and dry and wet bulk. Note that there is, however, a risk involved when infrastructural disruptions happen in those countries from where the Netherlands imports its biomass.

**Table 3: Overview results of economic indicators (Ind = indicator)** #check uncertainties in methodology chapter

| Ind | Sub-indicator | Result | Measured unit |
|---|---|---|---|
| 17.1 | Productivity: Energy maize | 45.2 | ton/ha/yr |
| | Productivity: Rape seed | 4.4 | ton/ha/yr |
| | Productivity: SRC | 4.8 | ton/ha/yr |
| | Productivity: Miscanthus | 15.0 | ton/ha/yr |
| 17.2 | Processing efficiency: Energy maize | 6050 | MJ/tonne |
| | Processing efficiency: Rape seed | 13653 | MJ biodiesel/tonne rapeseed |
| | Processing efficiency: SRC | 10345 | MJ/tonne |
| | Processing efficiency: Miscanthus | 14433 | MJ/tonne |
| | Processing efficiency: Wood pellets | 10870 | MJ Pellets/tonne Wood |
| | Processing efficiency: Wood chips | 9059 | MJ Chips/tonne Wood |
| | Processing efficiency: Biodiesel from UCO | 33808 | MJ biodiesel/tonne UCO |
| 17.3 | Amount bioenergy: Energy maize | 273470 | MJ/ha/yr |
| | Amount bioenergy: Rape seed | 60073 | MJ/ha/yr |
| | Amount bioenergy: SRC | 50000 | MJ/ha/yr |
| | Amount bioenergy: Miscanthus | 216495 | MJ/ha/yr |
| 17.4 | Production cost: Energy maize | 0.02 | USD/MJ |
| | Production cost: Rape seed | 0.01 | USD/MJ |
| | Production cost: SRC | n/a | USD/MJ |
| | Production cost: Miscanthus | 0.06 | USD/MJ |
| | Waste combustion | 0.02 | USD/MJ |
| | Small scale biomass combustion <10 MWe | 0.07 | USD/MJ |
| | Large scale biomass combustion 10-50 MWe | 0.04 | USD/MJ |
| | Landfill gas | 0.03 | USD/MJ |
| | Wastewater treatment | 0.02 | USD/MJ |
| | Manure co-digestion | 0.07 | USD/MJ |
| | Other digestion | 0.06 | USD/MJ |
| 18.1 | Energy ratio feedstock production | 0.02 | |
| 18.2/3 | Energy ratio bioenergy processing &use | 0.56 | |
| 19 | Gross value added per MJ bioenergy | 0.0083 | US$/MJ |
| | Gross value added to GDP | 0.081% | % Of national GDP |
| 20.1 | Substitution of fossil fuels | 70277 | TJ TPES |
| 20.2 | Annual savings | 120 | MEuro/year |
| | Municipal waste; renewable fraction | 121 | MEuro/year |
| | Co-firing of biomass in electr. Plants | 25 | MEuro/year |
| | Wood boilers for heat in companies | -2 | MEuro/year |
| | Wood stoves in households | 14 | MEuro/year |
| | Other biomass combustion, total | 48 | MEuro/year |
| | Biogas | 80 | MEuro/year |
| | Bioethanol | -77 | MEuro/year |
| | Biodiesel | -88 | MEuro/year |
| 20.3 | Substitution of traditional biomass | 0 | TJ |
| 22.1 | Energy diversity (Herfindahlindex) | 0.37/0.39 | With / without bioenergy |
| 23.1 | Number of critical distribution systems | 3 | - |
| 23.2 | Capacity of routes for critical distribution systems | n/d | - |
| 23.3 | Proportion of bioenergy of total capacity | 0-5 | % |
| | Storage and transport capacity biofuels | 5 | % |
| | Biogas transportation grid | 0 | % |
| | Port facilities | <1 | % |
| 24.1 | Ratio bioenergy potential / actual production | 0 or 1 | - |
| 24.2 | Ratio flexible production vs. actual production | 0 to 1 | (For bioenergy) |

There are obviously various technical, economic and legal barriers that need to be overcome when expanding bioenergy use, as in the case of feeding green gas into the main gas grid. But these aspects may be considered as business-as-usual and are not expected to endanger the energy security.

Results on productivities of bioenergy in tonne and MJ per hectare are restricted to domestically cultivated crops. The results differ per crop, which can be attributed to the physical differences between the crops, their cultivation conditions and end-uses. Also the processing efficiencies differ per crop, and also per residue processed, at least when expressed in MJ processed product per tonne feedstock.

In monetary terms, bioenergy production costs are all in the same order of magnitude: 0.01 to 0.07 $US per MJ bioenergy. The gross value added per MJ has been calculated at 0.0083 US$. Bioenergy crosses various economic sectors; almost all sectors can have a relation to bioenergy, directly through bioenergy consumption or indirectly through services or goods supplied. In total, bioenergy adds 0.081% to the national GDP.

The results also indicate that the Netherlands has still potential capacity available to extend its actual bioenergy production of municipal solid waste combustion, co-firing of biomass and biofuel use for road transport. Increased use of bioenergy from other smaller scale bioenergy systems requires, however, expansion of production capacity. Especially the production and use of biogas is expected to increase rapidly during coming decades. The use of biofuels for road transport and the co-firing of biomass will increase as well as a result of EU legislation.

### *3.1.4 Netherlands as trading country: Footprint in and outside the Netherlands*

The Netherlands is a trading country of bioenergy. Biomass is imported for internal consumption, (further) processed for export or re-transferred to other countries. Sustainability of bioenergy in the Netherlands is therefore inextricably linked with the activities that take place outside its border.

Firstly, the Netherlands is dependent on the bioenergy activities in other countries. For example, weak infrastructure or capacity shortages in other (mainly importing) countries may have serious consequences for the continuous supply of imported biomass. This is especially relevant for bioenergy systems that rely on imported biomass, such as biofuels for road transport and co-firing of biomass.

Secondly, import of biomass to the Netherlands also means that (part of the) producing and processing activities of biomass takes place in other countries. Several of the indicators show the high possibility that part of the generated sustainability impacts takes place outside the Netherlands. An example is the water use of bioenergy or the emissions to air in the production phases. Other example relate to the harvest levels of bioenergy or to biodiversity impacts.

As third example: the results show no net annual conversion rates in the Netherlands between land-use types caused directly by bioenergy feedstock production. The situation can, however, be different in biomass exporting countries with insufficient land management policies. Indirect land use change is not included in the GBEP indicators but may be a driving force for further land use changes as well.

Note that the division between domestic and import is not the same in different phases of the lifecycle. An example can be given for rapeseed biodiesel: The rapeseed can be imported or domestically produced, oil extraction can be national or foreign, conversion to biodiesel can take place domestically or abroad and the end-use can be national, or the biodiesel can be exported. Multiple indicators rely on the fact that all lifecycle steps have the same scope, so can be summed up. In the case of the Netherlands this is, however, not possible for almost the entire bioenergy production.

Results should therefore be interpreted in perspective with the bioenergy production, consumption and trade flows of a country.

## 3.2 Recommendations for future use

The outcomes of the indicators have their uncertainties and limitations. They do, however, provide a useful input for the main objective of GBEP: to show the level of sustainability of current bioenergy production in the Netherlands, where improvements can be made, and how this relates to established national goals for sustainable development.

### *3.2.1 Recommendations for future use: improving sustainability*

The outcomes of the indicators do provide insight in how bioenergy production and processing in the Netherlands can be further improved to make it more sustainable.

The results indicate that losses in soil carbon may happen when changes are made in selection of crops or intensification of agriculture. A change in crops within the same agricultural area may also result into (small) changes of higher water needs, biodiversity impacts or fertilizer needs. Selecting a suitable crop for biomass production is therefore of importance, also in the Netherlands, even when produced on small scale.

The Netherlands is a country with an oversupply of manure from livestock. The choice to use organic residues or manure for (co-) digestion has influence on various sustainability impacts as the soil quality or GHG emissions (e.g. methane from manure). The use of the GBEP indicators can provide insight in the environmental impact of these feedstocks, which can form a basis for adjustment of policies based on well-founded trends and priorities. This requires a better quantification of residues and waste streams though.

A substantial amount of the total bioenergy feedstock used in the Netherlands comes from waste and residues. Most of the waste is used for waste incineration or for biogas. Most of the residues are used for co-firing or biomass incineration. Insufficient data are available to discriminate between the waste coming from the biobased economy and from other types of waste. A growth in biobased products should preferably show a decrease of high value waste and residues for bioenergy.

Results indicate the possibility in the Netherlands for further promoting positive benefits from bioenergy in other economic sectors. An example is the integration of bioenergy in nature areas or, vice versa, promoting nature conservation in energy crop production areas.

Some final outcomes of the GBEP indicators do not realize their full potential in terms of giving insight in how to improve sustainability. Disaggregated data are for most indicators available though. In the case of non-GHG emissions to air, it appears that the specific technical system used to combust the bioenergy is the main determining factor in emission levels. In the case of GHG emissions, bioenergy for electricity appears to have lower GHG emission values than bioenergy for transport or for heat. This information is of use to compare for example promising technologies or crops (see also 3.2.2).

An important aspect of the bioenergy use in the Netherlands is that large quantities of biomass and bioenergy are imported (see also 3.1). The sustainability of the production of these imports can be improved and assured by using certification systems like the NTA 8080 / 8081 or one of the certification schemes approved by the European Commission as part of the Renewable Energy Directive.

Most of the bioenergy systems are more expensive compared to fossil energy systems. A key aspect of the production and use of bioenergy is that it is (still) policy driven and more expensive than conventional fuels, partially except of the use of residues and waste. This aspect is not reflected in the savings of convertible currencies, which only takes into account import and export and not the total macro-economic costs. A more elaborated macro-economic impact assessment, in which various bioenergy systems and biomass supply options (domestic vs. import) are compared, would help to evaluate the total aggregated impacts.

### *3.2.2 Recommendations for future use: policy objectives*

It can be concluded that the GBEP indicators are of use for the Netherlands, but to a certain extent. They do provide insight in the level of sustainability of bioenergy production in the Netherlands and how improvements can be made.

At this moment, the GBEP indicators do provide insufficient insight to extend conclusions to the broader context of the biobased economy, taking into account the policy context and the characteristics of an industrialised country like the Netherlands. Some of the issues addressed in the GBEP indicators are especially relevant for developing countries. They are, however, of limited relevance for the Netherlands and for the objectives of the Dutch bioenergy policies. Especially important thereby are the impacts on other countries, such as indirect land use change and the associated greenhouse gas emissions, food security impacts, impacts on fresh water etc. These aspects have been and are still subject of intense debate in the Netherlands but are not addressed in the GBEP indicators and in this report.

Expansion of the scope of the GBEP indicators or using a more flexible approach that allows more emphasis on above-mentioned aspects, aimed at ensuring the sustainability of imported biomass, might further improve the relevance of the GBEP results for policy makers. It could be an option to refer more to certifications systems.

Additionally, it might be considered to monitor some of the indicators on European level when dynamics take place on a higher aggregated level. Examples are indicator 10 on price and supply of a national food basket (not included in this study) or indicators 5 and 6 on water use and quality. Other examples are the processing efficiencies and emissions of bioenergy technologies (indicator 17, 1 and 4). These depend on the level of technology used and not on the country they are used in.

The GBEP indicators provide the possibility to monitor sustainability on international level. Differences between countries for the same indicator can be analyzed and lessons on best practices may be learnt. Examples are more efficient technologies, symbiosis with non-bioenergy applications or forestry and agriculture best practices. Comparing between different countries may also provide insight in the effects of the differences in bioenergy policy between countries.

The monetary indicators, such as production costs can be helpful in policy developments. They could provide insight for determining where tax incentives or other financial support may be appropriate in order to achieve economic feasibility. They could also serve to provide insight whether the currently stimulated forms of bioenergy are the most efficient and/or sustainable ones.

When the GBEP indicators are available over a longer period, the progress over time will be valuable for the analysis of the impact of bioenergy policy. Outcomes over multiple years can serve for the identification of areas where policy objectives are being achieved and which new or existing areas require attention from policy makers. An important condition for multi-year comparison is that the calculation methodology does not undergo more revisions than necessary and that monitoring of the GBEP indicators is robust though efficient.

# 4 Individual outcomes

This chapter starts with an overview of the bioenergy sector in the Netherlands, followed by a discussion on the individual outcomes of the selected indicators.

## 4.1 The bioenergy sector in the Netherlands

The key characteristics of the use of biomass in the Netherlands and the end consumption are shown in table 4.

**Table 4: Key characteristics of the bioenergy production in the Netherlands (data from CBS, IEA Bioenergy Task 40, Dutch progress Report)**

| | | Use of biomass in PJ | Total energy supply in PJ | End consumption in energy ktoe | Gross final consumption; end-use in PJ |
|---|---|---|---|---|---|
| Biomass, total | Total<br>Electricity<br>Heat<br>Transport | 107.6 | 111.07 | | 64.2<br>25.4<br>29.2<br>9.6 |
| Biomass, total | <br>Solid<br>Gaseous<br>Liquid | | | 698<br>569<br>116<br>14 | |
| Waste incineration | Total<br>Electricity<br>Heat | 33 | | | 11.3<br>6.3<br>5.0 |
| Co-firing biomass | Total<br>Electricity<br>Heat | 34.1 | | | 12.9<br>11.7<br>1.3 |
| Woodstoves heat companies | Total<br>Electricity<br>Heat | 2.8 | | | 2.8<br><br>2.8 |
| Wood stoves heat households | Total<br>Electricity<br>Heat | 12.2 | | | 12.3<br><br>12.3 |
| Charcoal consumption households | Total<br>Electricity<br>Heat<br>Transport | | | | 0.3<br><br>0.3 |
| Remaining biomass incineration | Total<br>Electricity<br>Heat | 13.4 | | | 6.4<br>3.7<br>2.8 |
| Biogas, total | Total<br>Electricity<br>Heat | 12.1 | 12.89 | | 8.6<br>3.8<br>4.8 |
| Biofuels, total | Total<br>Electricity<br>Heat<br>Transport<br>*Biodiesel*<br>*Biobenzine* | <br><br><br><br>4<br>5.6 | | <br><br><br><br>95<br>134 | 9.6<br><br><br><br><br>9.6 |

The Dutch progress Report (2012) on energy from renewable sources 2009-2010 for compliance to the European Directive 2009/28/EG estimates the biomass from waste on 6687 ktonnes per year. Some waste streams are imported, such as UCO or talloil for biofuels. Some residues after sorting for waste incineration are imported as well.

Around 27 PJ bioenergy comes from forest resources (including fresh wood, waste wood and processing residues). Forest resources are mostly used for stoves, co-firing and biomass incineration. An additional amount of wood is imported (especially pellets). Wood is also exported.

This study bases itself in principle on the area of cultivated energy crops that is reported by the Dutch progress report (2012) for compliance to the European Directive 2009/28/EG (see also table 5). The voluntary reporting on biofuels from the Dutch Emissions Authority (NEA) in 2010 mentions that no domestic energy crop production takes place in the Netherlands for biofuels. Note that the mandatory reporting on biofuels by the NEA will take place from 2012 onwards on a yearly basis. This reporting will also include the origin of the biofuels.

**Table 5: Estimated area size of energy crops by the Dutch progress report (2012) and National Service (2012)**

| Energy crops | Dutch progress report (2012) | National Service (2012) |
|---|---|---|
| Maize | 8000 ha<br>Based on silage maize | 1974 ha<br>Based on energy maize |
| SRC | 8 ha | n/a |
| Miscanthus | 83 ha | 83 ha |
| Rapeseed | 2632 ha (for all end-uses) | 2558 ha (for all end-uses) |
| *Total* | *10723 ha* | *4615 ha* |

Area sizes and geographical locations of energy crops are also reported by the National Service (2012). The difference in maize area for energy crop production can be explained by the use of different crop codes. The Dutch progress report (2012) for compliance to the European Directive 2009/28/EG bases itself on the area of silage maize with crop code 259; silage maize is mainly used for fermentation. The National Services bases itself on the area of energy maize with crop code 2032 (personal communication with B. de Sturler, 2012).

As the geographical locations are only available in the maps from the National Service (2012), these data are in some cases used for analysis of the land use related GBEP indicators. When this is the case, this is specifically mentioned.

Agricultural (processing) residues are used for biofuel production, co-firing and biomass incineration. The Dutch progress Report (2012) estimates the amount of rest-and by-products from agriculture and from agricultural processing for heat and electricity are estimated at 15 PJ. The IEA Bioenergy Task 40 (2011) gives an estimation of 12 PJ for all biomass streams from agriculture. Most of the agricultural (processing) residues for biofuels are imported.

## 4.2 Environmental indicator 1: Lifecycle GHG emissions

This indicator looks at how much greenhouse gases (GHGs) are emitted per MJ produced bioenergy in the Netherlands. The outcome is presented in g of $CO2_{eq}$ emitted per MJ bioenergy produced.

The average lifecycle GHG emissions of national bioenergy in g of $CO_{2eq}$/MJ could not be calculated. This was only possible for liquid biofuels, which resulted in 29.7 g of $CO_{2eq}$/MJ biofuel.

This indicator is also related to the GHG emission data for bioenergy reported bi-annually to the European Commission according to article 22 of the EU-RED. The Netherlands has submitted this report for 2009 and 2010. This report gives the total gross bioenergy consumed in PJ, disaggregated for electricity, heat and transport. The report also publishes the ktonnes of $CO_2$ avoided through the consumption of bioenergy instead of fossil fuels. With these inputs, the average avoided $CO_2$ emissions by the national bioenergy consumptions were calculated to be 95.6 g of $CO_{2eq}$/MJ bioenergy. It should be noted that this considers only avoided fossil fuel, not GHG emissions from bioenergy production based on a lifecycle analysis.

**Table 6: Lifecycle GHG emissions**

| End product from biomass | Gross final consumption*<br>End-use in PJ | Avoided $CO_2$ emissions*<br>$CO_2$ in kton | Avoided $CO_2$ emissions**<br>$gCO_2$/MJ | Lifecycle GHG emissions**<br>g of $CO_2$ eq / MJ |
|---|---|---|---|---|
| Electricity | 25.4 | 4336 | 171 | ? |
| Heat | 29.2 | 1283 | 44 | ? |
| Transport | 9.6 | 518 | 54 | **29.7** |
| **Totals** | 64.2 | 6137 | **96** | ? |

** Based on data from CBS (2011) based on avoided fossil fuels, ** own calculations*

The results in table 6 show that the average lifecycle GHG emissions per MJ biofuel, aggregated over all bioenergy in accordance with GBEP methodology is 29.7 g $CO_{2,eq}$ / $MJ_{biofuel}$. This is significantly lower than the standard emission of 83.8 g $CO_{2,eq}$ / MJ of fossil transport fuel as determined in EU-RED (2009). The low average GHG emissions per MJ biofuels can be explained by the large share of biofuels from wastes and residues: The lifecycle GHG emissions are a lot lower for these chains than for biofuels from agricultural crops.

