Netherlands Enterprise Agency

PROTOCOL FOR MONITORING OF MATERIAL STREAMS IN THE BIOBASED ECONOMY

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Foreword

The biobased economy is only at its nascent stage. It is both necessary and challenging to analyse the development in this particular phase. This is only possible if definitions, starting points, and the method of monitoring are properly defined. You are looking at the first protocol for monitoring of material streams in the biobased economy. This protocol builds on the many monitoring activities that have taken place during recent years. This protocol takes a step in the development of an unequivocal tracking method for this new sector.

The protocol is a policy paper, which provides in the need to standardise the monitoring of the developments in these sectors. In this initial version, the elaboration is still limited to an initial restricted mass balance. The choice was made to start with a small manageable volume, which can subsequently be elaborated in stages. A more detailed explanation is available in Chapter 1.

The protocol was compiled by WUR-FBR, by order of and in cooperation with Netherlands Enterprise Agency and the Ministry of Economic Affairs. Knowledge parties and market parties were involved in the compilation of the protocol, to achieve the best possible structure. The results of their involvement were incorporated in this protocol to the greatest extent possible. The protocol thus corresponds to the actual market situation and the opportunities for data collection, as observed by market parties.

Work is also being carried out at a European level for the monitoring of the biobased economy. From the Netherlands' side, the Ministry of Economic Affairs and Netherland Enterprise Agency are involved in the Bioeconomy Observatory project carried out by the European Commission's Joint Research Centre. Monitoring is an important topic in this regard.

This protocol contributes insight into the developments. The monitoring of raw materials can be further refined and expanded in the future, which will also increase our insight.

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1 Introduction

1.1 Motivation

The Dutch government refers in its coalition agreement to the biobased economy (BBE) as one of the pillars of 'sustainable growth and development', where a choice is made for a realistic and ambitious renewable growth strategy. The EU also has ambitious objectives for the BBE. The use of biomass, renewable raw materials and the reutilisation of scarce materials correspond to the objectives for the circular economy. Incentive policy measures are implemented in various ways, such as the blending obligation or certification and the SDE: Renewable Energy Production Incentive Scheme (*Stimulering Duurzame Energieproductie*, Netherlands Enterprise Agency). The use of biomass is thus on the rise for heat and energy generation and for production of biofuels. Comparable incentive measures still lack for other sectors in the BBE, such as the chemical industry.

The transition from an economy based on fossil raw materials, to the biobased economy (BBE) and circular economy, requires a structural approach to innovation and consistent policy aimed at the efficient use of biomass and residual streams. To determine the effects of government policy in this field and in order to direct policy, it is necessary to be able to track the development of the BBE and to be able to compare this to international trends. This requires a proper and unequivocal method of data collection and definition of terms.

From this perspective, a monitor is needed with which the use of renewable biobased raw materials in the Dutch economy can be observed. It is important, for reliable monitoring of the BBE, that unequivocal definitions and units are used and that the system boundaries are established unequivocally in a protocol. Transparent information on available and usable sources is important in order to obtain a clear picture of the BBE over time. This calls for analysis of the goals, the data required, and available basic data in order to achieve a monitoring methodology. This protocol for monitoring will bear a strong resemblance to the Renewable Energy Monitoring Protocol started around 1995.

1.2 Goal of the Monitor Biobased Economy

The goal of the Monitor BBE is to quantify the volume of the biobased economy in the Netherlands and to follow the development thereof over time. The underlying goal is to make trends visible and to allow for comparison thereof with developments abroad.

The Monitor BBE must answer these two questions:

1. How large are the streams that move in the BBE?
2. How do these streams develop over time?

The volume of the raw material streams does not necessarily have to be related to the value that is created. A large quantity of biomass can result in a minor added value, and the reverse is also possible. This monitoring focuses exclusively on the volumes.

1.3 The goal of the Protocol Monitoring Biobased Economy

The goal of the Protocol Monitoring BBE is to achieve an unequivocal methodology for establishing the volume of the BBE. The protocol establishes the system boundaries and the unit in which the volume / quantity is expressed. The protocol describes the manner in which available data is used and also how missing data can be obtained.

1.4 Conditions

The Monitor BBE must provide insight into which activities - that contribute to the transition from the fossil-based economy to the BBE - are developing. The monitor must provide representative and unequivocal information. The monitor must connect to existing statistical data on - preferably recent - production and consumption data, which can be obtained on a periodic basis (annually or bi-annually). The monitor should be complete and without double-counting. The Monitor BBE must result in the least amount of extra administrative burdens possible. The Monitor BBE must be able to quantify the current and new developments over the long-term and must connect to the definitions that are used for formulating Dutch and EU policy.

Basic conditions for the Monitor BBE are:

1. Provides a periodic (annual or bi-annual) overview of the volume of the BBE
2. Unequivocal unit of measurement
3. Unequivocal system boundaries
4. Unequivocal selection of measurement point in the chain
5. Completeness
6. No double-counting
7. Corresponds with international developments and provides the possibility to draw comparisons with neighbouring countries
8. Can be used to calculate the EU BBE, using the data for individual member states

1.5 Questions that could be answered by the Monitor Biobased Economy

There are various questions which could be posed to a Monitor BBE:

1. What volume of biobased raw materials does the Dutch industry use?
2. What volume of biobased products does the Dutch consumer use?
3. What is the BBE's contribution in reducing fossil CO_2 emissions in the Netherlands?
4. How much renewable carbon is captured in the Netherlands in products (not food or feed)?
5. To what extent are fossil raw materials replaced through the application of renewable raw materials?
6. What is the magnitude of the Dutch contribution to the EU biobased economy?
7. What is the Dutch biobased economy's contribution to: the Gross National Product (GNP), added value, job opportunities?