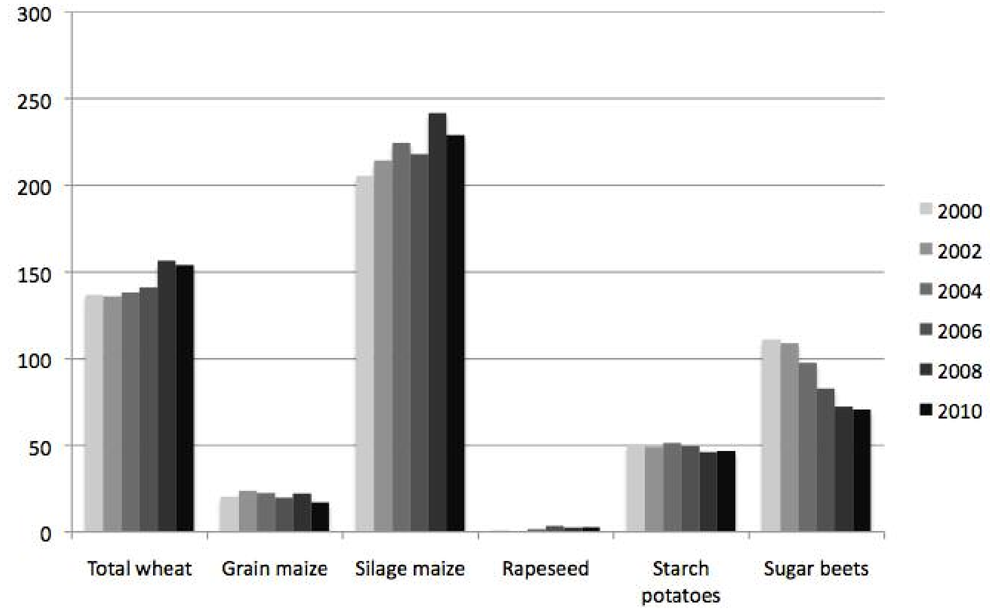
The GBEP methodology prescribes that bioenergy import and export should not be in the scope of the indicators. In the Netherlands, bioenergy import plays an important role, especially for biofuels and their feedstocks, and for solid biomass for co-combustion. However, disaggregated data that differentiates between imported bioenergy and that of national origin is not available and therefore not excluded in this indicator. Excluding non-domestic crop production or feedstock processing activities from the overall lifecycle, results in ignoring a substantial part of the *total* generated lifecycle GHG emissions for bioenergy consumption in the Netherlands.

## 4.3 Environmental indicator 2: Soil organic carbon

This indicator looks at the percentage of land for which soil quality, in particular in terms of soil organic carbon, is maintained or improved out of the total land on which bioenergy feedstock is cultivated or harvested.

The total land on which bioenergy is cultivated is estimated by the Dutch progress report (2012) for compliance to the European Directive 2009/28/EG on maximum 10.723 ha. The geographical location of these areas is partly known for 2010, based on data from the National service (2012). The reference year for the previous land use is 2007. Figure 1 shows the historical land use change for a selection of crops, including energy crops. The results show that the total area for maize has been stable over this time period, though with minor fluctuations. The area for wheat and the area for rapeseed have slightly increased over time. The total area for energy crops has remained constant since 2007.

**Figure 1: Historical land use change for selected crops from 2000 to 2010 (based on CBS, 2011) in 1000 ha**




For estimating this indicator, we have first assumed the following previous land uses for the existing energy crops, based on figure 1 and additional publications:

- Energy maize: It is assumed that energy maize is cultivated within the existing maize area in the Netherlands. The end-use may have changed;
- Rapeseed: It is assumed that there is a small increase in the crop area for rapeseed for energy. Two options are selected as previous land use: a) Wheat as rotation crop or b) Rapeseed for food production;
- SRC and Miscanthus: It is assumed that both experimental can be cultivated on various different land use types. Three options are therefore selected as previous land use: grassland, arable land or building area (fallow or set-aside);

Table 7 shows the existing land uses and assumed previous land uses for the energy crops in the Netherlands. This information is used to estimate the change in soil carbon content for the different land use change scenarios.

**Table 7: Expected changes in organic soil carbon energy crops when changing from assumed previous to current land use, based on different literature resources**

| Current use | Storage t C/ha | Previous use | Storage t C/ha | Change / ha |
|---|---|---|---|---|
| Energy maize | 22 | Maize | 22 | 0 |
| Rapeseed | 27 | Wheat | 60.8 | -34 |
| Rapeseed | 27 | Rapeseed | 27 | 0 |
| SRC | 52 | Grassland | 114.1 | -62 |
| SRC | 52 | Arable land | 26.7 (average) | 25 |
| SRC | 52 | Building land | 10 (estimation) | 42 |
| Miscanthus | 114 | Grassland | 114.1 | 0 |
| Miscanthus | 114 | Arable land | 26.7 (average) | 87 |
| Miscanthus | 114 | Building land | 10 (estimation) | 104 |

The previous production on the biomass production locations is unknown. We therefore assume that 50% of the existing rapeseed area is cultivated on land that was earlier cultivated with wheat. We also assume that 50% of the current area with SRC has replaced cultivated grasslands. Based on this and the data in table 7, the expected change in carbon stock is calculated for the total energy crop production area for the scenarios assumed. It can be concluded that at least 88% (9403 ha) of the cultivated land for biomass is maintaining or improving the soil carbon quality.

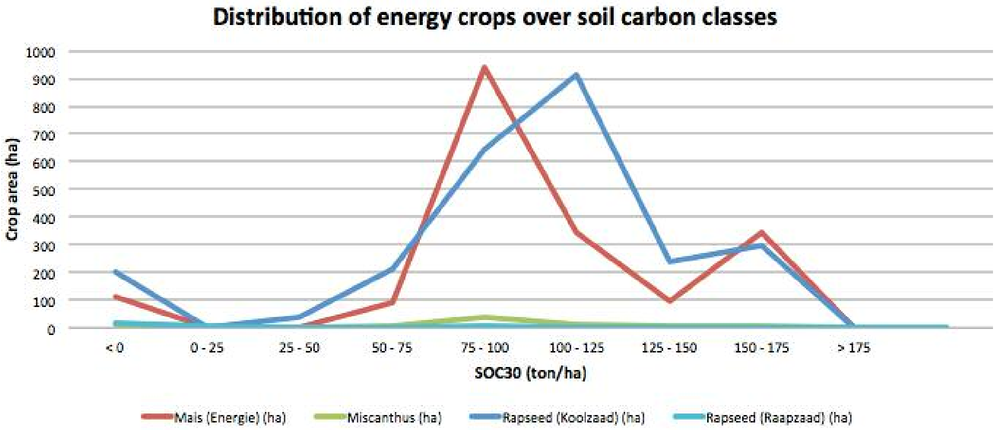
A risk assessment is done for those areas (in total 1320 ha) that *may* have a risk for decrease in soil carbon. These are the areas for rapeseed that may have replaced areas for wheat as rotation crop or the areas for SRC that may have replaced grasslands.

No systematic monitoring data available that give a clear conclusion whether average soil organic matter levels in soils in the Netherlands are decreasing or increasing – and the risk associated with this. Various publications are available; some of them are contradictive in results.

Reports indicate that some soils have probably gained organic matter (notably permanent grasslands), also due to the use of fertilizers and manure. Grassland soils contain in general more organic matter than arable soils. Consequently, a possible decrease in soil organic carbon on grasslands does not seem to result in a risk of to too low organic carbon contents in these areas. A possible decrease of soil carbon because of producing SRC on grasslands therefore seems to have limited risks.

Rapeseed replacing wheat crops may decrease soil organic carbon content. Figure 2 shows that the current cultivated land for crops used for energy purposes is generally on land areas with an average to high soil organic carbon content.

**Figure 2: The distribution of crops for energy purposes over soil carbon classes, based on an intersection of the soil carbon map and the crop locations from the National Service (2012)**




A publication from Chardon et al (2009) indicates that a decrease in SOC contents in agricultural soils is not confirmed for Dutch soils. A report form Kuijkman et al (2003) indicates that some areas may have lost soil organic matter, notably peat soils and intensively cultivated soils. Rapeseed is not expected to be cultivated on peat soils but may be cultivated on intensively cultivated soils.

Risk impacts related to a lowering soil organic carbon content are expected to be limited though (Romkens et al, 2004):

- *Soil erosion:* At present soil erosion in the Netherlands is only locally and regionally a problem. The combination of soil characteristics and current land use practices make the sandy soils in the "Veenkolonien" susceptible to wind erosion during dry periods in winter and spring;
- *Soil compaction:* There is not much quantitative information about compaction of soils in the Netherlands. Most farmers are well-aware of the risks of soil compaction and try to avoid compaction;
- *Soil salinization*: This is not (yet) a big problem in the Netherlands, because of the large precipitation surplus.

Decrease in soil organic carbon content can be minimized with good soil management practices (e.g. straw on ground).

## 4.4 Environmental indicator 3: Harvest levels of wood resources

Sub-indicator 3.1 estimates the annual harvest of wood resources by volume and as a percentage of net growth or sustained yield. Sub-indicator 3.2 estimates the percentage of the annual harvest used for bioenergy. The estimated outcomes are as follows:

- Annual harvest of wood resources by volume: 1.200.000 $m^3$
- Annual harvest of wood resources as percentage of net growth: 55%
- The percentage of the annual harvest used for bioenergy: 0,07%

The results indicate that forests in the Netherlands are being harvested sustainably and that wood resources even increase in time. Forests are thus able to renew their resources. Information about the total use of wood resources for bioenergy is uncertain. The results, however, clearly indicate that a very limited amount of fresh harvested wood and harvest residues is used for energy purposes.

Resources indeed confirm that most of the wood for bioenergy comes from secondary processing residues or waste wood.

Data sources also indicate that large amounts of wood resources (90% of the resources for wood pellets) are imported from abroad. Some pellets are also (further) exported. There is no clear distinction of the resource categories of e.g. imported pellet resources (processed wood, waste, fresh wood). The results show, however, the contribution of activities to this indicator also takes place in other countries.

## 4.5 Environmental indicator 4: Emissions of non-GHG air pollutants, including air toxics

This indicator estimates the emissions of non-GHG air pollutants ($PM_{2.5}$, $PM_{10}$, $NO_X$, $SO_2$) including air toxics. Four sub-indicators are distinguished. The emissions are to be estimated for:

- 4.1: Bioenergy feedstock production;
- 4.2: processing;
- 4.3: Transport of feedstock, intermediate products and end products;
- 4.4: Use.

Sub-indicator 4.1 looks at the non-GHG emissions from the cultivation of energy crops. This includes energy maize and rapeseed, based on data from the Dutch progress report (2012) for compliance to the European Directive 2009/28/EG. Sub-indicator 4.2 estimates the non-GHG emissions from the processing of bioenergy feedstocks. Not all feedstocks require processing, or the processing step is taken together with the end use. Sub-indicator 4.3 looks at the non-GHG emissions from the transport processes needed for the production of bioenergy. For liquid biofuels, this includes both the transport of the (domestic) feedstock and of the biofuel. Sub-indicator 4.4 looks at the non-GHG emissions from the use of the bioenergy, so in practice from the combustion of the feedstock or bioenergy carrier. Methodological assumptions for this indicator are described in the methodology section in section 6. The results for all sub-indicators are presented in table 8. The results of the sub-indicators 4.1 to 4.3 do not allow for a direct comparison with emissions from fossil fuels.

Most air emissions from bioenergy use are significant higher than the average emissions from fossil alternatives, see table 9. Only when comparing to coal, the $NO_x$ emissions are a bit lower and $SO_x$ emissions are much lower. Table 9 also shows that large-scale bioenergy performs better than the average. Main underlying reason is the inefficient and incomplete combustion of bioenergy in technically less advanced systems, such as household fireplaces. As an example of the opposite, biodiesel has lower non-GHG emissions than fossil diesel for most pollutants. Differences in emission levels depend for this example largely on the blending concentration and on the vehicle type, see table 10.

Another result from the extensive research done for this indicator is that non-GHG emissions differ very strongly, depending on the exact technologies used, and on feedstock characteristics. In this study, averages and aggregated groups of technologies and feedstocks had to be used. Consequently, emission levels for specific technologies may be higher or lower than is currently assumed.

**Table 8: non-GHG emissions of bioenergy in different parts of the life cycle**

| | Sub-indicator | | Unit |
|---|---|---|---|
| 4.1 | Feedstock production emissions: PM2.5 | 202 | g/ha |
| | Feedstock production emissions: PM10 | 226 | g/ha |
| | Feedstock production emissions: $NO_x$ | 2486 | g/ha |
| | Feedstock production emissions: $SO_2$ | 29 | g/ha |
| 4.2 | Processing emissions: PM2.5 | 0.11 | mg / MJ |
| | Processing emissions: PM10 | 0.15 | mg / MJ |
| | Processing emissions: $NO_x$ | 9.12 | mg / MJ |
| | Processing emissions: $SO_2$ | 2.86 | mg / MJ |
| 4.3 | Transport emissions: PM2.5 | 0.01 | mg / MJ |
| | Transport emissions: PM10 | 0.01 | mg / MJ |
| | Transport emissions: $NO_x$ | 0.29 | mg / MJ |
| | Transport emissions: $SO_2$ | 0.03 | mg / MJ |
| 4.4 | End-use emissions: PM2.5 | 99 | mg / MJ |
| | End-use emissions: PM10 | 103 | mg / MJ |
| | End-use emissions: $NO_x$ | 237 | mg / MJ |
| | End-use emissions: $SO_2$ | 13 | mg / MJ |

**Table 9: Non-GHG emissions from energy per energy source**

| | VOC (mg/MJ) | CO (mg/MJ) | NOx (mg/MJ) | PM10 (mg/MJ) | SOx (mg/MJ) |
|---|---|---|---|---|---|
| Bioenergy - all | 108.2 | 802.7 | 237.5 | 102.9 | 12.5 |
| Bioenergy – large scale | 7.3 | 258.0 | 211.0 | 38.0 | 11.0 |
| Natural gas | 1.5 | 39.0 | 89.0 | 0.9 | 0.3 |
| Coal | 1.2 | 150.0 | 310.0 | 20.0 | 820.0 |

**Table 10: Emission differences when comparing different biodiesel blends to fossil diesel (source: source: EMEP/EEA emission inventory guidebook 2009, updated June 2010, 1.A.3.b.i, 1.A.3.b.ii, 1.A.3.b.iii, 1.A.3.b.iv, Passenger cars, light-duty trucks, heavy-duty vehicles including buses and motor cycles, Table 3-102)**

| Pollutant | Vehicle type | B10 | B20 | B100 |
|---|---|---|---|---|
| | Passenger cars | -1,5% | -2,0% | |
| | Light-duty vehicles | -0,7% | -1,5% | |
| $CO_2$ | Heavy-duty vehicles | 0,2% | 0% | 0,1% |
| | Passenger cars | 0,4% | 1,0% | |
| | Light-duty vehicles | 1,7% | 2,0% | |
| NOx | Heavy-duty vehicles | 3,0% | 3,5% | 9,0% |
| | Passenger cars | -13,0% | -20,0% | |
| | Light-duty vehicles | -15,0% | -20,0% | |
| PM | Heavy-duty vehicles | -10,0% | -15,0% | -47,0% |
| | Passenger cars | 0% | -5,0% | |
| | Light-duty vehicles | 0% | -6,0% | |
| CO | Heavy-duty vehicles | -5,0% | -9,0% | -20,0% |
| | Passenger cars | 0% | -10,0% | |
| | Light-duty vehicles | -10,0% | -15,0% | |
| HC | Heavy-duty vehicles | -10,0% | -15,0% | -17,0% |

## 4.6 Indicator 5: Water use and efficiency

Sub-indicator 5.1 estimates the water withdrawn from nationally determined watershed(s) for the production and processing of bioenergy feedstock. The outcome is to be expressed as the percentage of total actual renewable water resources (TARWR) and as the percentage of total annual water withdrawals (TAWW).

Sub-indicator 5.2 estimates the volume of water withdrawn from nationally determined watershed(s) used for the production and processing of bioenergy feedstock. The outcome is to be presented per unit of useful bioenergy output. Preferably, both sub-indicators are further disaggregated into renewable and non-renewable water sources.

The total Renewable Water Resources (TARWR) in the Netherlands is 91 $km^3$/year (2008). From this total, internal renewable water resources provide 80 $km^3$/year. External renewable Water Resources provide 11 $km^3$/year.

The total annual water withdrawal (TAWW) is 16.3 $km^3$ in 2010 (10.6 $km^3$ in 2008). This results in a moderate water stress level in the Netherlands. Disaggregation of the TAWW per watershed in the Netherlands is shown in table 11. A map of the watersheds in the Netherlands is shown in annex 1.

**Table 11: Division of TAWW per watershed in the Netherlands (based on total water consumptions per watershed)**

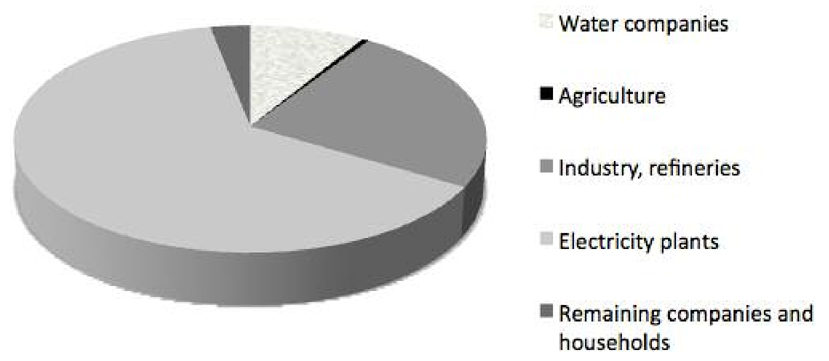
| | TARW in $km^3$/year | TAWW in $km^3$ |
|---|---|---|
| Rijndelta | 57.1 | 10.2 |
| Eems | 4.2 | 0.7 |
| Scheldestroomgebied | 8.4 | 1.5 |
| Maas | 21.3 | 3.8 |

*Cultivation and biomass resources*

The cultivated area of energy crops is based on estimations from the Dutch progress report (2012) for compliance to the European Directive 2009/28/EG. The estimated proportional contribution of energy crops to TARWR is 0.15%. This is 0.01% of TAWW. The water use of residues and waste is not considered in the calculation. See also the Practicality report (SQ Consult, 2012), for further argumentation.

Estimations from PBL indicate that the total water use of the agricultural sector originates for 34% from surface water and for 66% of groundwater resources. Based on this percentage, we come to the rough indication that $4.5*10^{-5}$% of the TAWW is used for surface water for energy crop production. Groundwater resources for energy crop production consist of $8.8*10^{-5}$% of the TAWW. Pie 1 shows that the water use by the agricultural sector in the Netherlands is very limited compared to other economic sectors.

**Pie 1: Contribution of sectors in the Netherlands to the total water use (based on 2008), Source: PBL Compendium**




*Processing*

Winrock (2009) indicates that the proportion of water used for biofuel processing is generally much smaller than that of the feedstock cultivation stage. This generally represents around 1-2% of the total water use compared to the 98%-99% during cultivation. Water required in the production of feedstock that does not require cultivation (e.g. residues) is likely to be substantially reduced though. Reason is the allocation of the water use to the primary product. For residues, the processing stage represents therefore a larger proportion of the total water requirement.

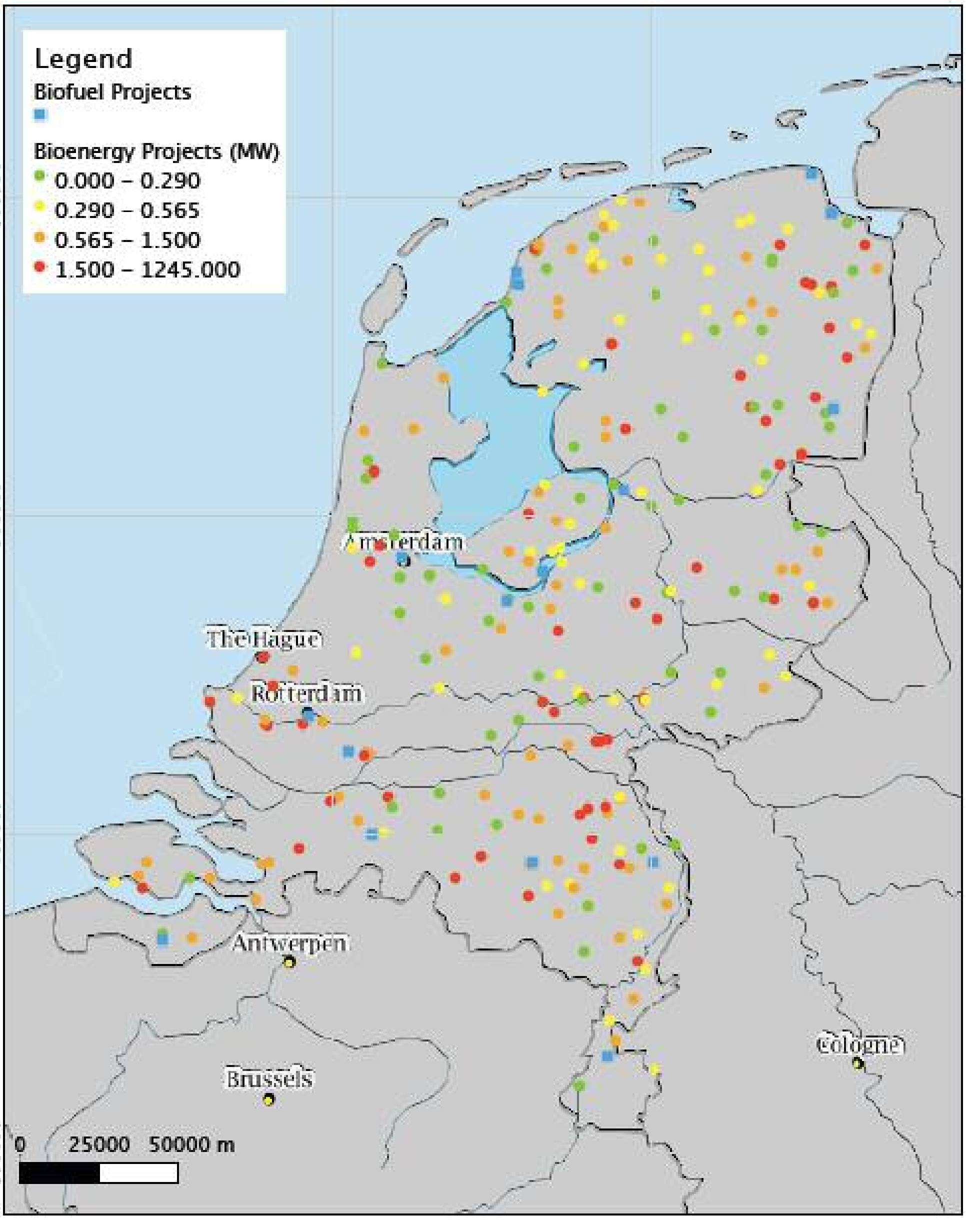
Individual resources show that estimations on water use by processing facilities are highly variable (depending on technology and efficiency). Examples given are:

- 1.9 to 9.8 gallons of water per 1 gallon cellulosic ethanol (Winrock, 2009);
- Biomass based steam plants: 0.7 Mg/GJ bioenergy (constructed in USA in mid 1980s); 0.5 Mg/GJ bioenergy (for improved biomass based steam plant); 0.1 Mg/GJ bioenergy (for gasification based biomass electricity), (Berndes, 2002);
- Biomass co-firing: 150 liter/kWh for cooling water, 0,1 liter/kWh for processing water. Around 0,02 liter of discharge water is generated per kWh (individual company source).

Gerbens-Leenes (2008) gives as indication that 2% of the measured Water Footprint for bioenergy is used for processing in the Netherlands. The estimated total WFP for bioenergy is estimated on 24.2 $m^3$ per GJ. When we use these indications as a proxy for the Netherlands, we come to an estimated water use of 0,48 $m^3$ per GJ bioenergy for bioenergy processing. Note that the data from (Gerbens-Leenes, 2008) also cover the green WFP[1].

[1] Both the evaporative flow and the runoff flow can be made productive for human purposes. The evaporative flow can be used for crop growth or left for maintaining natural ecosystems; the green water footprint measures which part of the total evaporative flow is actually appropriated for human purposes. The runoff flow – the water flowing in aquifers and rivers – can be used for all sorts of purposes, including irrigation, washing, processing and cooling.

**Map 1: Biofuel and bioenergy projects in the Netherlands (based on company location), based on intersecting database with locations of bioenergy projects with GIS map of administrative boundaries in the Netherlands**




The volume of water consumed for processing can generally be considered lower compared to the cultivation stage. This water use could, however, potentially be concentrated into one hydrological unit area. Its effects can therefore be substantial on local scale (Winrock, 2009). In the Netherlands, no specific concentrations of biofuel and bioenergy projects are found (see map 1). The risk for excessive water consumption in one concentrated region therefore seems to be limited.

*Water use per unit of bioenergy output*

Gerbens-Leenes (2008) has calculated the total average water footprint (WFP) for all bioenergy in the Netherlands on 24.2 $m^3$/GJ. The WFP of biomass for heating shows large variations though. Estimations range from 9.1 $m^3$/GJ to 19.7 $m^3$/GJ for Miscanthus to 67.3 $m^3$/GJ for winter oil seed rape. Note that these estimations assume that the full bioenergy chain is taking place within the Netherlands.

*Water footprint in and outside the Netherlands*

Hoekstra et al (2009) estimated the total WFP of the Netherlands to be about 2300 $m^3$/year/cap. Of this number, 67% relates to the consumption of agricultural goods, 31% to the consumption of industrial goods, and 2% to domestic water use. About 11% of the total WFP of the Netherlands is internal and 89% is external. This study indicates that a substantial amount of the overall water use for consumption in the Netherlands, and most likely also of bioenergy, is taking place outside the Netherlands.

## 4.7 Indicator 6: Water quality

This indicator on water quality has two sub-indicators:

- 6.1: The amount of pollutant loadings to waterways and bodies of water attributable to fertilizer and pesticide application for bioenergy feedstock production;
- 6.2: The amount of pollutant loadings to waterways and bodies of water attributable to bioenergy processing effluents.

The outcomes are to be expressed as a percentage of pollutant loadings from total agricultural production or from total agricultural processing effluents in the watershed. This indicator makes use of the estimated crop areas for energy purposes from the National Service (2012).

Sub-indicator 6.1 requires an estimation of the pollutant loadings to water attributable to fertilizer and pesticide application for bioenergy feedstock production. The legally maximum allowed amounts of fertilizer use of N and P are (depending on the soil of the agricultural area):

- Maize: 150 to 185 kg N/ha and 70 to 85 kg P/ha
- Rapeseed: 120 to 205 kg N/ha and 70 to 85 kg P/ha
- Perennials (SRC): 90 kg N/ha

An indication about the maximum allowed amount of fertilizer is not provided for Miscanthus. Hilst et al (2012) estimate the required yearly amount of fertilizer for Miscanthus at 37 kg N/ha and 2 kg P/ha.

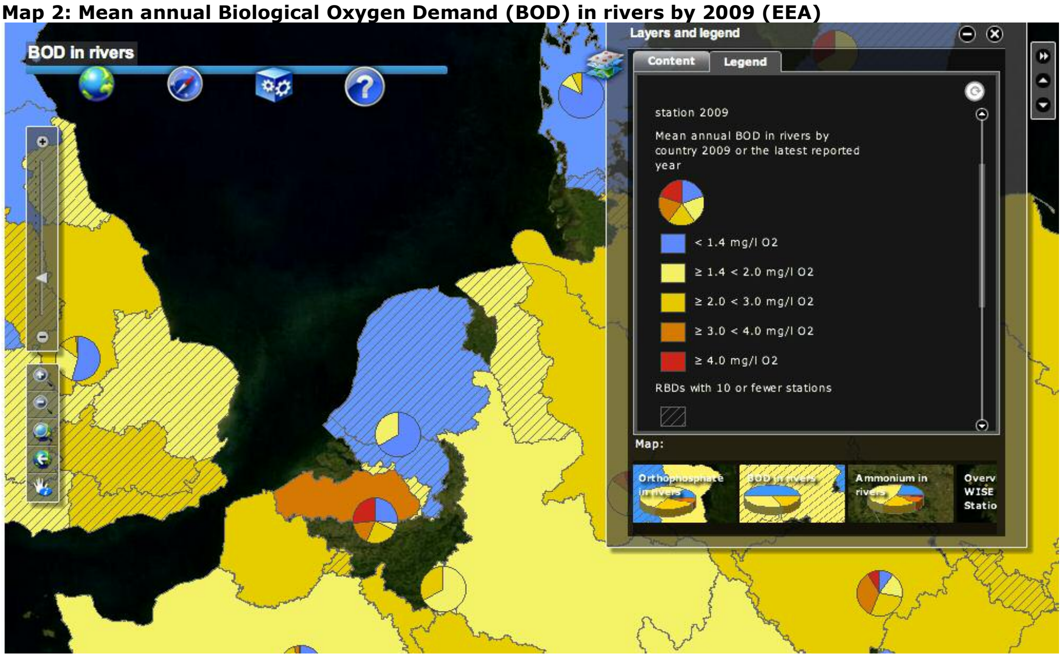
Note that these maximum allowed amounts of fertilizer use are only a relative indication for the pollutant loadings to the water. There is a large uncertainty involved as the crop itself also consumes nitrogen and phosphorus for further growth.

It is estimated that maize for energy, SRC and rapeseed represent together between 0.2% and 0.5% of the total N fertilizer use on agricultural land. This is based on maximum allowed input. The lower and higher range depends on the soil type on which crops are cultivated. Maximum 0.3% of the total P fertilizer use on agricultural land is used for maize for energy, SRC and rapeseed. Miscanthus is not included in the estimations.

Due to lack of data, the pollutant loadings from residues and waste are not separately estimated. The publication Heldergroen Gas (2011) has expressed its concerns on the removal of organic residues for co-digestion and the need to complement resulting nutrient shortages in the soil with manufactured fertilizers.

The use of chemical pesticides in agriculture is estimated on watershed level (see also annex 1). The contribution of maize for energy and rapeseed compared to the total use of chemical pesticides in agriculture is 0.1% for the Rijn-Oost and Eems. This is 0% for the other watersheds.

**Map 2: Mean annual Biological Oxygen Demand (BOD) in rivers by 2009 (EEA)**



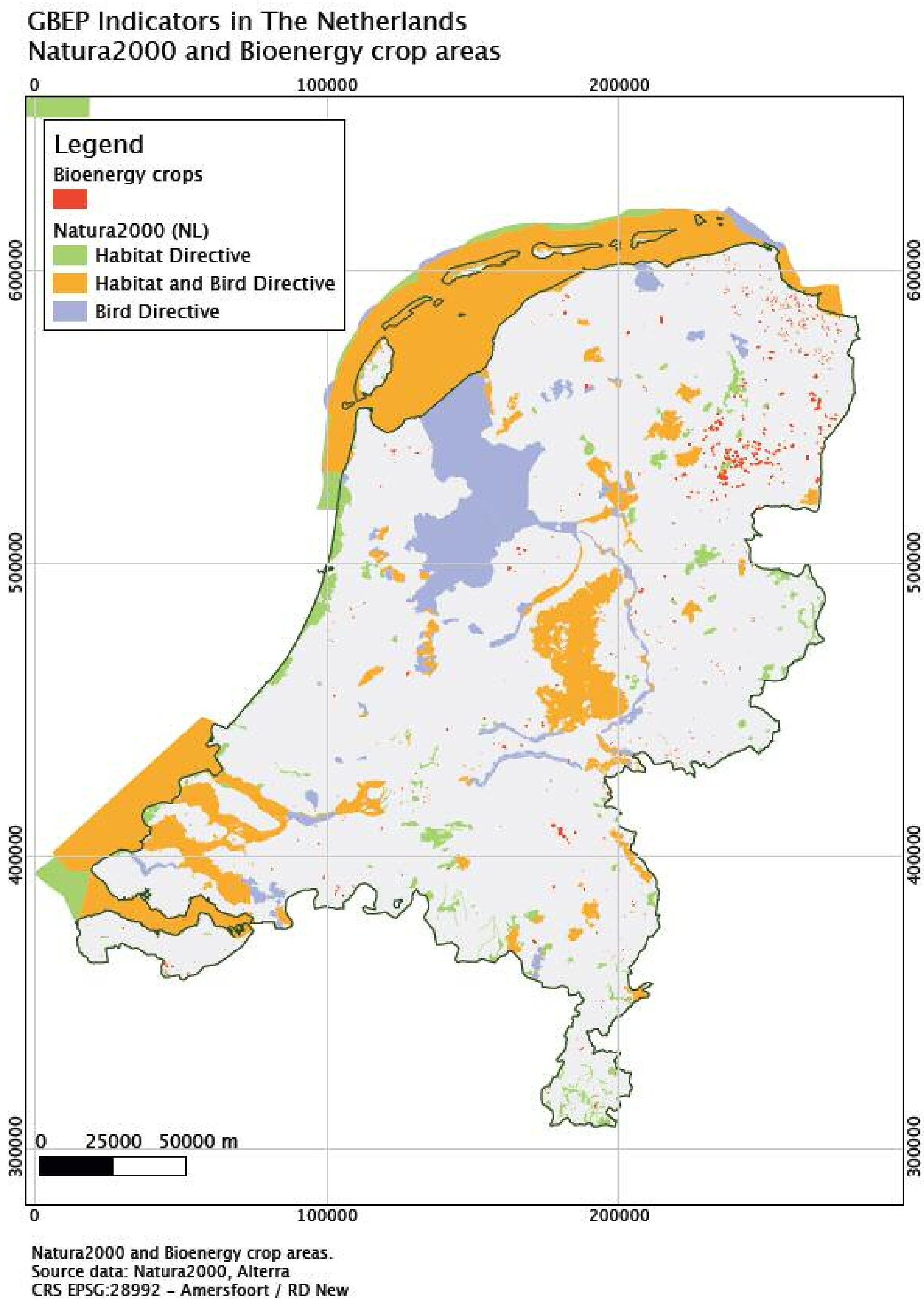

Information is lacking about the amount of pollutant loadings to waterways and bodies of water attributable to bioenergy processing effluents. CBS (2011) provides information about the amount of P and N compounds of the total industry in the Netherlands. This information is differentiated to separate economic sectors. The chemical and metal industry release relatively most of the N compounds to the water are the chemical and metal industry. The food industry releases, compared to other sectors, most of the P compounds. PBL (2008) and CBS (2011) indicate that a limited amount of the total BOD effluents is actually released to the surface water (around 11%). Most of the effluents are captured by wastewater plants. Map 2 from EEA (2011) show that the average BOD level in the Netherlands is low, also compared to other surrounding European countries.

## 4.8 Indicator 7: Biological diversity in the landscape

This indicator includes three sub-indicators. These are:

- 7.1: The area and percentage of nationally recognized areas of high biodiversity value or critical ecosystems converted to bioenergy production
- 7.2: The area and percentage of the land used for bioenergy production where nationally recognized invasive species are cultivated
- 7.3: The area and percentage of the land used for bioenergy production where nationally recognized conservation methods are used

**Map 3: Intersection of croplands map (National Service, 2012) and Natura 2000 areas (received from Krw Portal, Framework Directive Water)**




There has been a continuous growth of the natural and forest area in the Netherlands. The Ecological Main Structure (EHS) has also extended in the last years. Direct land use conversion from bioenergy crops (see indicator 8) has not been taken place either. It can therefore be assumed that the area and percentage of nationally recognized areas of high biodiversity value or critical ecosystems *converted* to bioenergy production has been zero. This argumentation is underlined with our interpretation from map 3, which shows that current energy crop production does not take place in existing nature areas in the Netherlands.

Note, however, that some bioenergy production activities (e.g. SRC in nature areas) are integrated within the conservation of nature areas when explicitly used for nature management purposes.

No invasive species (based on available databases) are used for energy crop production in the Netherlands. Note that Giant Reed and Switchgrass, though not listed as crop for bioenergy production, are mentioned as having a higher risk.

For sub-indicator 7.3, national recognized conservation methods are interpreted as those methods, which are used as one of the supporting tools for managing the EHS in the Netherlands. This is based on the geographical data from the National Service (2012) with areas that have a practice of agrarian nature management (based on this categorization). These data are integrated with the GIS map of crop production from the National Service (2012). It is assumed that some form of nature management practices take place on all Miscanthus and SRC areas.

Nationally recognized conservation methods are used on an estimated 5% (232 ha) of the land used for bioenergy production.