1.6 Demarcation

For the time being, the monitor will focus on establishing the application of biobased raw materials in the economy. This means that question 1 (paragraph 1.5) is the only question that can actually be answered. Appendix 1 explains why the other questions cannot be answered. For some sectors, question 2, 3 and 5 can also be answered. Question 6 can be answered if the imports and exports within Europe are excluded from the calculation (refer to paragraph 4.5.2). Monitoring the economic scope of the biobased economy is of significant importance for policy evaluation. The inclusion of economic parameters was not part of WUR-FBR's assignment from the Ministry of Economic Affairs and AGNL. The questions formulated with question 7 will therefore not be answered in this report. AGNL asked CE Delft to formulate an economic monitor for the Dutch BBE.

Nitrogen and phosphate also play an important part in the biobased economy, in addition to carbon. This protocol will only develop a monitor for dry matter. The developed system (definitions, system boundaries and units) can be used to a significant extent at a later stage for the development of a carbon (C), nitrogen (N), or phosphate (P) monitor.

1.7 Structure of this report

Chapter 1 describes the motivation, goal, conditions, and demarcation of the study. Chapter 2 provides an overview of the raw materials, products, chains, and sectors in the biobased economy, as well as their interdependence. Chapter 3 provides a more detailed look at the production of lactic acid, a typical and relatively large-scale example of the recent developments in the biobased economy. Chapter 4 establishes the system boundaries and measurement points. Chapter 5 provides the definitions for a few important terms. Chapter 6 establishes the measurement parameters and units. Chapter 7 explains how the volume of the biobased economy can be calculated from existing data and how missing data can be inferred, per sector. Chapter 8 demonstrates how the procedures from Chapter 6 lead to figures relating to the volume of the biobased economy. Chapter 9 provides an overview of the results that were obtained: two tables provide the available numbers for application of biomass in the biobased economy and for consumption of products from the biobased economy. Chapter 10 provides a summary of the most important conclusions.

2 Biobased Economy (BBE)

For an unequivocal monitor, it is essential that a clear picture is obtained regarding what is understood under the term biobased economy. This chapter describes the biobased economy in terms of embedding, chains, raw materials, products, and sectors.

2.1 Embedding the biobased economy in the bioeconomy

Figure 1shows how the BBE is embedded in the overall bioeconomy. The BBE is part of the bioeconomy, but with exclusion of the food and feed sector. The production of biofuels and the generation of heat and electricity (Bioenergy) are part of the BBE.

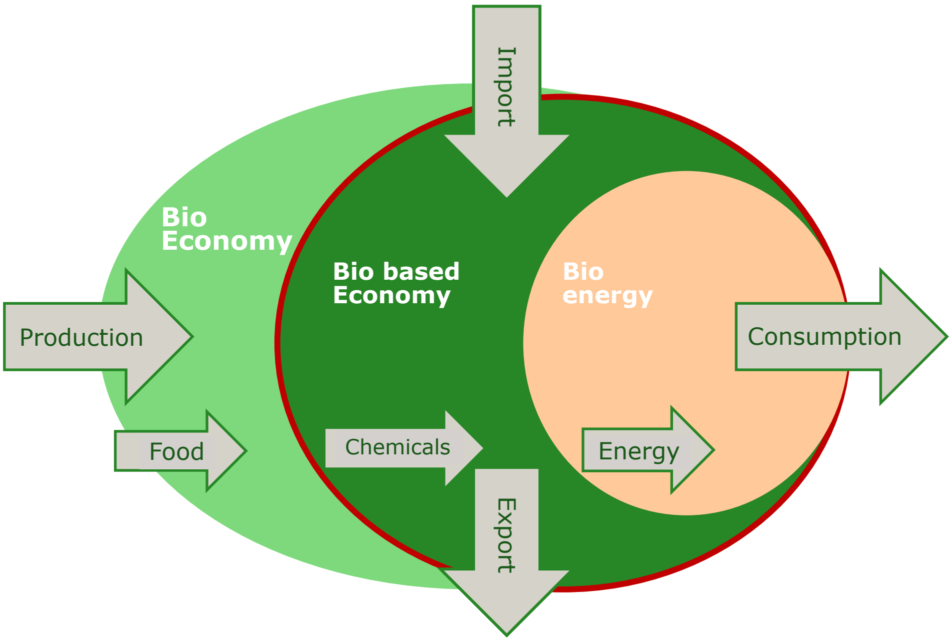

Figure 1. The biobased economy embedded in the overall bioeconomy (K. Kwant, AgNL)

The BBE includes the production and processing chains for renewable vegetal and animal raw materials used outside the food and feed sector for the production of materials, chemicals, additives, fuels, and energy. This generally involves production chains in which raw materials are converted to intermediary products in multiple steps. These intermediary products are subsequently converted to products. Figure 2 shows some possible raw materials, intermediary products, and products in an illustration similar to Figure 1.