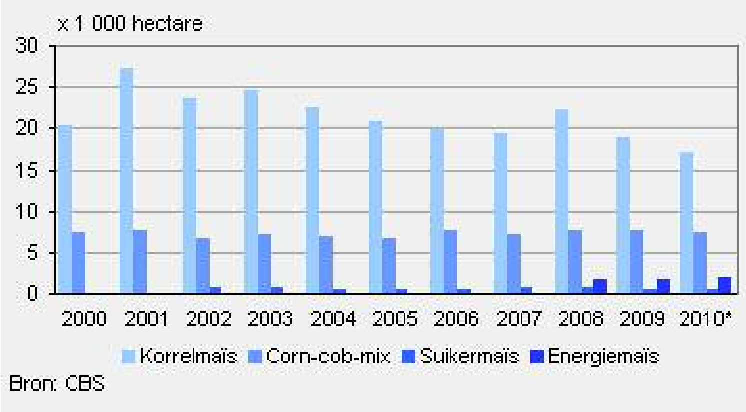
## 4.9 Indicator 8: Land use and land use changes compared to bioenergy feedstock production

This indicator includes four sub-indicators.
- 8.1: Total area of land for bioenergy feedstock production, and as compared to total national surface
- 8.2: Total area of land for bioenergy feedstock production as compared to agricultural land and managed forest area
- 8.3: Percentage of bioenergy from yield increases, residues, wastes and degraded or contaminated land
- 8.4: Net annual rates of conversion between land-use types caused directly by bioenergy feedstock production

The maximum total area of land for bioenergy feedstock production (based on the Dutch progress report, 2012) compared to the total national surface is only 0,3%. This is maximum 2% compared to the agricultural land and 3,1% when compared to the managed forest area. Note that energy crop production in the Netherlands is mainly cultivated on agricultural land. Comparing the total bioenergy feedstock production with the total managed forest area provides therefore a percentage that is disproportionately high compared to the actual situation.

Yield increases have been realized in the last years in the Netherlands. Examples are the yield increases for maize (CBS, 2012). Yield levels have increased from 34 t/ha in 1994 to 46,2 t/ha in 2010. End-uses (feed sector, energy, food) have been fluctuating while the total crop area has remained more or less stable. See also figure 2. These yield increases can, however, not be directly attributed to bioenergy production given the relatively small amount of crop production for energy compared to other end-uses.

**Figure 2: Fluctuating end-uses for maize over time from 2000 to 2010 (CBS)**




The contribution of bioenergy from degraded land is assumed to be zero. The Dutch progress report (2012) for compliance to the European Directive 2009/28/EG defines degraded land as "land that has become less suitable for the cultivation of arable crops (e.g. eroded soils, closed landfill sites)". The Netherlands has very little land of this type. The Netherlands is not expected to have unused arable land either, given the price paid for land in the Netherlands. Furthermore, it seems unlikely that possibly unused land will be used for the cultivation of energy crops. Main underlying reasons is the economic balance per hectare, which still remains higher for arable crops (NREAP, 2011).

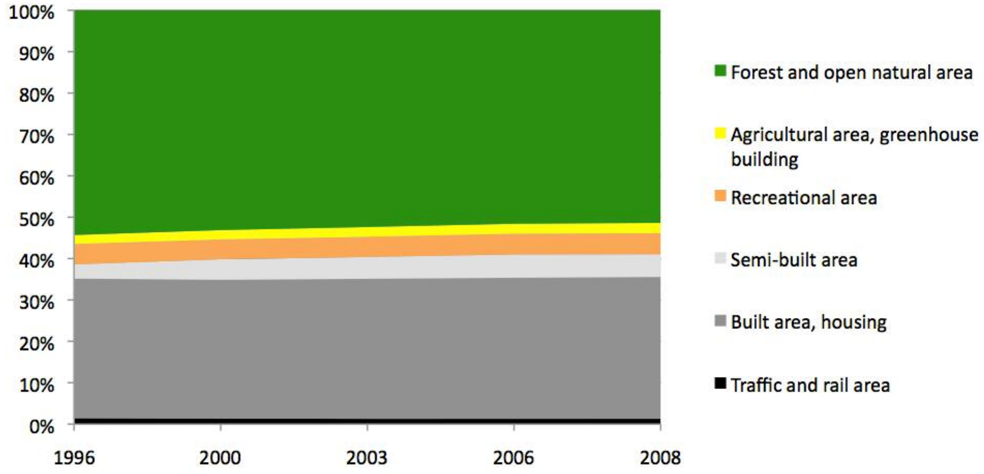
The use of residues and waste to bioenergy production is calculated for the total bioenergy use (including imports of feedstock resources) and for domestic use only. The relatively higher percentage of residues for the total bioenergy production (see table 12) can be explained by the import of for example pellets or bagasse to the Netherlands.

**Table 12: contribution of residues and waste to bioenergy production**

| | For domestic bioenergy production | For total bioenergy production |
|---|---|---|
| Residues | 48% | 53% |
| Waste | 50% | 39% |

The net annual conversion rates between land-use types have been minimal in the last years (see figure 3). The Dutch progress report (2012) for compliance to the European Directive 2009/28/EG mentions that the Netherlands had no "significant fluctuations in land use due to increased use of biomass and other forms of energy from renewable resources". The report also indicates that: "the increase of maize for fermentation has not resulted into an increase of the maize area or change in land use" and that "the rapeseed area in 2009 and 2010 has remained unchanged". This study assumes that no direct land use conversion has been taken place that has been directly caused by bioenergy feedstock production. Note that an assessment of possible indirect land use conversion caused by bioenergy feedstock production falls outside the scope of this indicator.

**Figure 3: Coverage of land use types in the Netherlands from 1996 to 2008 (CBS, 2012)**




Peat areas are not considered as a land use type in the Netherlands. It is a soil type on which various land uses take place. No conversion of peat areas has been taken place in the Netherlands due to bioenergy feedstock production. Various studies indicate, however, a decrease in peat areas due to a loss in organic matter for soil areas used for agriculture, in combination with drainage or not. For example, around Schoonebeek there has been a decrease of peatsoil areas of 46% from 1980 to 2003 (Smit and Kuijkman, 2005).

## 4.10 Indicator 11: Changes in income

This indicator aims to measure the changes in both wage and non-wage income due to bioenergy production. The indicator has two sub-indicators:

- Sub-indicator 11.1: Wages paid for employment in the bioenergy sector in relation to comparable sectors;
- Sub-indicator 11.2: The change in income derived from sale, barter and/or own-consumption of bioenergy products, including feedstocks, for self-employed households or individuals.

As the bioenergy sector is still fully integrated in traditional sectors, information for sub-indicator 11.1 is used from comparable economic sectors.

The average income paid per employer per year in 2010, including special rewards is (CBS, 2011) for comparable economic sectors:

- 19810 €/year for the agricultural and forestry sector;
- 54010 €/year for the energy supply sector;
- 33170 €/year for the transport and storage sector.

In comparison, the average income in 2010 for all economic sectors is 30950 €/year. The income in the agricultural and forestry sector is thus below the national average. The incomes in the transport, storage and energy supply sector are above the national average in 2010. This study assumes that people that start working in bioenergy sector originate from a similar economic sector. For example, farmers will use part of their land for biomass production. Therefore expected change in income is 0%.

Sub-indicator 11.2 looks at the net income from the sale, barter and/or own-consumption of bioenergy products, including feedstock, by self-employed households/individuals. Companies are excluded.

The saved income by households using woodstoves for heat, with fresh wood or waste wood as feedstock, ranges roughly from 134 to 235 € per year. This is an overestimation as investment costs for the stoves are not included. Based on these estimations, the maximum savings are only 0.43% to 0.76% of the total average income in 2010.

## 4.11 Indicator 12: Jobs in the bioenergy sector

This indicator includes five different sub-indicators:

- 12.1: Net job creation as a result of bioenergy production and use; total
- 12.2: This disaggregated into skilled and unskilled jobs;
- 12.3: This disaggregated into indefinite and temporary jobs;
- 12.4: Total number of jobs in the bioenergy sector; and % adhering to nationally recognized labour standards consistent with the ILO principles;
- 12.5: This in relation to comparable sectors.

All results for indicator 12 are shown in box 1 below. Box 1 presents the outcomes as shown in the Excel template. Indicator 12.1 gives the net job creation from 2009 to 2010 in total number and per MJ of total bioenergy produced.

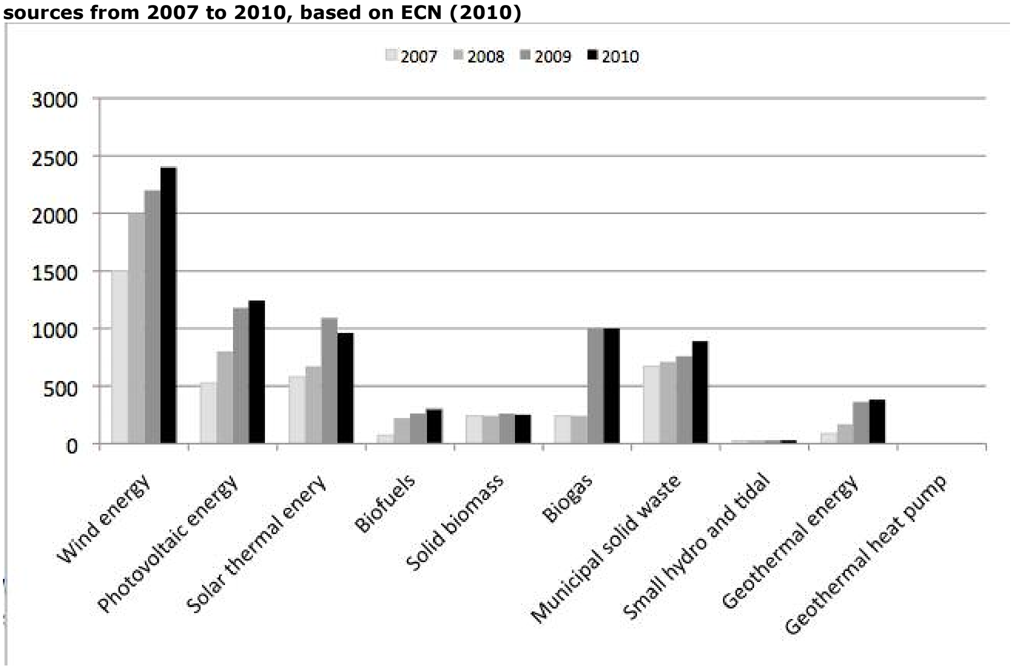
**Box 1: Results for indicator 12**

| | | | | | | |
|---|---|---|---|---|---|---|
| | Net job creation | | | | | |
| | 6517.05 | number | | | | |
| Indicator 12.1 | 5.12E-08 | number / MJ | | | | |
| | If possible disaggregated to (leave blank if info not available): | | | | | |
| Indicator 12.2 | 4344.70 | number | of skilled jobs | 3.41E-08 | number / MJ | of skilled jobs |
| | 2172.35 | number | of unskilled jobs | 1.71E-08 | number / MJ | of unskilled jobs |
| 12.3 | n.a. | number | of indefinite jobs | n.a. | number / MJ | of indefinite jobs |
| | n.a. | number | of temporary jobs | n.a. | number / MJ | of temporary jobs |
| | Total number of jobs | | | | | |
| 12.4 | 11920.45 | number | total | | | |
| | 0.19% | % | in relation to total working population | | | |
| 12.5 | 100 | % | Compliance of ILO | | | |
| | 100 | % | Compared with any other sector | | | |
| | Indicate to which sector compared | | | For all sectors in Netherlands | | |

Net job creation due to bioenergy development can be compared to the amount of jobs generated in the fossil fuel industry as well as in other renewable energy sectors. Figure 4 shows the growth of jobs in the bioenergy sector in comparison to other renewable energy sources from 2007 to 2010. The information is based on the report from ECN (2010).

The average growth of jobs in the total renewable energy sector from 2007 to 2010 is 189%. More specifically, this is 200% for the total bioenergy sector and 160% for the wind energy sector. These results show that there is a positive growth of employment in the bioenergy sector, also in comparison to other renewable energy sectors.

**Figure 4: Growth of jobs in the bioenergy sector in comparison to other renewable energy sources from 2007 to 2010, based on ECN (2010)**




## 4.12 Social indicator 16: Incidence of occupational injury, illness and fatalities

This indicator provides data on work-related injuries, illnesses and fatalities. It is considered as a direct measure of the safety of the population employed in the industry, also in comparison to other sectors.

The outcomes for this indicator are based on the percentages of sick leave (re-calculated to number of sick days) in the "industry and energy" sector. This sector is used as comparable sector for the bioenergy sector and has a percentage of sick leave of 4.7%. Based on this number and the estimated jobs in the bioenergy sector (see indicator 12), the number of sick day leaves is approximately 4,4 $*10^{-9}$ per MJ bioenergy.

The estimated percentage of sick day leaves in the energy and industry sector (4,7%) is slightly higher compared to the total national average of 4,2%. To place this in perspective with other economic sectors:

- Agriculture, forestry and fishery sector has 2,6% of sick day leaves per year
- Public governance sector has 5,1% of sick day leaves per year

Due to lack of data, this indicator cannot give information about the number of injuries in the bioenergy feedstock sector per hectare. Above mentioned numbers indicate, however, that the number of sick day leaves per year in the forestry and agricultural sector are relatively low compared to other economic sectors.

## 4.13 Economic Indicator 17: Productivity of each step in the bioenergy life cycle.

This indicator estimates how much bioenergy is produced per unit of input.

This is distinguished into four sub-indicators estimating the produced bioenergy per:

- 17.1: Feedstock production per unit of land
- 17.2: Bioenergy product per unit of feedstock
- 17.3: Bioenergy end product per unit of land

The fourth sub-indicator 17.4 requires an estimation of the production cost in USD/MJ bioenergy.

This indicator is described in the GBEP methodology as restricted to bioenergy from nationally cultivated feedstock. This limits its scope to a very small share of bioenergy in the Netherlands. Only two *agricultural* crops are used for bioenergy: maize for co-digestion with manure (or mono digestion, ratio between both options is unknown) and biodiesel from rapeseed, assuming that all rapeseed cultivation in the Netherlands is used for biofuel. Further, two experimental crops have been included: Short Rotation Coppice (SRC) and Miscanthus. The scope of this indicator covers only about 2% of the Dutch bioenergy consumption in 2010 (see methodology section in Chapter 6).

**Table 13: Outcomes indicator 17 per feedstock- end use combination**

| Sub-indicator | 17.1 | 17.2 | 17.3 | 17.4 |
|---|---|---|---|---|
| Outcome | Productivity (ton DM/ha/yr) | Processing efficiency (MJ/tonne) | Amount of bioenergy end-products (MJ/ha/yr) | Production costs (USD/GJ) |
| Energy maize co-digestion | 45.2 | 6050 | 273470 | 19.10 |
| Biodiesel from rape seed | 4.4 | 13653 | 60073 | 13.77 |
| SRC wood fuel | 4.8 | 10345 | 50000 | NA |
| Miscanthus for heat | 15.0 | 14433 | 216495 | 56.70 |

NA = Not Available

The results show strong differences in productivity, processing efficiency and amount of bioenergy produced per ha per feedstock or per end use combination. This result can be clarified because of the intrinsic differences between the crops and between their conversion processes into bioenergy. The higher production cost for Miscanthus is possibly explained by the fact that it is still considered an experimental crop. Note that various publications have been used to obtain data for each feedstock. It is unclear how much of the found differences are caused by the different underlying assumptions in these publications.

Sub-indicators 17.2 and 17.4 can also be applied to bioenergy that does not result from domestic agriculture. Processing efficiencies for the relevant bioenergy processing chains in the Netherlands (see also indicator 4) are presented in table 14. The differences are mainly due to the energy content of the feedstock. Available data on production costs in the Netherlands for various bioenergy technologies are shown in table 15. These figures were used to determine the 2010 subsidies for these chains of bioenergy.

**Table 14: Processing efficiencies taking place in the Netherlands for non-agricultural crops**

| Processing efficiencies | |
|---|---|
| 10870 | MJ $_{Pellets}$/tonne $_{Wood}$ |
| 9059 | MJ $_{Chips}$/tonne $_{Wood}$ |
| n.a. | MJ $_{methanol}$/tonne $_{glycerine}$ |
| 33808 | MJ $_{biodiesel}$/tonne $_{UCO}$ |

**Table 15: Production costs for non-agricultural bioenergy chains in the Netherlands**

| Production costs (total) | | |
|---|---|---|
| 0.07 | USD/MJ | Waste combustion |
| 0.04 | USD/MJ | Small scale biomass combustion <10 MWe |
| 0.03 | USD/MJ | Large scale biomass combustion 10-50 MWe |
| 0.02 | USD/MJ | Landfill gas |
| 0.07 | USD/MJ | Wastewater treatment |
| 0.06 | USD/MJ | Manure co-digestion |
| 0.04 | USD/MJ | Other digestion |

## 4.14 Economic Indicator 18: Net energy balance of each step in the bioenergy life cycle

This indicator looks into the amount of energy needed for each unit of bioenergy produced and has four sub-indicators. The net energy balance is distinguished into the following phases of the bioenergy life cycle:

- 18.1: Feedstock production;
- 18.2: Feedstock processing into a bioenergy product; T
- 18.3: The use of this bioenergy product.

Sub-indicator 18.4 combines the first three sub-indicators into an outcome for the entire life cycle.

The net energy ratio is described in as the ratio of energy output compared to the total energy input for bioenergy production. The estimation for sub-indicator 18.1 is limited to domestically produced energy crops. In the case of residues, energy input is considered to be zero until the point of collection.

**Table 16: energy ratio calculation for feedstock production**

| Crop | Energy input for feedstock production (MJ/ha/year) | Area cultivated (ha) | TJ feedstock/ year | TJ $_{fossil}$/year | Ratio |
|---|---|---|---|---|---|
| Energy maize | 3634 | 8000 | 2188 | 29.07 | 0.01 |
| Rape seed | 6509 | 2632 | 158 | 17.13 | 0.11 |
| SRC | Not available (but low) | 83 | 4 | na | na |
| Miscanthus | Not available (but low) | 8 | 2 | na | na |
| **Total** | | | 2352 | 46.21 | **0.02** |

NA = Not Available

A combined outcome is estimated for sub-indicators 18.1 and 18.2. A correction factor has been applied in order to exclude imported feedstock (see methodology section in Chapter 4). An exception is made for biofuels. Here, the total amount of nationally produced feedstock has been derived from the IEA Bioenergy Task 40 report (2011).

Estimating sub-indicator 18.4 requires further details on energy expended with collection, transport, storage and distribution of both feedstock and bioenergy product for each bioenergy pathway for which the full life cycle falls within the national borders. This information is not available. Therefore this sub-indicator was not calculated.

**Table 17: energy ratio for conversion of feedstock into bioenergy**

| | % Feedstock of national origin | National feedstock (TJ) | National end use (TJ) | Ratio |
|---|---|---|---|---|
| Municipal waste; renewable fraction | 100% | 32927 | 11537 | 0.35 |
| Co-firing of biomass in electr. Plants | 50% | 14179 | 6460 | 0.46 |
| Wood boilers for heat in companies | 100% | 2766 | 2766 | 1.00 |
| Total wood stoves in households | 90% | 12232 | 12232 | 1.00 |
| Charcoal use by households | 100% | 0 | 270 | n.a. |
| Other biomass combustion, total | 50% | 7338 | 3201 | 0.44 |
| Biogas | 100% | 12069 | 8347 | 0.69 |
| Biofuels for road transport | n.a. | 26622 | 15400 | 0.58 |
| **Total** | | 108132 | 60213 | **0.56** |

NA = Not Available

The results of sub-indicator 18.1 show that there can be large differences in the energy input needed to produce bioenergy feedstocks in agriculture. This can be attributed to the differences in productivity (see indicator 17) and the specific cultivation requirements for the individual crops. The combined outcome of sub-indicators 18.2 and 18.3 show that on average of 56% of the energy contained in biomass is converted into the useful form(s) of energy. The losses can be explained by the energy that is needed for the conversion process itself, for the energy contained in by-products or co-products or efficiency-related losses of conversion technologies.

## 4.15 Economic indicator 19: Gross value added

This indicator looks at the value added to the national economy, expressed in $US/MJ and in percentage of the GDP. Gross value added is defined as: The total output value minus the intermediate inputs.

Table 18 shows the gross value added of bioenergy in 2008 for biogas, solid biomass and waste, and biofuels, as well as the bioenergy produced in each of these fields.

This study assumes that the Dutch GDP in 2008 is 788,638 million US Dollar. The conversion rate used is 1 Euro = 1.3266 U.S. dollars. Based on this information, bioenergy is estimated to contribute 0.081% of the national GDP.

**Table 18: Gross value added of bioenergy in 2008 (based on data from CBS)**

| Sector | Added value (M€) | Bioenergy produced (2008) | US$/MJ |
|---|---|---|---|
| Biogas | 90 | 6399 | 0.0187 |
| Solid biomass and waste | 290 | 58101 | 0.0066 |
| Biofuels | 100 | 12048 | 0.0110 |
| **Total** | 480 | 76548 | **0.0083** |

Biogas has the highest added value per MJ. Solid biomass and waste have the lowest added value. This means that the latter have a relatively higher input of intermediate products. In other words: the costs are higher.

## 4.16 Economic indicator 20: Change in consumption of fossil fuels and traditional use of biomass

This indicator has the following sub-indicators:
- 20.1a: The substitution of fossil fuels with domestic bioenergy measured by energy content;
- 20.1b: The annual savings of convertible currency from reduced purchases of fossil fuels;
- 20.2: The substitution of traditional use of biomass with modern domestic bioenergy measured by energy content

Table 19 shows the total amount of bioenergy used in the Netherlands in 2010 and the total amount of avoided fossil energy. More detailed results can be found in the Excel spreadsheet. The total bioenergy use in the Netherlands in 2010 was 64228 PJ. Of this total, 25408 PJ, 29243 PJ and 9577 PJ were used for electricity, heat and liquid biofuels respectively.

The total impact of bioenergy on savings of convertible foreign currencies is positive for the Netherlands (+120 Meuro). More detailed results (see table 20) show that the impact of bioenergy on savings of convertible foreign currencies is neutral to positive for most systems, except for bioethanol and biodiesel. An important assumption thereby is that the use of biomass for electricity generation replaces electricity from imported gas, although most gas is produced domestically. Note that the estimated savings should not be interpreted as savings in terms of cost reductions. Most bioenergy systems depend on subsidies or mandates. For example, the total amount of subsidies for bioenergy production is equal to 372 Meuro (Agentschap.nl, 2010).

**Table 19: Change in consumption of fossil fuels.**

| | | Fossil fuel avoided | | Main fossil fuel substituted |
|---|---|---|---|---|
| Total bioenergy production | | 70277 | TJ | |
| Electricity | | 44069 | TJ | gas and coal |
| Heat and cooling | | 19675 | TJ | Gas |
| Liquid biofuels | | 6533 | TJ | gasoline, diesel |
| Municipal waste; renewable fraction | Electricity | 11328 | TJ | gas and coal |
| | Heat | 5546 | TJ | Gas |
| Co-firing of biomass in electr. plants | Electricity | 19687 | TJ | gas and coal |
| | Heat | 1123 | TJ | Gas |
| Wood boilers for heat in companies | Electricity | 0 | TJ | n/a |
| | Heat | 1905 | TJ | Gas |
| Total wood stoves in households | Electricity | 0 | TJ | n/a |
| | Heat | 7314 | TJ | Gas |
| Charcoal use by households | Electricity | n/a | TJ | n/a |
| | Heat | n/a | TJ | n/a |
| Other biomass combustion, total | Electricity | 5285 | TJ | gas and coal |
| | Heat | 1927 | TJ | Gas |
| Biogas | Electricity | 7214 | TJ | gas and coal |
| | Heat | 1741 | TJ | Gas |
| Biofuels for road transport | Bioethanol | 1552 | TJ | gasoline, diesel |
| | Biodiesel | 4980 | TJ | gasoline, diesel |

**Table 20: Savings in convertible foreign currencies for selected bioenergy systems**

| Bioenergy system | Savings in Meuro |
|---|---|
| Municipal waste (renewable fraction only | 121 |
| Co-firing of biomass in electricity plants | 25 |
| Wood boilers for heat in companies | -2 |
| Wood stoves in households | 14 |
| Other biomass combustion | 48 |
| Biogas | 80 |
| Bioethanol | -77 |
| Biodiesel | -88 |

Substitution of traditional use of biomass with modern biomass is negligible in the Netherlands.

## 4.17 Economic indicator 22: Energy diversity

The focus of this indicator is on total primary energy supply due to bioenergy. Two sub-indicators are distinguished:

- Sub-indicator 22.1 estimates the contribution of various energy sources in the total primary energy supply in the case of with and without bioenergy;
- Sub-indicator 22.2 estimates the Herfindahl index of energy diversity.

Results are shown in table 21.

**Table 21: The impact of bioenergy on the energy mix and energy security.**

| | With bioenergy | Without bioenergy | |
|---|---|---|---|
| Herfindahlindex | 0.37 | 0.39 | range 0-1 |
| | | | |
| Coal and coal products | 9.1 | 9.5 | % of TPES |
| Oil and oil products | 37.5 | 37.8 | % of TPES |
| Gas | 47.2 | 49.0 | % of TPES |
| Hydro energy | 0.0 | 0.0 | % of TPES |
| Wind energy | 1.0 | 1.0 | % of TPES |
| Solar energy | 0.0 | 0.0 | % of TPES |
| Geothermal energy | 0.1 | 0.1 | % of TPES |
| Waste combustion | 0.5 | 0.0 | % of TPES |
| Co-combustion biomass | 0.8 | 0.0 | % of TPES |
| Biomass boilers companies | 0.1 | 0.0 | % of TPES |
| Wood stoves households | 0.2 | 0.0 | % of TPES |
| Charcoal households | 0.0 | 0.0 | % of TPES |
| Other biomass combustion | 0.3 | 0.0 | % of TPES |
| Biogas | 0.3 | 0.0 | % of TPES |
| Liquid biofuels | 0.3 | 0.0 | % of TPES |
| Nuclear energy | 1.1 | 1.1 | % of TPES |
| Waste and other energy carriers | 1.5 | 1.5 | % of TPES |
| TOTAL | 3482 | 3481 | PJ TPES |

The contribution of bioenergy to the total primary energy supply is 85 PJ or 1,9 % of the total. The Herfindahl index in 2010 without bioenergy was 0.39. When including the use of bioenergy (from both domestic and imported feedstock), the index decreases slightly to 0.37. The results show that bioenergy contributed to the energy diversity of the Netherlands. It should, however, be noted that the contribution of bioenergy to the TPES is limited. The impact of bioenergy on the energy diversity (Herfindahl index) in 2010 was relatively limited as well.

## 4.18 Economic indicator 23: Infrastructure and logistics for distribution of bioenergy

This indicator deals with the infrastructure and logistics for distribution of bioenergy. Three sub-indicators are distinguished:
- 23.1: The number of routes for critical distribution systems;
- 23.2: Capacity of routes for critical distribution systems
- 23.3: The proportion of the bioenergy associated with each

This indicator assumes that existing infrastructure used for fossil energy and other commodities is also suitable for bioenergy. Three potentially critical distribution systems are considered for this indicator (see also table 22):
- Storage and transport capacity biofuels;
- Biogas transportation grid;
- Port facilities.

**Table 22: The capacity use for bioenergy compared to total capacity**

| Capacity use for bioenergy | % |
|---|---|
| Biofuels storage and transport | 5 |
| Biogas distribution via main grid | 0 |
| Import, transport and storage of biomass and port facilities | <1 |

Biofuels for transport require dedicated infrastructure before mixing it with conventional gasoline and diesel. After mixing, the use of additional and dedicated infrastructure for biofuels is limited as biofuels are assumed to replace conventional fuels. Consequently, only the net impact of the higher volume of biofuels compared to conventional road transport fuels is relevant for this part of infrastructure. The current contribution of biofuels in road transport is 4% on energy basis and 5 % on volume basis. This limited additional increase is assumed to have a negligible impact on the fuels' infrastructure capacity.

Biogas distribution via the main gas grid is currently negligible because of various technical and economic limitations. These could be overcome with the appropriate policies and adjustments.

In general, the infrastructure and logistical capacities of Rotterdam harbour are well developed and suitable for all kind of raw and processed biomass feedstock. It is not exactly known to what extend these facilities can be used for biomass. The current trade of biomass is limited to less than 1% of the dry bulk capacity of the Rotterdam harbour. Rotterdam harbour wants to further expand its position as the main European hub when it comes to the exchange of biofuels, in both a dry and liquid form. Several projects are currently being carried out to make this happen. Similar projects are undertaken in other Dutch harbours as Eemshaven.

## 4.19 Economic indicator 24: Capacity and flexibility of use of bioenergy

This indicator asks for an estimation of the capacity and flexibility of use of bioenergy and the resulting impact on energy security. Two sub-indicators are distinguished:
- 24.1: Ratio of capacity for using bioenergy compared with actual use for each significant utilization route
- 24.2: Ratio of flexible capacity, which can use either bioenergy or alternative fuel sources to total capacity

The results of this indicator are shown in table 23.

For a number of reasons – including the financial crisis – the supply of waste has dropped recently. At the end of 2009, due to an imminent overcapacity, an agreement was signed between the waste sector and the government. This stated not to undertake new initiatives aimed at expanding incineration capacity until 1 January 2020. Some waste incineration plants will be fast-tracked to so-called 'R1 status'. These plants will become waste recovery plants, which will make it easier for them to source waste for incineration from other countries. On 1 March 2010 the R1 status has been granted to several waste incinerators with a total capacity of 4.3 Mton waste per year. The total national capacity is 7 Mton compared to 6.3 Mt waste burned in 2010, of which the biomass fraction is determined at 51%.

Combustion of biomass waste can (in theory) be replaced by the use of non-biomass waste. The flexibility ratio is therefore set at 1.0.

**Table 23: The capacity and flexibility of bioenergy use and production: The ratio shows the potential versus the actual production and ratio flexible versus actual production.**

| Ratio potential / actual production | | |
|---|---|---|
| *Municipal waste; based on incineration capacity vs. actual production of electricity* | *1.1* | Ratio |
| *Co-firing of biomass in plants; based on production vs. technical capacity based on 10% co-firing of biomass* | *>1.4* | Ratio |
| *Wood boilers for heat in companies* | *1.0* | Ratio |
| *Total wood stoves in households* | *1.0* | Ratio |
| *Charcoal use by households* | *n/a* | Ratio |
| *Other biomass combustion - total* | *n/d* | Ratio |
| *Biogas* | *1.0* | Ratio |
| *Biofuels for road transport-bioethanol* | *>10* | Ratio |
| *Biofuels for road transport-biodiesel* | *3.4* | Ratio |
| Ratio flexible / actual production | | |
| *Municipal waste; MW incinerators are flexible as they can use both non biomass fraction of MW and biomass fraction* | *1.0* | Ratio |
| *Co-firing of biomass in plants; the use of biomass for electricity generation can be replaced without investments by conventional fuels.* | *1.0* | Ratio |
| *Wood boilers for heat in companies* | *1.0* | Ratio |
| *Total wood stoves in households* | *0.0* | Ratio |
| *Charcoal use by households* | *n/a* | ratio |
| *Other biomass combustion. total* | *n/d* | ratio |
| *Biogas* | *0.0* | ratio |
| *Biofuels for road transport-bioethanol* | *0.0* | ratio |
| *Biofuels for road transport-biodiesel* | *0.0* | ratio |

The capacity of co-firing of biomass is much lower compared to what is technically feasible. Increasing co-combustion is possible by increasing the biomass use in existing co-firing installations or by modifying existing coal and gas fired plants. According to various sources, the capacity can be expanded to 5, 10 or 20%. Higher percentages (50%) have also been realised. This study assumes a possible expansion of co-firing to 20%. Considering this, and the current limited production of electricity from co-firing of biomass compared to electricity from coal (22 versus 3.2 million MWhe), the estimated ratio is 1.4. Co-firing in gas-fired plants is also possible although technically more limited. The factor 1.4 is therefore a crude approximation. All co-firing facilities can also use conventional fuels instead of biomass. The flexibility ratio is therefore 1.0.

No data were found about the exact capacity versus the actual use of wood boilers for heat in companies, of the total wood stoves in households and of biogas. There is no information either that suggest an overcapacity or that these systems did not operate at full capacity or at required capacity. Therefore a ratio of 1 is assumed. Wood boilers can switch between gas and biomass. Wood stoves are designed to use wood only. The flexibility ratio is thus 1 and 0, respectively.

The installed biodiesel capacity is 1306 kton and the production was 382 kton in 2010. The ratio potential to actual production is thus 3.4. The production capacity of ethanol is not given in statistics by CBS. It is, however, estimated to be higher than the production, which has been very limited due to high feedstock prices. The ratio for ethanol is therefore set at 10. This is potentially an underestimation, because several new ethanol plants were supposed to become operational in 2010. Also important is the share of biofuels in the total fuel mix. A 10% mix is technically feasible and desired by EU policies. The actual use in 2010 was slightly above 4%. When considering the 10% as a policy threshold, the desired policy potential to actual use ratio is circa 2.5. Higher biofuel shares are of course possible. This will require at some stage flexi fuel vehicles or technical modifications of car engines. Biofuel production facilities cannot shift to conventional fuel production, so the flexibility ratio of production is set at 0.

# 5 General approach for estimating the indicators

The general approach for estimating the outcome of the indicators covered three consecutive steps: Data collection, analysis and reporting. Various GBEP indicators are strongly interrelated. Therefore, there have been clear interactions between the data collection needs and analysis of the individual indicators.

The methodological approach, the data sources used, and the result of the indicators are described in this report. The practicality (data availability, methodological constraints, usefulness, etc) of the GBEP indicators has been described in a separate report, called "Using GBEP indicators in the Netherlands, Practicality of the indicators" from (SQ Consult, 2012).

## 5.1 Selection of GBEP indicators for analysis in this study

In total, eighteen out of the twenty-four GBEP indicators are assessed in this study. This selection is based on the relevance of the indicators for the Dutch case. Care was taken that indicators were selected from the three main pillars of the GBEP indicators: the social, environmental and economic pillar.

Six indicators are *not* included in this study. These are the social indicators on land tenure (I.9), on price and supply of a national food basket (I.10) and on change in unpaid time by women and children collecting biomass (I.13). Also not included are the social indicators 14 and 15 on "bioenergy used to expand access to modern energy services" and on "change in mortality and burden of disease attributable to indoor smoke". The economic indicator 21 on training and re-qualification of workers is not part of this study either.

An overview of the evaluated environmental indicators is presented in table 24. Table 25 gives the overview of the evaluated social and economic indicators.

## 5.2 Development of a data collection and calculation template

An excel template has been developed in this desk study for the collection of data and the assessment of the indicators. This template was developed for two key reasons:

- It facilitates the comparison between data and between the evaluated indicators. It also allows for easy tracing of calculations;
- It provides a basis for building up a database for monitoring the GBEP indicators in the coming years.

The template has been shared with other GBEP partners to promote harmonization in reporting and data collection.