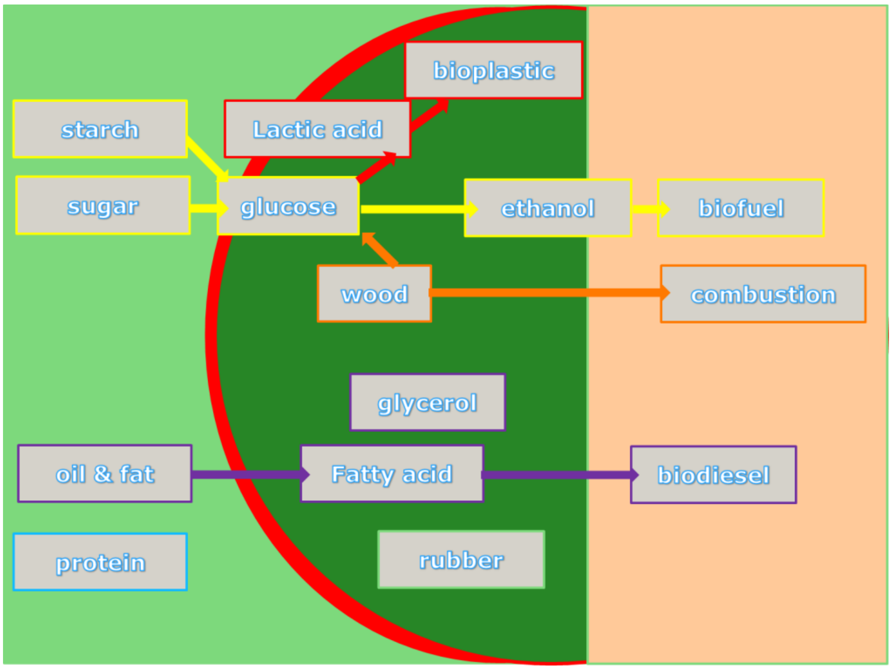

Figure 2. Raw materials, intermediary products and products in the BBE

This figure shows the raw materials for the biobased economy, produced by the agricultural industry, on the left. The products from the biobased economy are shown to the right of the red line. To the far right in the figure are the products from the biobased economy that are used for the production of bioenergy. The figure shows two important chains of the biobased economy: the chain based on carbohydrates and the chain based on oils and fats. A third important chain, based on wood, has only been shown to a partial extent in this figure. Besides carbohydrates, oils, fats, and wood, there are still many other raw materials for the biobased economy: flax, wool, cotton, leather, down. These raw materials are only produced and processed in the Netherlands to a very limited extent,and were therefore excluded from this study.
Some products can be used for the production of materials and chemicals, and also for the production of bioenergy. These products are at the boundary between the biobased economy and bioenergy (such as ethanol in this figure). Ethanol can also be used in food-related applications, and should therefore actually traverse the red line as well.

2.2 Raw materials for the biobased economy

The raw materials for the biobased economy are extremely varied in terms of quality and origin. They can be classified on the basis of composition (comparable to the FAO commodities and trade system). Distinction is made between the following raw material categories:

1. carbohydrate-rich commodities (starch and sugar)
2. oil crops
3. lignocellulose raw materials
4. protein crops

5. other crops (natural rubber, amongst others)

The derived non-food biobased products which are imported as intermediary products (paper pulp) or as platform chemicals (ethanol, lactic acid) for the production of goods with added value (biopolymers, for example, such as biopolyethylene or polylactide) are also raw materials for the BBE.

2.3 Important production chains in the biobased economy

A typical production chain (Figure 3) for biobased products starts with cultivation of the crop (wheat, soybeans, trees). The crop is then harvested from the land and converted to a primary commodity (grain, oilseeds, logs) with a few processes that are often simple. These commodities are then transported and refined to intermediary commodities (flour, sugar, paper pulp). These intermediary commodities can then be used for the production of consumer products (biofuels, bioplastics, and paper, for instance).

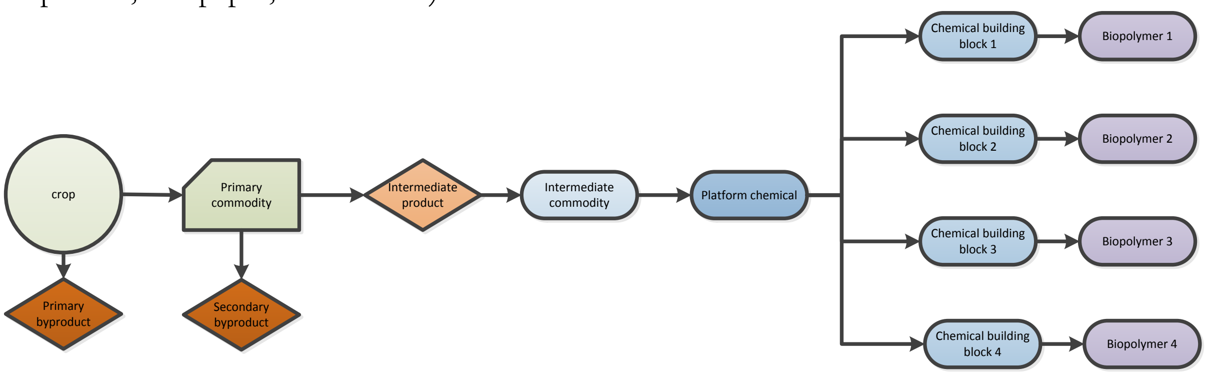

Figure 3. Typical production chain in the BBE (from cultivation to product)

A few important chains are shown in more detail below, based on the raw material categories mentioned in paragraph 2.2.

2.3.1 Chains based on carbohydrate-rich raw materials

The crops are harvested after cultivation and processed to sugar and starch in the agricultural industry (Figure 4, Figure 5 and Figure 6). Grains, potatoes, and sugar beets are the most important carbohydrate-rich crops in the Netherlands. A significant amount of carbohydrates are also imported from abroad (tapioca, sorghum, wheat, wheat flour, cane sugar). The products from the agro industry form the starting materials for the BBE, but also for the food and feed industry. Therefore, the agro industry is not allocated to the BBE.

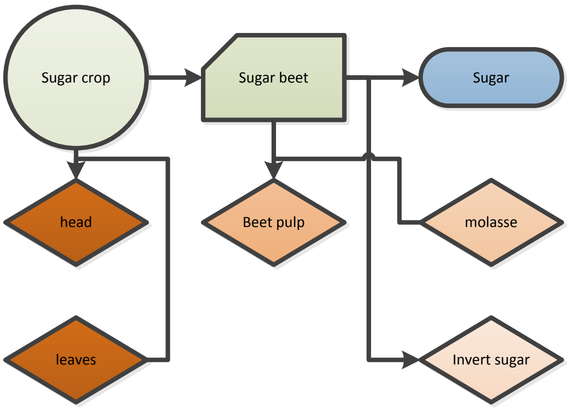

Figure 4. Production of sugar on the basis of sugar beet

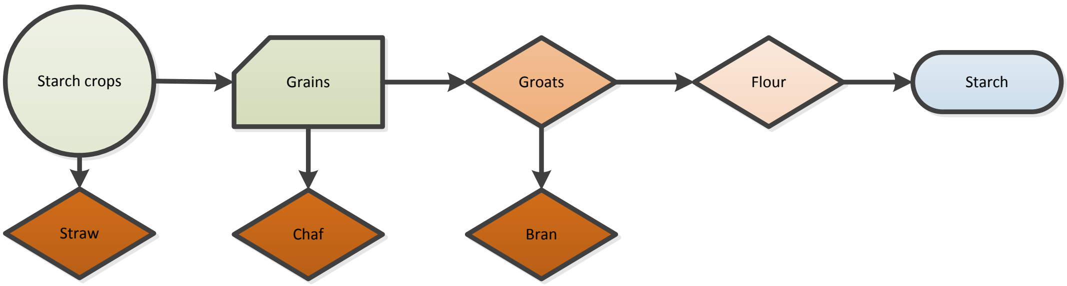

Figure 5. Production of starch on the basis of grains

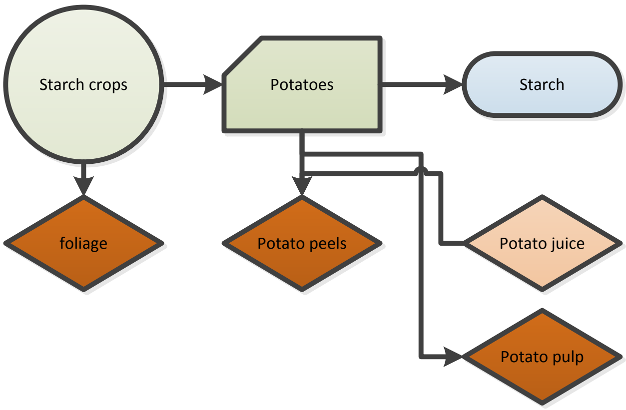

Figure 6. Production of starch on the basis of potatoes

Starch can be used in its direct form or it can be modified (Figure 7). Glucose, which can serve as a raw material for the products in Figure 8, can be obtained through hydrolysis.

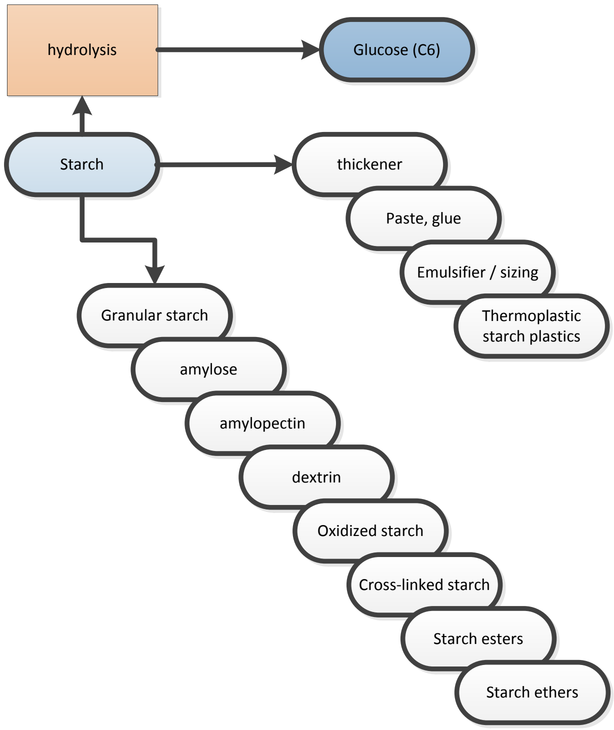

Figure 7. Applications and derivatives on the basis of starch

Sugars can be (bio)chemically converted to a multitude of products (Figure 8).

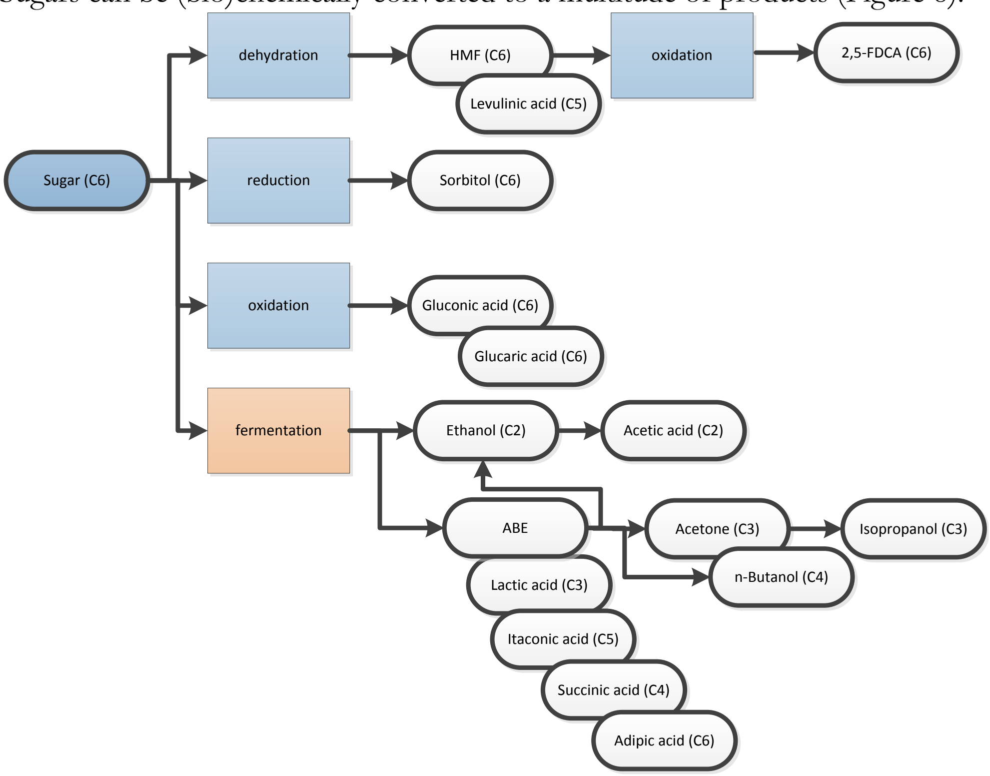

Figure 8. Products on the basis of sugar

2.3.2 *Chains on the basis of oil crops*

Figure 9 shows the entire chain for oil crops, from cultivation to products. Rapeseed is cultivated in the Netherlands on a small scale. A much larger part of the oil is imported in the form of oil seeds (soybeans), pure vegetal oil (palm oil) or derivatised oils (biodiesel, epoxidised soybean oil). The first part of this chain is part of the agricultural industry and is therefore not part of the biobased economy.