**Table 24: Evaluated environmental GBEP indicators and their sub-indicators in this study (non-selected indicators are not included in this overview), Ind = indicator, sub-indicators are shown with square brackets**

| Ind | Name of indicator |
|---|---|
| Environmental pillar | |
| 1 | Lifecycle GHG emissions |
| 2 | Soil carbon |
| 3 | Harvest levels of wood resources<br>• [3.1] The annual harvest of wood resources by volume and as a percentage of net growth or sustained yield<br>• [3.2] The percentage of the annual harvest used for bioenergy |
| 4 | Emissions of non-GHG air pollutants, including air toxics, from:<br>• [4.1] Bioenergy feedstock production;<br>• [4.2] Processing;<br>• [4.3] Transport of feedstock, intermediate products and end products<br>• [4.4] Use |
| 5 | Water use and efficiency<br>• [5.1] Water withdrawn from nationally determined watershed(s) for the production and processing of bioenergy feedstock, expressed as % of TARWR and as % of TAWW<br>• [5.2] Volume of water withdrawn from nationally determined watershed(s) used for the production and processing of bioenergy feedstock per unit of useful bioenergy output.<br>Both disaggregated into renewable and non-renewable resources |
| 6 | Water quality (estimated on watershed level)<br>• [6.1] Pollutant loadings to waterways and bodies of water attributable to fertilizer and pesticide application for bioenergy feedstock production, expressed as % of pollutant loadings from total agricultural production.<br>• [6.2] Pollutant loadings to waterways and bodies of water attributable to bioenergy processing effluents, expressed as a % of pollutant loadings from total agricultural processing effluents. |
| 7 | Biological diversity in the landscape<br>• [7.1] The area and percentage of nationally recognized areas of high biodiversity value or critical ecosystems converted to bioenergy production<br>• [7.2] The area and percentage of the land used for bioenergy production where nationally recognized invasive species are cultivated<br>• [7.3] The area and percentage of the land used for bioenergy production where nationally recognized conservation methods are used |
| 8 | Land use and land use changes from bioenergy production<br>• [8.1] Total area of land for bioenergy feedstock production, and as compared to total national surface<br>• [8.2] Total area of land for bioenergy feedstock production as compared to agricultural land and managed forest area<br>• [8.3] Percentage of bioenergy from yield increases, residues, wastes and degraded or contaminated land<br>• [8.4] Net annual rates of conversion between land-use types caused directly by bioenergy feedstock production |

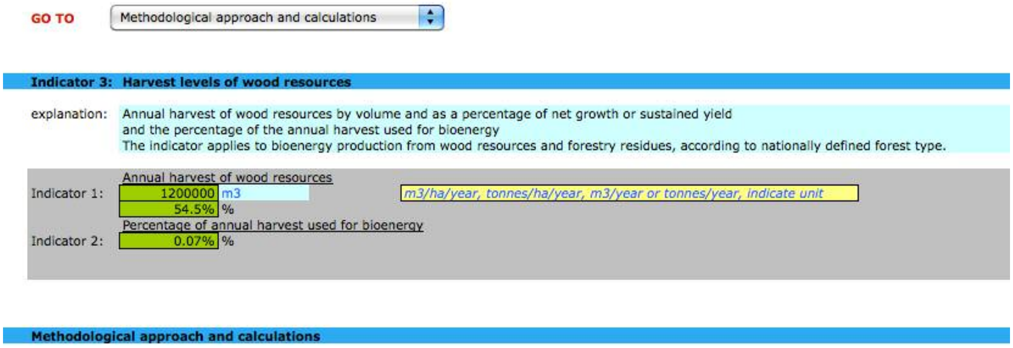
**Table 25: Evaluated social and economic GBEP indicators and their sub-indicators in this study (non-selected indicators are not included in this overview), Ind = indicator, sub-indicators are shown with square brackets**

| Ind | Name of indicator |
|---|---|
| Social pillar | |
| 11 | Changes in income<br>• [11.1] Wages paid for employment in the bioenergy sector in relation to comparable sectors<br>• [11.2] The change in income derived from sale, barter and/or own-consumption of bioenergy products, including feedstocks, for self-employed households or individuals |
| 12 | Jobs in the bioenergy sector<br>• [12.1] Net job creation as a result of bioenergy production and use; total<br>• [12.2] This disaggregated into skilled and unskilled jobs;<br>• [12.3] This disaggregated into indefinite and temporary jobs;<br>• [12.4] Total number of jobs in the bioenergy sector; and % adhering to nationally recognized labour standards consistent with the ILO principles<br>• [12.5] This in relation to comparable sectors |
| 16 | Incidence of occupational injury, illness and fatalities |
| Economic pillar | |
| 17 | Productivity, distinguished into:<br>• [17.1] Feedstock production per unit of land<br>• [17.2] Bioenergy product per unit of feedstock<br>• [17.3] Bioenergy end product per unit of land<br>• [17.4] Production cost in USD/MJ bioenergy |
| 18 | Net energy balance, distinguished into:<br>• [18.1] Feedstock production<br>• [18.2] Feedstock processing into a bioenergy product<br>• [18.3] The use of this bioenergy product<br>• [18.4] Combined for the entire life cycle |
| 19 | Gross value added |
| 20 | Change in consumption of fossil fuels and traditional use of biomass<br>• [20.1a] The substitution of fossil fuels with domestic bioenergy measured by energy content<br>• [20.1b] The annual savings of convertible currency from reduced purchases of fossil fuels<br>• [20.2] The substitution of traditional use of biomass with modern domestic bioenergy measured by energy content |
| 22 | Energy diversity<br>• [22.1] The contribution of various energy sources in the total primary energy supply in the case of with and without bioenergy<br>• [22.2] The Herfindahl index of energy diversity |
| 23 | Infrastructure and logistics for distribution of bioenergy<br>• [23.1] Number of routes for critical distribution systems<br>• [23.2] Capacity of routes for critical distribution systems<br>• [23.3] The proportion of the bioenergy associated with each |
| 24 | Capacity and flexibility of use of bioenergy<br>• [24.1] Ratio of capacity for using bioenergy compared with actual use for each significant utilization route<br>• [24.2] Ratio of flexible capacity which can use either bioenergy or alternative fuel sources to total capacity |

The developed template consists of three main items:

*1. Individual factsheets*
Individual factsheets have been developed to fill in the data for each indicator and to make their calculations. Every factsheet contains the following items: methodological approach and calculations, limitations in calculations, data sources used and data gaps. The outcomes are all presented in a similar format for each indicator (see figure 5).

**Figure 5: Format for presenting results in individual factsheets**




*2. Basic data sheets*
Two data sheets have been developed to provide an overview of the feedstock resources, processing technologies and end-uses in the Netherlands.

*3. Main sheet: outcomes of calculations*
The main worksheet provides a summarized overview of the outcomes of the indicators; they are automatically filled in, based on the results of the individual worksheets. This sheet provides the basis for monitoring results over subsequent years.

The Excel template is a separate output of this project. The file is available from the GBEP coordinators of the Netherlands.

## 5.3 Baseline and reference year

The reference year for measuring the GBEP indicators in the Netherlands is 2010. In case that no data are (yet) available for this year, an earlier year has been selected.

Indicator 2 (on soil carbon) requests for a baseline year to measure the change in soil carbon over time. The selected baseline year was 2007.

## 5.4 Use of GIS maps in measuring the indicators

The calculation of GBEP indicators requires the collection of discrete data (for example the geographical location of the processing plants) and continuous surface data (for example soil class areas, biodiversity areas). Continuous data are needed for the calculation of land-use related indicators. These types of data are often (partly) available in maps.

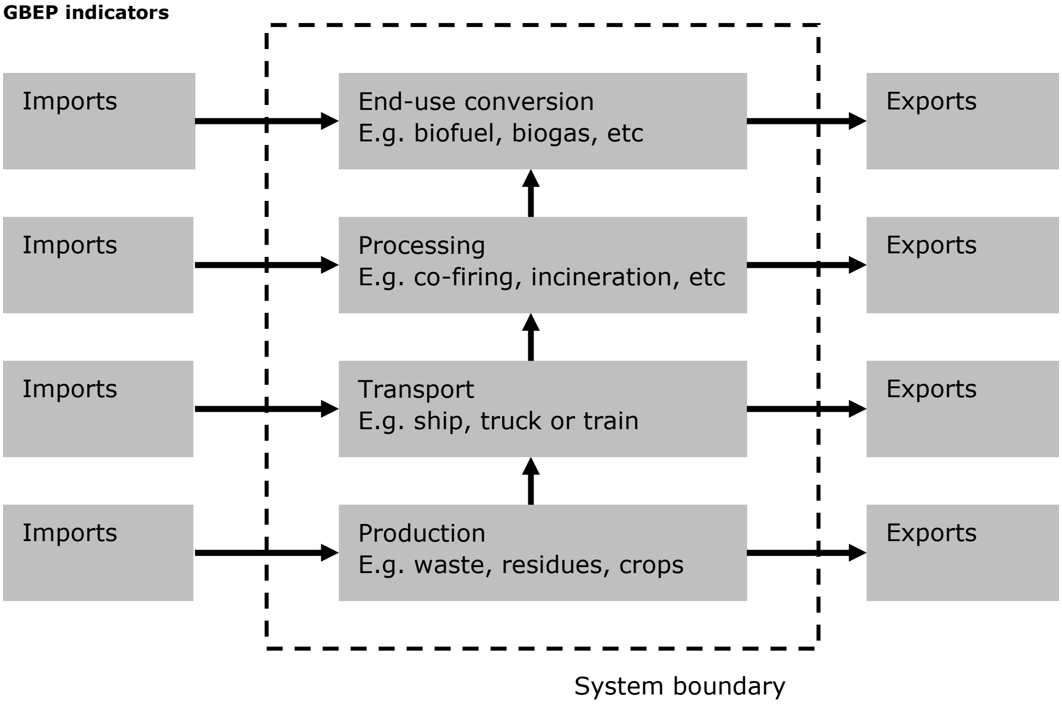
A specific aspect of this study is therefore to look at the possibility of using Geographical Information Systems (GIS) for obtaining the required information from maps. GIS expertise provides the possibility to:

- Automatically extract information from the map to link the associated discrete information (in the form of a table) to a geographical characteristic. For example: the project X is situated over soil class Y;
- Use the so-called "map algebra" to merge and/or intersect datasets (e.g. detect land with soil of class X and land use of class Y inside watershed Z).

## 5.5 Defining the scope of the required data

A basis for the calculation of the GBEP indicators is to have a complete overview of the bioenergy sector on national level. The scope of the GBEP indicators covers bioenergy feedstock resources, processing, transport and conversion to energy on national level. See also the report "Using GBEP indicators in the Netherlands, Practicality of the indicators" from (SQ Consult, 2012). Detailed information is therefore needed as well as information about import and export streams, volumes and geographical locations. See figure 6.

**Figure 6: Flowchart of a bioenergy sector in a country and system boundary for measuring GBEP indicators**




This study made use of various information resources to quantify the import, export, production and consumption flows of bioenergy in the Netherlands. Still, assumptions had to be made due to the contradictions in data, data gaps and uncertainties. See also the Practicality report from (SQ Consult, 2012).

# 6 Methodological approach for assessing the indicators

This chapter presents the methodological approaches that have been followed in this study for assessing the selected indicators. This chapter should be read along with:

- The methodology sheets provided by the report 'The Global Bioenergy Partnership Sustainability Indicators for Bioenergy, First edition' from GBEP from December 2011. This report suggests methodological approaches and relevant data sources;
- The report "Using GBEP indicators in the Netherlands, Practicality of the indicators" from (SQ Consult, 2012). This report provides a description of the data gaps and methodological constraints per indicator. This report also gives the motivation for alternative approaches when they were needed.

## 6.1 Environmental indicator 1: Lifecycle GHG emissions

Different bioenergy feedstock and different production pathways can have significant variation in GHG emission per MJ. The GBEP methodology requires that the GHG emissions per MJ bioenergy are presented in one final outcome. This single outcome has to reflect the variability of all national bioenergy production pathways, feedstock, processes and uses. See also the Practicality report from (SQ Consult, 2012).

In practice, this means that exact data on the main bioenergy pathways are needed as well as the GHG emitted at each step of the pathway. In many cases this data is not available in a form that can be used to calculate the national average: Data on total bioenergy use and data on how much GHG is emitted by specific technologies are available, but it is unknown how much a specific technology is used within the total.

A consolidated national calculation methodology and official data gathering is already in place regarding avoided GHG emissions related to bioenergy except liquid biofuels. The "Renewable Energy Protocol Monitoring 2010" lays down the GHG calculation methodology. The Central Bureau of Statistics (CBS) gathers the required data. These data are published by CBS (2011) and used for the bi-annual national renewable energy Dutch progress report (2012) under EU-RED article 22. This calculation methodology does, however, not take into account the amount of GHG emitted by biomass; this is taken as zero. Instead it calculates the amount of GHG avoided by the reduction in consumption of fossil fuels, cause by bioenergy use. Although this is not what GBEP requests, this is the only data available at a national level.

The situation is different for liquid biofuels. CBS provides data on avoided $CO_2$ emissions for all types of bioenergy, except for liquid biofuels. Underlying reason is that emissions from feedstock production would be required for this calculation, which is not covered in the "Renewable Energy Monitoring Protocol - 2010". For the Dutch progress report (2012), avoided $CO_2$ emissions from biofuels have been calculated by NL Agency (S. te Buck, personal communication). This calculation was based on the "Rapportage duurzaamheid biobrandstoffen 2010" (NEa, 2011), in which the type of feedstock (if known) was voluntarily reported for over twothirds of the biofuel placed on the Dutch market. NL Agency assumed in its calculations that this data was representative for the complete Dutch market, and that the typical values in for $CO_2$ emissions per MJ biofuel in EU-RED (2009) annex V apply (if available). In order to calculate the biofuel part of GBEP indicator 1, the author (S. te Buck, personal communication) has made the original calculation data per feedstock for the Dutch progress report available to the project team. These data were further modified to calculate indicator 1. We re-calculated the avoided $CO_2$ emissions to emitted $CO_2$ per MJ biofuel.

This indicator could not be calculated for all bioenergy consumed in the Netherlands, as prescribed by GBEP. Instead, two alternative indicators have been calculated:
1. The GHG emission in $gCO_{2eq\ emitted}$ /$MJ_{\ biofuel,}$ for liquid biofuels only;
2. The avoided GHG emissions by the whole national bioenergy sector, calculated from the CBS data in Kton $CO_2$ emissions avoided per year, together with the gross final bioenergy consumption in TJ per year.

In both cases, the outcome also includes emitted $CO_2$ emissions from imported feedstock and biofuels. This, because the official source data from CBS and the Dutch progress report (2012) already include imported feedstock and it is not possible to make further distinction. In de case of liquid biofuels, some data on feedstock origin is available, but whether this feedstock is converted into biofuel in the Netherlands or abroad is unknown.

## 6.2 Environmental indicator 2: Soil carbon

The baseline year used for determining whether soil quality is maintained (or improved) is 2007.

*Total land on which bioenergy is cultivated*
Information on cultivated land area for biomass comes from the generic data of the bioenergy sector in the Netherlands with all its uncertainties. See also section 3.5 and the Practicality report (SQ Consult, 2012) for a further motivation. Land is used for the cultivation of the following crops for bioenergy:
- Energy maize;
- Rapeseed;
- Short rotation coppice (SRC) and fast growing grasses

GIS information from the National Service of the Ministry of Economic Affairs, Agriculture and Innovation (EL&I) provides insight in the geographical location of energy maize, SRC and rapeseed. The latter is not distinguished to end-use.

The previous occupation and land use of energy crops in 2007 is difficult to define. This is because of the lack of geographical information on the location of these biomass production areas. Trends in land use changes from CBS (2011) are therefore used.

*Soil organic carbon content per crop*
Systematic monitoring data of soil carbon content, as recommended by GBEP (2011), is not available. The most recent soil carbon map in the Netherlands is based on samples from the late nineties. This map and publications about the soil organic carbon content in the Netherlands are used.

Land use change scenarios are used to estimate the possible change in soil organic carbon content from 2007 to 2010. A risk assessment is done for those land use changes, which may have a risk in decreased soil organic carbon content. Intersecting the soil carbon map and the geographical data from the National Service of the Ministry of (EL&I) has provided insight in the average soil carbon level per crop type.

## 6.3 Environmental indicator 3: Harvest levels of wood resources

Probos (2011) gives information on the growing stock (including dead wood), current increment and auction of wood (= annual harvest) in the Netherlands. The sustained yield, as input for sub-indicator 3.1, is calculated by dividing the growing stock by the annual harvest.

Information on the yearly produced wood in the Netherlands is available for the year 2010. The harvested wood used for bioenergy is based on data about the amount of fresh wood used for bioenergy (excluding industrial processing wood and A, B, C waste wood). Based on these data, the percentage of annual harvest used for bioenergy could be calculated, as required for sub-indicator 3.2.

The calculation for estimating this indicator is straightforward. Assumptions had to be made, though, to estimate the amount of fresh wood used for bioenergy. This is because of the following underlying reasons:

- It is unknown how much of the fresh wood comes from forests (assumed to be 50% in this study) and how much comes from parks or municipalities;
- The amount of wood used for bioenergy refers to the production for internal use and export in total (no further distinction is available);
- There are highly contradictive data sources about the yearly amount of wood used for bioenergy in the Netherlands.

## 6.4 Environmental indicator 4: Emissions of non-GHG air pollutants, including air toxics

Sub-indicator 4.1 is limited to domestic crop cultivation for bioenergy in the Netherlands. These crops are energy maize and rapeseed. SRC and Miscanthus are considered negligible for this indicator. No crop burning takes place in the Netherlands. For calculating the non-GHG emissions from the selected crops, the diesel input per hectare has been derived from literature. It is assumed that diesel for the farming tractor is the only energy input in cultivation. The emissions from a diesel tractor have been taken from the GREET model (2011). It is assumed that the crops are fertilized with manure, for which the emissions are accounted for as caused by animal husbandry. No further emissions from fertilizer production are taken into account.

Sub-indicator 4.2 requires an assessment of the air emissions from biomass feedstock processing. Many of the Dutch bioenergy systems directly use a residue stream as feedstock (e.g. MSW, wood stoves). Therefore, no significant processing is needed to prepare it for end-use. Other feedstocks do require a form of processing. As example: waste wood undergoes removal of e.g. plastics or metals, and will be chipped or grinded before combustion. It is assumed that in such cases the energy needed for processing is taken from the energy output. Thus some of the gross energy produced is needed for processing, considered to be part of the parasitic load. In such cases the processing emissions are not separately available. They are included in the end-use emissions in sub-indicator 4.4, being the parasitic load in the calculated end-use emissions.

Processing emissions are only calculated separately in those cases where a feedstock is specifically processed/converted into a solid, gaseous or liquid biofuel, and combusted in a next step and in a separate system. These cases are:

- Pellets (for co-combustion);
- Chips (for co-combustion and other combustion);
- Biofuels from feedstocks produced in the Netherlands: biomethanol, and biodiesel from UCO and rapeseed.

Several of the mentioned biofuels have multiple procession steps (e.g. rapeseed drying, oil extraction, refining, esterification). These may require multiple energy inputs that need to be accounted for separately. The required energy inputs (in MJ fossil fuel), the conversion factors and the allocation factors[2] for these processes have been taken from the $CO_2$ tool (2011) and from Biograce (2011). Emission factors for the energy inputs (diesel, electricity and natural gas) are based on EMEP/EEA (2009). Note that it is assumed here that the only source of non-GHG emissions is the fossil energy use needed for processing.

Differentiating between domestic production, import and export is quite clear for pellets and chips. For these products, the amount of processed pellets and chips in another country is known. These amounts are therefore not included in the calculation. The case of biofuels is more complex; see also the Practicality report (SQ Consult, 2012) and insufficient data are available to make this picture complete for the Netherlands. As data are available on feedstock origin, this study only includes those biofuels made from domestic feedstocks in the calculation.

Sub-indicator 4.3 looks at the air emissions from all the transport needed in the bioenergy production chain. No actual data are available on transport use for bioenergy. Therefore, a maximum of 100 km truck transport for all bioenergy types is assumed. No matter if the feedstock is imported or not, some transport inside the Netherlands is required. No differentiation is therefore made on feedstock origin. The following exceptions are made:

- UCO and rapeseed oil transport of 100 km has been assumed, and another 100 km for the transport of the biodiesel produced from it;
- It is assumed that the transport of waste to the incineration plant is part of the service of municipal waste disposal, so the emissions for transport are not attributed to the bioenergy produced.

Truck transport emission factors have been taken from the GREET[3] model (2011).

Sub-indicator 4.4 looks at the emissions from the end use of biofuel. For the best possible calculation, detailed information would be needed on how much biomass or biofuel is combusted in what type of system or motor. These data are not available. Emission factors per type of technology are therefore based on literature sources. When no specific emission factor was found, the emission factor of large-scale biomass combustion from EMEP/EEA (2009) was used. This sub-indicator has

2 As example: part of the emissions should be allocated to the biofuel, part to the co-products, e.g. rapeseed cake)

3 Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Model by Argonne National Laboratory, US

been calculated for all national bioenergy consumption, including from imported feedstocks.

All sub-indicators require one outcome of the non-GHG emissions per pollutant for the whole national bioenergy sector. Therefore, weighted averages of emissions per considered feedstocks, biomass or bioenergy are used.

Note that, due to lack of data, various strong assumptions were required to come to an outcome for this indicator. Results should therefore be interpreted as indicative.

## 6.5 Environmental indicator 5: Water quantity

Data sources on the water withdrawn for biomass and bioenergy production from watersheds are scattered and based on different methodological approaches. These are, apart from the approach on estimating the total actual renewable water resources (TARWR) and total annual water withdrawals (TAWW):

- The Water Foot Print (WFP); this is the total annual volume of fresh water used to produce the goods and services related to consumption. The WFP is subdivided into green water (water that is evaporated during crop growth), blue water (amount of (evaporated) surface and ground water used for irrigation) and grey water (water that becomes contaminated during the production process);

- The Water Use Efficiency (WUE) per crop expressed in kg DM/ha/mm ET; this is defined as the yield of plant product per unit of crop water use. Yield and water use are interrelated (higher yields result into higher water use) and its function depends on climate, soil and precipitation conditions in a region.

- Indicative data on water use in processing efficiencies are scarcely documented; various international experts are consulted.

- Actual or estimated data on water use or water withdrawal. Data can be based on statistics, agricultural databases or information from the Dutch watersheds. Information is often aggregated into overall water use per economic sector.

The above-mentioned approaches are not fully compatible with each other. This is discussed more in detail in the Practicality report (SQ Consult, 2012). Given these inconsistencies and data limitations, an alternative approach is chosen.

Estimations on TAWR and TAWW are available from FAO. These data are combined with information about water use per economic sector in the Netherlands – with all its uncertainties. The contribution of energy crops to TAWR and TAWW is further assessed by using the proportional land use of energy crop production to the total agricultural crop area. This approach assumes that all crops consume a similar amount of water, which is not the case in reality. Biomass (processing) residues and waste are not included in this comparison given the large variability of streams and sources of origin (already processed or not).

The division of water use by renewable and non-renewable sources is based on data from the Netherlands Environmental Assessment Agency (PBL). These data give the use of surface water and groundwater by the agricultural sector. Note that the use of rainwater is not reported.

The water use by processing facilities, as required for sub-indicator 6.2, is qualitatively described, supported by data from individual resources. This information is supported by a rough back of the envelope calculation based on the total WFP of bioenergy in the Netherlands. The total water use per unit of bioenergy output is based on WFP calculations from the article from Gerbens-Leenes (2008). This article gives the average WFP for bioenergy streams in the Netherlands.

## 6.6 Environmental indicator 6: Water quality

Sub-indicator 6.1 requires information about the amount of pollutant loadings to waterways and bodies of water attributable to fertilizer and pesticide application for bioenergy feedstock production. The Watershed Plans 2009-2015 provide information about Nitrogen (N) and Phosphorus (P) loadings in kg/ha/yr for the total agricultural sector. The Ministry of Economic Affairs, Agriculture and Innovation (EL&I) provides information about maximum N and P fertilizer use per crop. This is the maximum allowed amount of fertilizer use per year or per crop rotation. The amounts vary per soil type. The maximum N fertilizer use is also provided for perennial crops. Statistical information about fertilizer use is not available for Miscanthus. This crop is neither part of the agricultural area in statistics. Given the small cultivation area of Miscanthus, this crop is considered to be negligible for the calculations.

The information from the Ministry EL&I is used to estimate the N and P loadings per crop, also as percentage of total pollutant loadings from agricultural production in the Netherlands.

Statistics from CBS provide data about the total use of pesticides per agricultural crop in kg/ha on a national level. This information is not available from statistics for SRC or for Miscanthus. Given the small cultivation area of Miscanthus and SRC, these crops are considered to be negligible for further calculations. An average number of pesticide use per ha is also available from CBS, which enables to come to a generic estimation of the total pesticide use on agricultural land.

Data from the National Service (2012) and the GIS map of watersheds (see annex 1) are intersected to come to an estimation of the energy crop area per watershed. CBS provides information about the total agricultural area per watershed. Data are combined to come to an estimation of the proportional use of Active Ingredients (AI) by the energy crops maize and rapeseed compared to the total agricultural area. The data are calculated on watershed level.

Biomass (processing) residues and waste are not included in this comparison given the large variability of streams and sources of origin (already processed or not).

Information about pollutant loadings for bioenergy processing, as required for sub-indicator 6.2, is basically not available. "Emissieregistratie" provides information about pollutant loadings per company. Information about the pollutant loadings for bioenergy cannot be distilled because of lack of insight in underlying assumptions. CBS (2011) gives information about N and P compounds per economic sector. The

European Environment Agency (EEA) provides geographical information about BOD concentrations on European level. Information from CBS and EEA together provide insight in the relative BOD levels in the Netherlands, compared to European levels, and in the expected proportional contribution of the bioenergy sector to this.

## 6.7 Environmental indicator 7: Biological diversity in the landscape

The first sub-indicator 7.1 requires insight in the (previous) location of nationally recognized areas of high biodiversity value or critical ecosystems in a country. There are several types of protected nature areas in the Netherlands:

- Natura 2000 areas (Bird Directive and Habitat Directive);
- Wetlands;
- Protected Nature areas (monuments);
- National landscapes (20 in total);
- National parks (20 in total, integral part of the NEN)
- The National Ecological Network "EHS" (in Dutch: Ecologische Hoofdstructuur); the EHS overlaps for 45% with the Natura 2000 areas.

Natura 2000 is a European network of nature areas that are protected under the European Bird Directive and Habitat Directive. The EHS consists of existing nature areas (amongst which the 20 national parks) and nature development areas. Agricultural areas, managed based on nature management practices, are also part of the EHS. Farmers receive a subsidy for implementing these practices. The EHS agricultural areas generally form corridors between existing nature areas.

No clear definition is given by GBEP on 'high conservation value' areas or areas of 'critical ecosystems'. This study assumes that Natura 2000 areas are representative. Data sources from CBS are used to look at changes in land use for agricultural and for nature areas over time (see also indicator 8). A map of Natura 2000 is intersected with the map of crop areas for energy purposes (National Service, 2012) to look at possible locations of energy crops in or close to nature areas in the Netherlands.

For sub-indicator 7.2, the Global Invasive Species Database, the list of GBEP and the GISP programme have been consulted. These data sources provide a list of crops that are considered invasive per country or world region. This study checked whether cultivated energy crops in the Netherlands were mentioned on these lists.

Sub-indicator 7.3 requires insight in the area of land used for bioenergy production where nationally recognized conservation methods are used. National recognized conservation methods are interpreted in this study as nature conservation methods in the agricultural sector. This is one of the recognized tools for managing the EHS and covers for example protection of bird species or nests, protection of boundaries in the agricultural land (e.g. riparian areas) or the promotion of herbaceous species in grasslands.

GIS data are available from the National Service of the Ministry of EL&I on the geometric planes for nature management, including a description of the packages codes for agricultural nature management. These data are intersected with the geographical locations of energy crops from the National Service (2012). The combined map provides an indication of the proportional use of nature management methods within bioenergy production.

## 6.8 Environmental indicator 8: Land use and land-use change related to bioenergy feedstock production

Sub-indicators 8.1 and 8.2 estimate the total area of land for bioenergy feedstock production compared to the total national surface, the agricultural land and managed forest area. The (maximum) cultivated area of energy crop production, based on data from the Dutch progress report (2012) for compliance to the European Directive 2009/28/EG is compared with CBS data about the national surface area, agricultural and forest area in the Netherlands in 2010.

Information about yield increases of individual crops, needed for sub-indicator 8.3, comes from CBS. The National Renewable Energy Action Plan (NREAP) of the Netherlands provides information about the use of contaminated or degraded land for bioenergy production. The percentage of waste and residues to bioenergy in the Netherlands is calculated for the domestic resources and for the total resources (including import). Information is based on data from CBS, from NEA (2010) for biofuels, and from the Dutch progress Report (2012) for biomass for heat and electricity.

Sub-indicator 8.4 assesses the net annual rates of conversion between land-use types caused directly by bioenergy feedstock production. The use of GIS for calculating the net annual rates of conversion between land-use types has been researched. Although this may be a strong land-use monitoring tool on the longer term, practical limitations hamper its application for this moment; see also the Practicality report (SQ Consult, 2012). CBS statistics are used for this study to look at the coverage of land-use types in the Netherlands over a longer period of time. The proportional contribution of bioenergy to changes in land use types, which has been minimal, is further argued with qualitative information from the Dutch progress report (2012) for compliance to the European Directive 2009/28/EG on land use change.

## 6.9 Social indicator 11: Change in income

For sub-indicator 11.1, GBEP recommends calculating the average wage paid for employment in the bioenergy sector by analysing a sample of employment contracts at different stages of the bioenergy supply chain. A second suggested approach is to consult relevant industry and worker associations. This study does not include the implementation of questionnaires. An alternative approach, based on data from CBS, is therefore applied:

CBS provides information about the wages per economic sector in the Netherlands. No specific distinction is made for the bioenergy sector or for other renewable energy sectors. Wages in comparable existing economic sectors are therefore used as reference for the bioenergy sector. Differences are expected to be minimal. This study assumes that people working in the bioenergy sector originate from a similar economic sector when changing jobs. As example: farmers will use part of their land for biomass production.

Sub-indicator 11.2 focuses on the change in income derived from bioenergy products for self-employed households or individuals. Companies are not included. GBEP recommends that input data for this sub-indicator are extrapolated from household surveys or from sales contracts of such products. This study does not include the implementation of questionnaires.

The level of own consumption of bioenergy products on household or individual level is expected to be limited in the Netherlands. Data availability on this topic is, however, minimal. CBS and IEA Bioenergy Task 40 indicate that households use fresh wood, for a small part imported, or waste wood for woodstoves for heat. The use of imported wood is therefore ignored. The saves income for households is calculated assuming that wood is used for heat instead of natural gas.

## 6.10 Social indicator 12: Jobs in the bioenergy sector

The report from ECN (2010) on socio-economic indicators of renewable energy in 2010 provides an important source for assessing the job creating in the bioenergy sector, as required for sub-indicator 12.1. The report gives estimations of jobs per individual company in the biogas, biofuel and solid biomass sector without explicit categorization to type of jobs. This monitoring report has now been published over various subsequent years.

The ECN report (2010) does not include data on the employment generation from bioenergy activities in the R&D sector, the transportation sector or the agricultural or forestry sector. With respect to solid biomass, the report does not include employment related to wood-fired furnaces and boilers in households. Employment related to co-firing of biomass in power plants is not included either. Information from CBS (2011) is used to get a general indication of the amount of jobs from bioenergy activities in the agricultural and government sector.

Sub-indicators 12.2 and 12.3 ask for a disaggregation of the outcome of sub-indicator 12.1 into skilled and unskilled jobs and into indefinite and temporary jobs. A study of CBS (2008) provides a ratio between specialized and un-specialized jobs for the pre-exploitation phase in the renewable energy sector. This ratio (67%) is used as default value for this study. CBS provides information about the number of part-time and full-time jobs in 2010 per economic sector. No information is available about the distinction of indefinite and temporary jobs in the bioenergy sector specifically.

Sub-indicator 12.4 asks for the percentage of generated bioenergy jobs adhering to nationally recognized labour standards. These standards should be consistent with the principles enumerated in the ILO Declaration on Fundamental Principles and Rights at Work. Compliance to national labour standards in the bioenergy sector has to be placed in perspective with compliance levels in comparable economic sectors (see sub-indicator 12.5).

According to the ILO "Declaration on Fundamental Principle and Rights at Work" (1998) the four principles enumerated in this Declaration have the status of human rights. These principles are:

- Freedom of association and the effective recognition of the right to collective bargaining;
- The elimination of all forms of forced or compulsory labour;

- The effective abolition of child labour; and
- The elimination of discrimination in respect of employment and occupation.

It is considered that these ILO principles are fully met in the bioenergy sector, as well as in other economic sectors in the Netherlands.

## 6.11 Social indicator 16: Incidence of occupational injury, illness and fatalities

This indicator requires information about the occupational injuries, illnesses and fatalities in the bioenergy sector, assuming that these data are collected per economic sector. The bioenergy sector is, however, not included in the statistics as separate sector. Interviews and questionnaires are proposed by GBEP to further distinguish the number of injuries per energy crop or process. This type of data collection is not included in this study.

Given the methodological and data limitations for this indicator, an alternative approach is applied. CBS provides data on the percentage of sick leave per economic sector. Sickness leave is defined by CBS as "the total amount of sick days of the employers, in percentage of the total number of available (work / calendar) days of the employees in the reporting period". The percentage of sick leave of the economic sector Energy and Industry is considered to be representative for the bioenergy sector. Combining these data with the number of jobs in the bioenergy sector (indicator 12) provides an estimation of the number of sick leave days in the bioenergy sector.

It is not possible to give an indication on the number of injuries (i.e. in this study interpreted as sickness leave per calendar year) for bioenergy feedstock production. This has two underlying reasons. First, there is the lack of data on number of jobs in the agricultural sector for bioenergy (see also indicator 12). Second, there is an uncertainty involved in the estimated produced area for bioenergy in the Netherlands.

## 6.12 Economic indicator 17: Productivity of each step in the bioenergy life cycle.

According to GBEP, the indicator applies to "bioenergy production and to all bioenergy feedstocks/pathways". Sub-indicators 17.1 and 17.3 are expressed per hectare of land. These are therefore only applicable to agricultural crops, and further restricted to crops produced in the Netherlands. Due to data uncertainties (origin, location, amounts), it is not possible to provide estimations for the agricultural residues in the Netherlands. This limits the scope of this indicator to a very small share of consumed bioenergy in the Netherlands; only to bioenergy from domestic crop production. About 98% of the bioenergy consumed in the Netherlands falls outside of the scope of this indicator.

For sub-indicator 17.1, the yield data for the year 2010 are available from CBS for energy maize and rapeseed. Yield data from Miscanthus and SRC are not available from statistics. They represent less than 1% of the land area used for bioenergy in the Netherland. Yield information from these experimental crops is based on publications.

Sub-indicator 17.2 requires information about processing efficiencies. In order to remain consistent with 17.1 and 17.3, processing efficiencies for the four domestically cultivated energy crops have been derived from literature. In addition, processing efficiencies for the feedstock conversion processes that are considered relevant in the Netherlands have been included in indicator 17.2 (see chapter 6). For sub-indicator 17.3, the bioenergy production per hectare is calculated with outcomes from sub-indicators 17.1 and 17.2.

In order to remain consistent with sub-indicator 17.1 and sub-indicator 17.3, the same four domestically cultivated energy crops have been included in sub-indicator 17.4. Their production costs per MJ for are derived from literature. Due to data unavailability, the production costs are not specific for 2010. Data availability on production costs is generally low. Some reliable data on production costs is have been derived from the calculation of the SDE subsidies in the Netherlands in 2010 (ECN, 2009). The Euro to $US exchange rate at the time of writing was used.

## 6.13 Economic indicator 18: Net energy balance of each step in the bioenergy life cycle

Sub-indicator 18.1 assesses the energy input for feedstock production. Only a small share of the Dutch bioenergy consumption is based on domestically cultivated feedstock (see also indicator 17). The amount of MJ bioenergy produced is calculated by multiplying the amount of MJ bioenergy per ha (see sub-indicator 17.3) with the assumed amount of land used for the cultivation of energy crops. The energy output is compared with the amount of direct energy input needed for cultivation per ha per feedstock. This indicator assumes that the needed fertilization is done with manure. No energy input for fertilizer production is taken into account. In accordance with the EU-RED methodology, labour and embedded energy in machinery are not taken into account.

An estimation of the energy input for the processing of feedstock into a bioenergy product is required for sub-indicator 18.2. Sub-indicator 18.3 estimates the gross end use of this bioenergy product. An example of such chain would be: Pelletisation of woody biomass (sub-indicator 18.2) for co-combustion (sub-indicator 18.3). Most bioenergy pathways do not have an intermediate processing step or product (here pellets). Feedstocks as wood or waste are generally directly combusted for heat and/or electricity. For those chains that have intermediate processing, including this step will only add data gaps to the calculations. An example is given:

> For heat and electricity from biogas, the net conversion efficiency from tonne waste to MJ biogas would be needed for each feedstock for sub-indicator 18.2. This feedstock could be a landfill, wastewater, or manure. In addition, the energetic efficiency from biogas into heat and/or electricity would be needed for the different biogas end uses.

Instead, the study uses only the available total feedstock input data for sub-indicator 18.2, and the gross end use data for sub-indicator 18.3, which includes in its outcome the intermediate conversion processes. This means that this study calculates a combined outcome[4] for sub-indicators 18.2 and 18.3.

4 Note that this is acceptable under GBEP methodology, which states: “The indicator can consist of a single value corresponding to the lifecycle energy ratio of the chain considered and/or a set of values for each step of the chain, including the efficiency of the feedstock production, processing and end-use of biofuels”

The combined outcome of sub-indicators 18.2 and 18.3 has been calculated by using the data for feedstock input and bioenergy output in table 3. This table includes both bioenergy from domestic and imported feedstocks. A correction factor has been used to exclude the imported share. For each relevant bioenergy technology, this correction factor is based on data from CBS (2010).

For calculating sub-indicator 18.4, the results for sub-indicators 18.1 to 18.3 are used. Beside, two additional factors are of importance:

- The amount of energy expended with the collection, transport, storage and distribution of both feedstock and bioenergy product.
- The allocation of energy expended for feedstock production/collection and transport between the bioenergy product and its co-products. This only applies when co-products are produced.

This data is not available. Therefore, this sub-indicator was not calculated. Given the expected low contribution of energy use from bioenergy transport or collection the result of sub-indicators 18.2 and 18.3 can be considered an approximation of the life cycle energy ratio. See also the Practicality report (SQ Consult, 2012).

## 6.14 Economic indicator 19: Gross value added

The gross added value of the renewable energy sector has been published for the Netherlands in the "Economische radar duurzame energiesector" (CBS, 2011). Results are separately presented for biogas, solid biomass and waste, and biofuels. Data for the calculation come from the internal CBS database. The data are gathered in various ways by CBS including detailed surveys of the Dutch industry and data from the government e.g. the Tax Agency. Not all companies are surveyed on all aspects. The report therefore assumes that the Gross added value per employee (FTE) for non-surveyed companies is the same as the average added value of the surveyed companies of the same type. Due to privacy reasons, data are published in a more aggregated form. The calculation of the Gross value added in the CBS report from 2011 is based on 2008 data (CBS, personal communication).

For this indicator, the gross value added is summed for biogas, solid biomass and waste, and biofuels. This number is divided by the bioenergy consumed in 2008 for each of these categories resulting in the added value per MJ of biomass stream. The data on consumed bioenergy and on gross added value both include imported biomass in their scope. It is not possible to eliminate the contribution of the imported biomass from the total number, due to lack of underlying data.