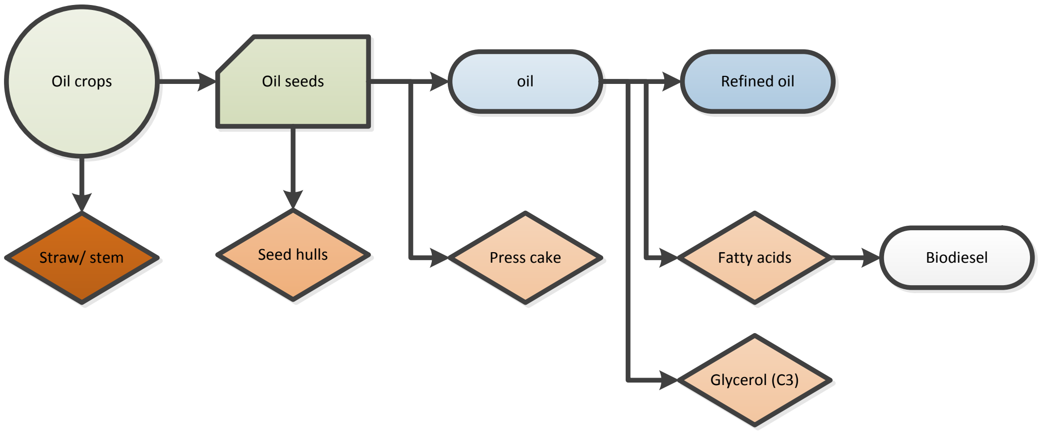

Figure 9. Chains on the basis of oil crops

2.3.3 *Chains on the basis of wood*

Since wood is not used for food or feed, the entire wood chain can be included in the biobased economy. Boards, panels, paper, and cardboard, as well as other materials, are produced from wood (refer to Figure 10 and Figure 11). Wood is cultivated to a very limited extent in the Netherlands. A significant portion of wood products are imported (trunks, boards, panels, wood pulp, wood pellets).

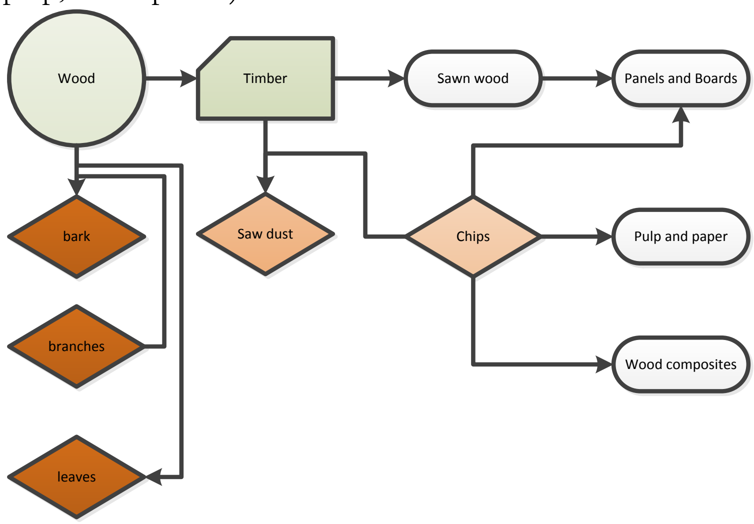

Figure 10. Products on the basis of wood

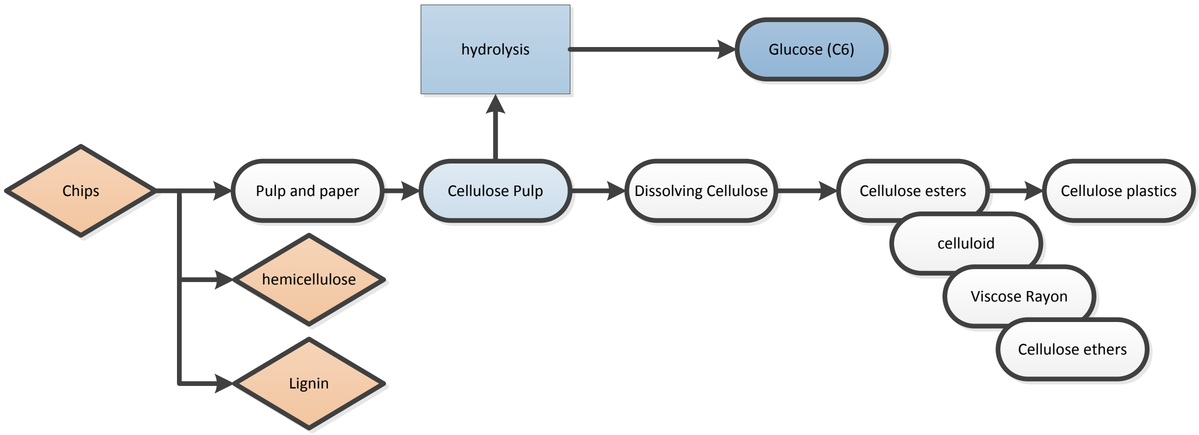

Figure 11. Further refinement of wood chips

Residual streams from the wood industry (branches, saw dust) are used to a significant extent for the production of renewable energy.