Finally, the added value of the total bioenergy sector is calculated. By dividing the total gross value added by the national GDP, the percentage of bioenergy in the GDP calculated. To convert Euro in US Dollar, the exchange rate at the time of writing has been taken.

## 6.15 Economic Indicator 20: Change in consumption of fossil fuels and traditional use of biomass

For sub-indicator 20.1a on the substitution of fossil fuels with domestic bioenergy, data on bioenergy production and biofuels were taken from CBS and calculated with the results on the energy balance from indicator 18. Data on bioenergy production are available for: Waste combustion, co-combustion biomass, biomass boilers companies, wood stoves households, charcoal households, other biomass combustion, biogas and bioethanol and biodiesel. For each system the production of electricity, heat and cooling is given, except for liquid biofuels. An even more detailed breakdown is used in the CBS statistics (see also the Excel file). Such a high level of detail is considered of little relevance for this study.

Data on the energy balance (or net energy ratio) were not available for all bioenergy chains. This study therefore assumes that the energy balance of wood boilers for heat in companies, wood stoves in households and other biomass combustion is the same as for co-firing of biomass. Wood pellets are the most important feedstock used for co-firing of biomass in large power plants. They are also an important feedstock for boilers for heat in companies. Wood stoves used in households and other biomass combustion use different types of feedstock with a higher or lower energy balance. The overall impact of this uncertainty is probably limited. This is because of the limited contribution of these applications to the total bioenergy production.

Sub-indicator 20.1b deals with the impact of modern bioenergy on the economic development and more specifically on savings of convertible currencies. Data are taken from various sources, except for wood stoves for households for which results are taken from indicator 11.

The second sub-indicator 20.2 estimates the substitution of traditional use of biomass with modern domestic bioenergy measured by energy content. The traditional use of biomass for energy in the Netherlands is limited to niche markets. These are for example consumers that prefer open fireplaces and traditional wood stoves for esthetical and other (non-financial) reasons. Many of these traditional systems are designed towards optimal comfort, ease of use and efficiency. Also the use of charcoal for barbequing is a niche market with little relevance for this indicator. For these reasons, the impact of modern biomass on traditional use of biomass is of very limited relevance to the Netherlands. The outcome is therefore further assumed to be negligible.

## 6.16 Economic indicator 22: Energy diversity

Detailed and accurate data on bioenergy production and on its contribution to the total primary energy supply are available from statistics of CBS. Data are given for total bioenergy production. This is the sum of electricity, heat and cooling and liquid biofuels. Data are also available for specific biomass systems, as already discussed in section 4.15. For each system the production of electricity, heat and cooling is given, except for liquid biofuels. Based on these data, the contribution of various types of bioenergy to the Total Primary Energy Supply (TPES) and the Herfindahl index values is calculated.

## 6.17 Economic indicator 23: Infrastructure and logistics for distribution of bioenergy

This indicator deals with the infrastructure and logistics for distribution of bioenergy. Some bioenergy production chains require dedicated infrastructure and logistics, especially in the biomass storage and handling phase. After converting the biomass into final energy conventional fossil energy infrastructure and logistics for distribution can be used. Some practical limitations might need to be overcome though. Based on these considerations three critical systems are selected for sub-indicator 23.1:

1. Biofuels for transport storage and transport;
2. Biogas distribution via main grid;
3. Import, transport and storage of biomass and port facilities.

A complicating factor was that conventional fossil energy infrastructure and logistics can be partially used for bioenergy as well. It is, however, not exactly known to what extent. The capacity of the three systems for specifically bioenergy, as requested by sub-indicator 23.2, could therefore not be quantified.

Sub-indicator 23.3 deals with the percentages of use for bioenergy compared to the total capacity. Accurate data about the capacity for biomass and bioenergy were not available. The calculations of the proportion of each system used for bioenergy are therefore based on the assumption that existing infrastructure and distribution systems are suitable for bioenergy. In the case of biofuels for road transport, we corrected for the lower energy density of the biofuel mix used in the Netherlands compared to conventional fuels, i.e. replacing conventional fuels with biofuels increases the demand for infrastructure and logistics for distribution.

## 6.18 Economic indicator 24: Capacity and flexibility of use of bioenergy

The collection of data on the capacity and flexibility of use of bioenergy was somewhat troubled. Underlying reasons was the confusion about the focus of the indicator (on bioenergy use or on bioenergy production). See also the practicality report (SQ Consult, 2012).

The focus in our analyses is on the capacity of actual production versus the technical production capacity in the case of municipal solid waste combustion, co-combustion of biomass and the production of biofuels for road transport. Data are taken from CBS, the report 'Status document bioenergy 2010' and various other sources. No distinction was thereby made between the production capacity for electricity and heat.

For this study, it is assumed that wood boilers for heat in companies, total wood stoves in households and biogas systems operate at maximum capacity or maximum required capacity when energy is needed. For most of the evaluated systems, the flexibility of use is by definition 100% as end users are assumed to have no preference. Exception is the case of biofuel use in cars. The flexibility of production is 0% in case of dedicated bioenergy systems. The flexibility in production is 100% in case of for example co-firing, where all existing co-firing capacity can be reverted back to coal.

# 7 Data sources used

The most relevant databases and information resources for each indicator are listed in chapter 8 on the References. The complete list of references is shown in the Excel template (available as separate annex).

Basically, five types of resources have been used to collect the data for the evaluated indicators. Note that these resources differ in accessibility, actualization (for example yearly to one time or incidental reporting) and type of source (government, company, institute, etc.). Preferred for this study are those information resources that are officially recognised, easily accessible and updated on a frequent basis.

***Statistics***
The Central Bureau of Statistics (CBS) is an important data source for several of the selected indicators.

***Databases***
Various databases have been used to retrieve data from. These include for example the National Renewable Energy Projections of the European Member States (NREAP) database of Energy Centre of the Netherlands. Another example is the data provided by Aguastat (FAO). These information sources provide consistent datasets monitored over various years.

***Monitoring reports***
Several monitoring reports have been consulted to retrieve data for the selected indicators. They are published on a frequent basis over a longer time period. Some examples are the 2-yearly Dutch progress Report to the European Commission and the yearly Biofuels Reporting from the Dutch Emissions Authority. Other examples are the country report from IEA Bioenergy Task 40 or the yearly monitoring of socio-economic indicators of renewable energy from ECN.

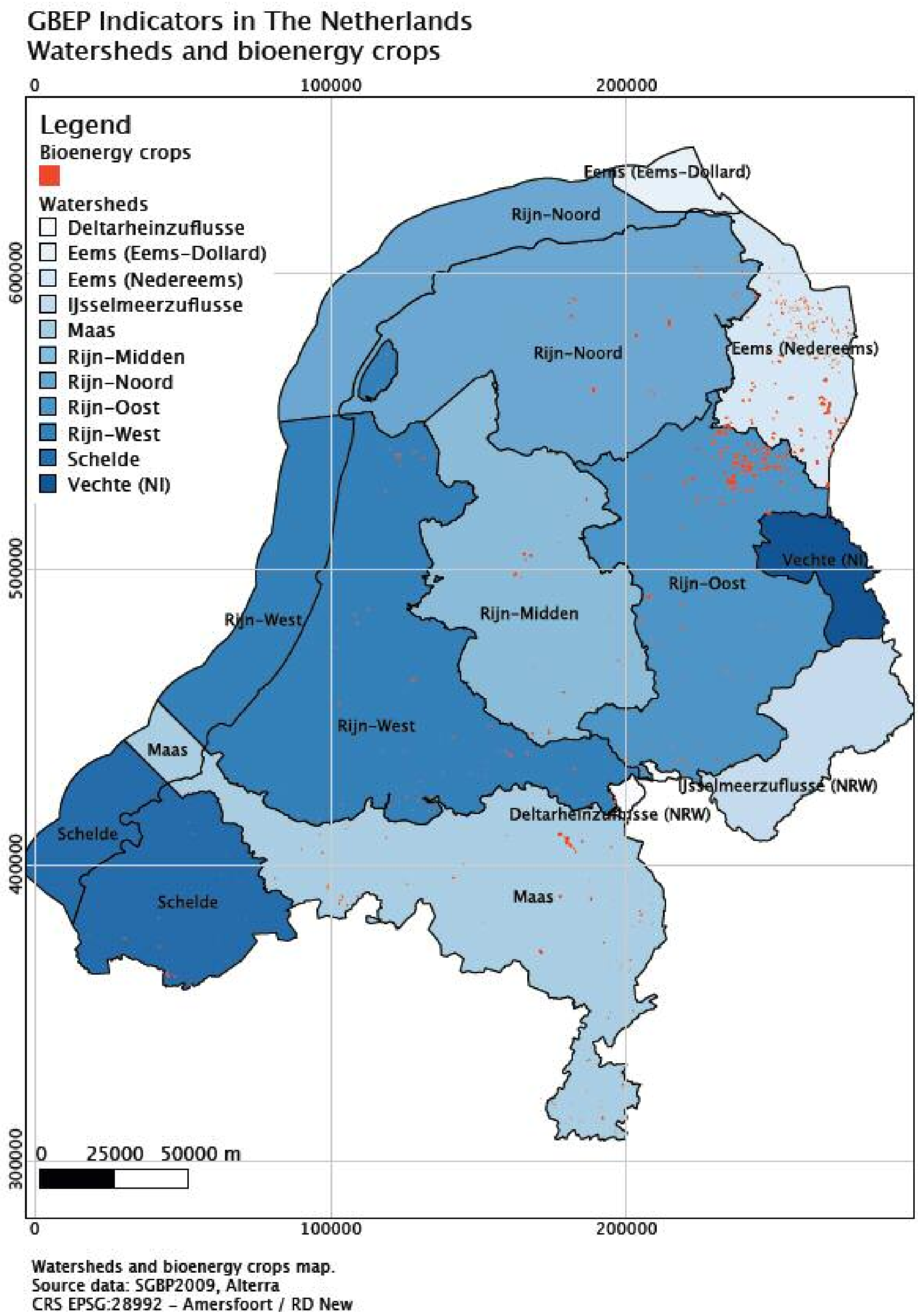
Note that some of these monitoring reports are government initiated, while others (like the reports from ECN and IEA Bioenergy Task 40) are non-government initiated. Relying on non-governmental databases for monitoring the GBEP indicators may require a stronger coordination effort to ensure their availability.

***Maps***
Maps are used and further processed to estimate land-use related indicators. Evaluated maps include the Global Land Cover 2000 database from the Joint Research Centre and the GADM database of Global Administrative areas. The Natura2000 map from Alterra is specifically used for indicator 7 on biodiversity while the Soil carbon map (2003), also developed by Alterra, is been used for the analysis of indicator 2 on soil carbon.

Additional GIS maps about croplands in Netherlands have been provided by the National Service of the Ministry of Economics, Agriculture and Innovation. These data have been used as input for processing indicators 2 (soil carbon), 7 (biodiversity) and 6 (water quality). A GIS map on the location of nature management practices has also been provided by the National Service, which served as input for indicator 7.

Map 4 shows an existing map that has been used as information source for analyzing the indicators. Map 5 shows how existing data resources and maps are further integrated to demonstrate the energy crop production (based on National Service, 2012) per watershed in the Netherlands.


**Map 4: bioenergy plants locations in www.b-i-o.nl. Dataset has been extrapolated from the webpage and further processed into a GIS shapefile.**




**Map 5: Integration of energy crop production areas (from National Service, 2012) and administrative boundaries of watersheds**

***Individual reports***

Individual (scientific) reports are mainly used for obtaining additional data when not available in existing statistics, databases or monitoring reports. Individual reports have also been for interpretations or additional clarifications on certain developments. For example, various reports are consulted to get more information about the trends of carbon stocks in Dutch soils and the possible implications of lowering carbon stocks.

***Individual consultations***

Various people and organizations have been consulted to ask for data availability. For example, various energy utilities have been consulted to ask about water use in their bioenergy processing unit. As second example: Departments at Wageningen and Twente University have been consulted on water use of energy crops and processing facilities.

# 8 References


- B. de Sturler (2012), personal communication in April 2012 on interpretation and use of GIS data as provided by the National Service (Dienst Regelingen) from the Ministry of Economics, Agriculture and Innovation
- GBEP (2011), The Global Bioenergy Partnership Sustainability Indicators for Bioenergy, First edition, December 2011
- SQ Consult (2012), Using GBEP indicators in the Netherlands, Practicality of the indicators


Literature resources used for the individual indicators are shown in table 26.

**Table 26: Literature resources used for the selected indicators of this study**

| Name indicator | Key references used |
|---|---|
| Basic data collection: Flowchart bioenergy sector | • Profundo (2011), Mapping the Dutch biofuels sector - an overview of the biofuel sector in the Netherlands, March 2011<br>• CBS (2011), databases of the Bureau of Statistics, viewed in December 2011<br>• NL Agency (2011), received database from GAVE catalogue on biofuel producers, December 2011, personal communication with Bregje van Keulen<br>• NEA (2011), Nea, Rapportage duurzaamheid biobrandstoffen 2010, Nederlandse Emissie Autoriteit<br>• Concawe, Eucar, JRC, "Well-to-Wheels analysis of future automotive fuels and powertrains in the European context. WELL-TO-TANK Report Version 2c",<br>• ECN (2010), Socio-economic indicators of renewable energy in 2010<br>• NL Agency (2010), afvalverwerking Nederland, gegevens voor 2010<br>• IEA Bioenergy Task 32 (2009), Deliverable 4 Technical status of biomass co-firing, August 2009, KEMA (Edited by M.F.G. Cremers)<br>• Dutch progress report (2012), Voortgangsrapportage energie uit Hernieuwbare bronnen in Nederland, 2009-2010, Richtlijn 2009/28/EG<br>• IEA Bioenergy Task 40 (2010), Country report the Netherlands<br>• National Service (2012), Geometric planes of the agricultural parcels with the date of 15-5-2010, provided by the 'Dienst Regelingen" from the Ministry of Economics, Agriculture and Innovation in April 2012 |
| Indicator 1: Lifecycle GHG emissions | • CBS Statline http://statline.cbs.nl/statweb/<br>• AgentschapNL $CO_2$ tool<br>• AgentschapNL (2010) Renewable Energy Protocol Monitoring 2010<br>• EU-RED (2009), European Directive 2009/28/EC<br>• S. te Buck , personal communication on CO2 emissions caclulations from biofuels<br>• NL Agency (S. te Buck, personal communication).<br>• NEA 2011 Rapportage duurzaamheid biobrandstoffen 2010 |
| Indicator 2: Soil carbon | • Romkens et al (2004), Quick Scan Soils in The Netherlands, Overview of the soil status with reference to the forthcoming EU Soil Strategy<br>• Kuijkman et al (2003), Stocks of C in soils and emissions of CO2 from agricultural soils in the Netherlands, Alterra report;<br>• W.J. Chardon H. Heesmans P.J. Kuikman (2009), Trends in carbon stocks in Dutch soils: datasets and modeling results, Alterra-rapport 1869, ISSN |

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| | 1566-7197;<br>• Hanegraaf et al (2007), Effecten van biomassaketens op landgebruik en bodemkwaliteit in Nederland Ontwikkeling en toepassing van een toetsingskader, University Wageningen<br>• Smit and Kuikman (2005), Organische Stof, onbekend of onbemind?,Alterra Rapport 1126;<br>• CBS Statline http://statline.cbs.nl/statweb/<br>• Alterra, Soil organic carbon map (2010), published in: Kuikman, P.J., W.J.M. de Groot, R.F.A. Hendriks, J. Verhagen and F. de Vries, 2003. Stocks of C in soils and emissions of CO2 from agricultural soils in the Netherlands. Wageningen, Alterra-report 561.<br>• Robert J. A. Jones, Roland Hiederer, Ezio Rusco Peter J. Loveland and Luca Montanarella (2003), the map of organic carbon in topsoils in Europe, version 1.2 (2003), September 2003;<br>• Additional references available in Excel sheet |
| Indicator 3: Harvest Levels of wood resources | • Probos (2011), Kerngegevens Bos en Hout in Nederland;<br>• Dutch progress report (2012), Voortgangsrapportage energie uit Hernieuwbare bronnen in Nederland, 2009-2010, Richtlijn 2009/28/EG |
| Indicator 4: Emissions of non-GHG air pollutants, including air toxics | • CBS Statline http://statline.cbs.nl/statweb/<br>• The GREET model (2011), http://greet.es.anl.gov/greet_1_series<br>• EMEP/EEA (2009), EMEP/EEA emission inventory guidebook 2009<br>• IEA Bioenergy Task 40 (2010), Country report the Netherlands<br>• CBS (2011), Hernieuwbare energie in Nederland 2010<br>• WUR (2007), Saldi van energiegewassen<br>• LEI (2010), Dutch energy crops<br>• Biograce (2011), BioGrace biofuel GHG calculation tool v4b<br>• CO2 tool (2011), http://www.agentschapnl.nl/content/co2-tool |
| Indicator 5: Water use and efficiency | • Winrock (2009), The Role of Water in the Sustainable Supply of Biofuels;<br>• Gerbens-Leenes, Hoekstra and van der Meer (2008), Water footprint of bio-energy and other primary energy carriers, UNESCO-IHE;<br>• Berndes (2002), Bioenergy and water, the implications of large-scale bioenergy production for water use and supply, Global Environmental Change<br>• Stroomgebied Beheersplannen 2009-2015, available at the Helpdesk Water from the Ministry of Verkeer en Waterstaat<br>• FAO, Aquastat, Factsheets 2008, http://www.fao.org/nr/water/aquastat/main/index.stm<br>• Hoekstra et al (2009), the external water footprint of the Netherlands: Geographically-explicit quantification and impact assessment, in Journal of Ecological Economics<br>• Compedium PBL (2012), http://www.compendiumvoordeleefomgeving.nl/indicatoren/nl0057-Waterwinning-en-waterverbruik-in-Nederland.html?i=3-126<br>• Administrative boundaries of the watersheds in the Netherlands, available in shape files at the http://krwportaal.nl/portaal/?q=node/26972<br>• Bestaande Bio-energieinstallaties, www.b-i-o.nl |
| Indicator 6: Water quality | • Manure Policy Ministry of Agriculture, Based on manure policy: https://www.hetlnvloket.nl/onderwerpen/mest/dossiers/dossier/gebruiksruimte-en-gebruiksnormen/gebruiksnormen<br>• Van der Hilst et al (2012), Nitrogen and P use Miscanthus, annex from Spatial variation of environmental impacts of regional biomass chains, Journal Renewable and Sustainable Energy Reviews; |

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# 9 Annex 1: Maps

Map: Four watersheds in the Netherlands (source: KRW Portaal, 2012)