2.4 System description for the biobased economy

Figure 12 provides an overview of the mass streams through the BBE and the most important sectors therein. The primary production in the Netherlands through cultivation and harvesting is shown on the left. The figure shows import at the top and export at the bottom. Some import streams are exported immediately (in an unchanged state), known as transit or re-export. These streams must not be included in the monitor, since they do not account for added value (except in the logistics sector). Consumption of renewable heat and electricity, biofuels and biobased materials, and chemicals are shown on the right. The producers of biobased products are shown in the figure: the electricity and heat sector, the timber industry, the paper and cardboard industry (P&C Ind.), the chemical industry, and the plastic and rubber processing industry (P&R Ind.). The biofuel sector is part of the chemical industry. The recycle sector makes waste streams that are released after consumption of materials and chemicals, suitable for reuse. The agricultural industry is not part of the biobased economy, but is an important supplier of raw materials to the biobased economy.

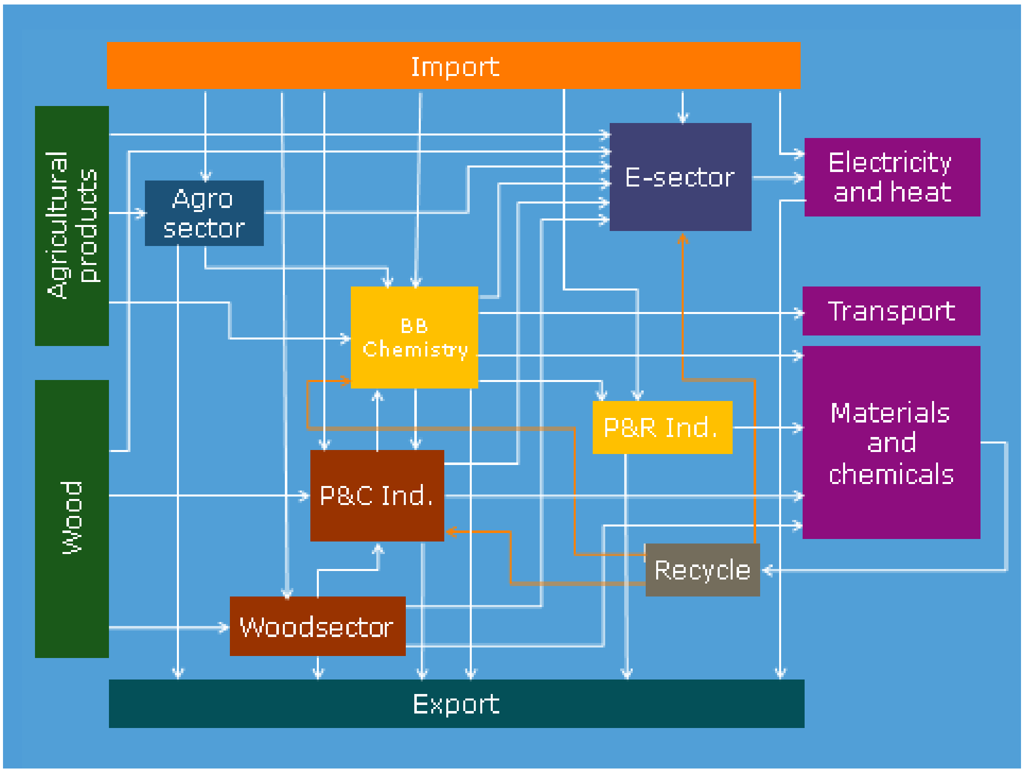

Figure 12. Connections between a number of important sectors of the biobased economy

2.5 Sectors of the biobased economy

Different sectors can be distinguished within the biobased economy (Figure 12). The sectors can be divided into 4 types:

1. sectors in which biobased products are consumed (electricity and heat sector, transport sector, consumption of materials and chemicals)
2. sectors in which biobased products are produced (timber industry, paper and cardboard industry, chemical industry, plastic and rubber processing industry)
3. the recycle sector, in which materials are collected and made suitable for reuse
4. the agricultural industry provides raw materials for the biobased economy, but does not form part of the biobased economy

2.5.1 Consumption

Products from the biobased economy are consumed in the consumption sectors.

2.5.1.1 Electricity and heat

The electricity and heat sector produces heat and electricity for households and industry. A distinction is made between the production of electricity, the production of combined heat and power, and the production of heat. The raw materials that are used are: wood, wood chips, wood pellets, saw dust, biogas, landfill gas, biogenic waste.

2.5.1.2 Transport

Biofuels are used in the transport sector to power cars, lorries, and buses. The transport sector includes private, public, and business transport. The biofuels are blended (bioethanol, bioMTBE, and biodiesel) or used in pure form (biodiesel, bioLNG, bioCNG).

2.5.1.3 Materials and chemicals

In addition to energy and fuels, the biobased economy also produces materials and chemicals. These are usually bioplastics and lubricants. Materials and chemicals will usually undergo further processing in the industry to become consumer products (such as light modules for cars). These materials and chemicals are not used up during consumption, but are actually released in the form of waste. In the Netherlands, this waste is mostly reused (recycled).

2.5.2 Production sectors

The production sectors manufacture products from biobased raw materials.

2.5.2.1 Timber industry

The timber industry processes wood from trees into wood products (beams, boards, sheets, window frames, doors, furniture). This takes place in roughly 3 steps: 1. Harvest, 2. Primary processing (sawing), 3. Secondary processing (sawing, milling, gluing, etc.). The typical products from step 1 to 3 are: 1. Roundwood, 2. Beams / boards, 3. Window frames, furniture, etc. by-products from the timber industry (saw dust, wood shavings) are used as litter, for the production of energy (refer to paragraph 2.5.1.1.), and for the production of board material.

2.5.2.2 Paper and cardboard industry

The paper and cardboard industry processes wood chips and wood pulp, and recycles paper into paper and cardboard products. Old paper is the most important raw material for the paper and cardboard industry. The old paper is supplemented with fresh pulp. The largest part of the fresh pulp is imported; only a small portion is obtained through pulping of Dutch wood or cotton linters.

2.5.2.3 Chemical industry

A relatively restricted number of chemical intermediary products are produced (the so-called platform chemicals) on the basis of carbohydrates (sugar, starch), oils and fats, protein and lignin: ethanol, ethylene, lactide, succinic acid, acetic acid, epoxidised fatty acids. These intermediary products form the basis for the production of a great deal of products (fibres, bioplastics, foam, thickeners, and surfactants), which in turn are used to form consumer products (rope/string, clothing, mattresses, paints, detergents, flooring).
The chemical industry processes many imported biobased intermediary products: bioethanol, bioethylene, glycerol, acetic acid, lactic acid, methanol, epoxidised soybean oil. A fast-growing group of intermediary products, which is still relatively small in volume, but which can, in the near future, become larger very fast: succinic acid, 1,3-propanediol, etc. Another growing group of intermediary products is partly produced from fossil resources and partly from renewable

resources: MTBE and ETBE. In the future, other raw materials will also play a role: lignin and protein.
The biofuel sector is part of the chemical industry. The chemical industry is therefore the largest producer of biofuels.

2.5.2.4 Plastic and rubber processing industry
A considerable amount of natural rubber is already being used in the rubber processing industry (approximately 30 %). The plastic processing industry is using biobased plastics to an increasing extent.
The rubber and plastic processing industry was not studied in detail during compilation of the protocol. It is recommended that this industry be studied in more detail at a later stage.

2.5.2.5 Textile, clothing, and leather industry
The textile, clothing, and leather industry in the Netherlands currently processes only a very limited amount of crude raw materials. These raw materials were not taken into account in this study. Cotton, linen, wool, silk, and other natural basic raw materials for production of textile are mostly imported as textile or as consumer products. These products are mostly already composite products, and therefore cannot be monitored.
Textile recycling provides secondary raw materials, which can also be considered biobased to a partial extent. Another part is burnt in waste incineration plants. The current calculations by Netherlands Statistics do not take this into consideration.

2.5.3 Recycling
The recycle sector makes waste streams suitable for reuse. This is achieved through the collection and separation of different waste streams at the consumer and in trade and industry. The waste is partly of mineral origin (stones/sand), partly of fossil origin (plastics), and partly biogenic (paper, cotton, bioplastics). Reuse of the biogenic part of the waste can be considered part of the biobased economy. The recycle sector supplies the paper industry (old paper), the electricity and heat sector (scrap wood, RDF), and in the future likely also the chemical industry. Since raw materials are actually used multiple times, it is not a problem to count the reused materials again, as raw material for the biobased economy.

2.5.4 Agricultural industry
The agricultural industry is not part of the biobased economy, but is an important supplier of raw materials for the biobased economy. In the agricultural industry, agricultural products are processed into commodities that are suitable for use in the biobased economy (sugar, starch, vegetal oils, and fats). Many companies from the agricultural industry are expanding their field of activities to include the chemical industry. These companies are therefore part of two sectors. Examples include: AVEBE, Cosun, and Cargill.

2.6 Usability of the Statistics Netherlands monitor for material streams

Statistics Netherlands (CBS) recently developed a monitor for material streams (CBS, 2013[a]). At first sight, this monitor seems very suitable as a basis for the Monitor Biobased Economy. This idea was formulated in Meesters *et al.* 2013. However, 3 problems need to be solved to make the monitor for material streams suitable in terms of a monitor for the BBE:

1. Classification of business sectors
2. Classification of product groups
3. Timely acquisition of data

2.6.1 Classification of business sectors (SBI codes)

Statistics Netherlands classifies companies according to the so-called standard business classification scheme (*Standaard Bedrijfs Indeling*). Each company is linked to one SBI code. The company's main activity is determinative for the allocated SBI code. Some companies have two different SBI codes. To illustrate this: DSM consists of 70 business units, most of which operate in the 'chemical product manufacturing' sector.

Some companies in the agricultural industry already have large-scale chemical processes based on their current raw materials (AVEBE), or are in the process of developing these (Cosun). These are essential developments. The current method will register these developments only at a very late stage, because SBI codes are kept unaltered for as long as possible.

At this point, the SBI codes are not an adequate selection criterion for the Monitor Biobased Economy. This problem could be solved by splitting relevant companies into two or more units with different SBI codes.

2.6.2 Classification of product groups

The Statistics Netherlands statistics use product groups. Unfortunately, there are some product groups that contain both biobased and fossil-based products: such as carbon acids, alcohols, amino acids, and ethers, amongst others. The biobased economy also sometimes manufactures products that are identical to products of fossil origin (polyethylene). These product groups do not differentiate and are therefore not useable as selection criterion for the Monitor Biobased Economy. This problem can be solved by dividing the product groups into a group for biobased and a group for fossil-based, and by marking them accordingly.

2.6.3 Timely data

Statistics Netherlands uses economic data as the basis for the monitor of material streams. This economic information is collected and processed annually. An initial version is released after 1 year and a more or less definite version is released after 2 years. Since the level of detail is higher for some of the groups of products after finalisation of the figures, the work for establishing the monitor for material streams may only start then. The monitor for material streams will be available with a 3 year delay. This means that condition 1 (paragraph 1.4), as set by Netherlands Enterprise Agency and the Ministry of Economic Affairs, cannot be met. Accelerated provision of data will only be possible if the monitor is based on provisional figures. This will reduce accuracy.

2.6.4 Conclusion regarding usability of the Statistics Netherlands monitor for material streams

The data in the monitor for material streams is not adequately useable for the Monitor Biobased Economy at this point in time. Classification of the companies is not sufficiently accurate, the product group classification does not differentiate between biobased products and fossil-based products, and the data is not available in a timely fashion. The monitor for material streams can be made useable with a few changes to the underlying registration of statistical data. The necessary interventions will require considerable effort.

3 Lactic acid case study

The lactic acid production chain was worked out in detail (refer to Figure 13), in order to arrive at a well-considered decision for the location of the measurement point for the monitor. A point must be determined where the agricultural industry ends and the biobased economy starts. Two points are conceivable for this:

1. Monitor at the polymer chemistry point of exit (blue line)
2. Monitor at the polymer chemistry point of entry (purple line)
3. Monitor at the fermentation industry point of entry (red line)

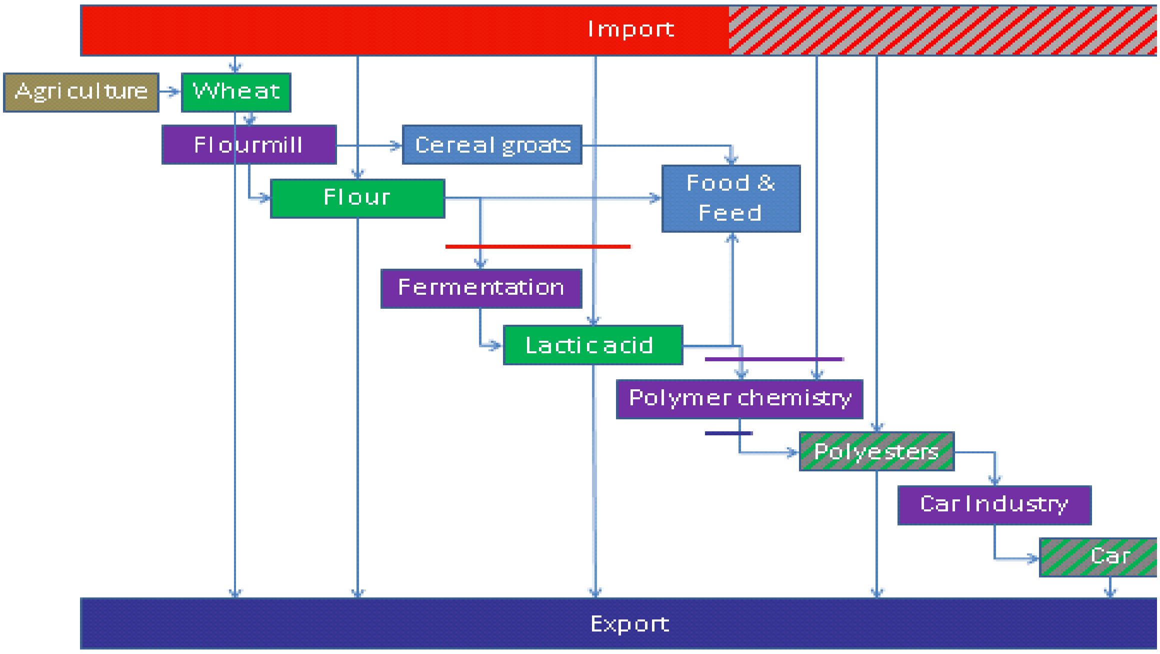

Figure 13, Chain for raw material to end product for PLA; the red line indicates where the monitor should be (raw materials and (intermediary) products from partial fossil sources are indicated with slanted grey shading)

3.1 Monitor at the polymer chemistry point of exit

A monitor at the polymer chemistry point of exit (blue line), where composite products, in particular, are delivered, is difficult to achieve in practice. Polymer chemistry often produces co-polymers based in part on crude oil. Further along the chain, the biobased share in the product is increasingly difficult to measure (PLA door panels, for example, form an incredibly small portion of a car's weight).

3.2 Monitor at the polymer chemistry point of entry

A monitor at the polymer chemistry point of entry causes problems in terms of imported raw materials. A number of raw materials can consist of fossil-based raw materials or renewable raw materials (such as succinic acid and glycol, for example). The statistics from Statistics Netherlands do not discriminate between the origin of materials. The polymer chemistry point of entry therefore involves a very large number of different raw materials.

3.3 Monitor at the fermentation industry point of entry

A very practical location for the monitor is at the fermentation industry point of entry (red line). The number of different raw materials at this point of entry is limited. A similar point is also applicable for comparable chains (ethanol, succinic acid, etc.).
One disadvantage of this location is the fact that lactic acid (but also ethanol, acetic acid, and succinic acid) is used for food and feed. This could be a sufficient reason to measure just beyond the fermentation point (refer to paragraph 3.2). We can also, on the other hand, simply accept that the (bio)chemical industry supplies ingredients for the food/feed industry. In principal, there is nothing wrong with this scenario: after all, the chemical industry based on fossil raw materials also supplies ingredients to the food/feed industry (glycine, DL-methionine, formic acid, acetic acid, methyl-, ethyl- and propyl p-hydroxybenzoate, benzoic acid). The use of fermentation products in food/feed involves relatively small quantities (often as an additive or preservative).

3.4 Conclusion

The best location for the monitor is at the fermentation industry point of entry (red line). In fact, this is also the current measurement point for co-combustion of biomass and for application in transport fuel. A monitor at the point of entry is also considered to be most practical for the timber industry.

4 System boundaries and measurement points

For an unequivocal monitor, it is essential that the system boundaries are properly established. The choice for certain system boundaries is determined by multiple factors:

1. The question that the monitor must be able to answer
2. Connection with existing statistics
3. International agreements
4. Practical feasibility

4.1 The question that the monitor must be able to answer

The monitor must be able to determine how the application of biobased raw materials develops over time (paragraph 1.5, question 1).

4.2 Connection with existing statistics

Various statistics are currently in place, which comprise part of the BBE, such as the registration for the blending obligation and the renewable energy monitor. The system boundaries for this are shown by the red lines in Figure 14.

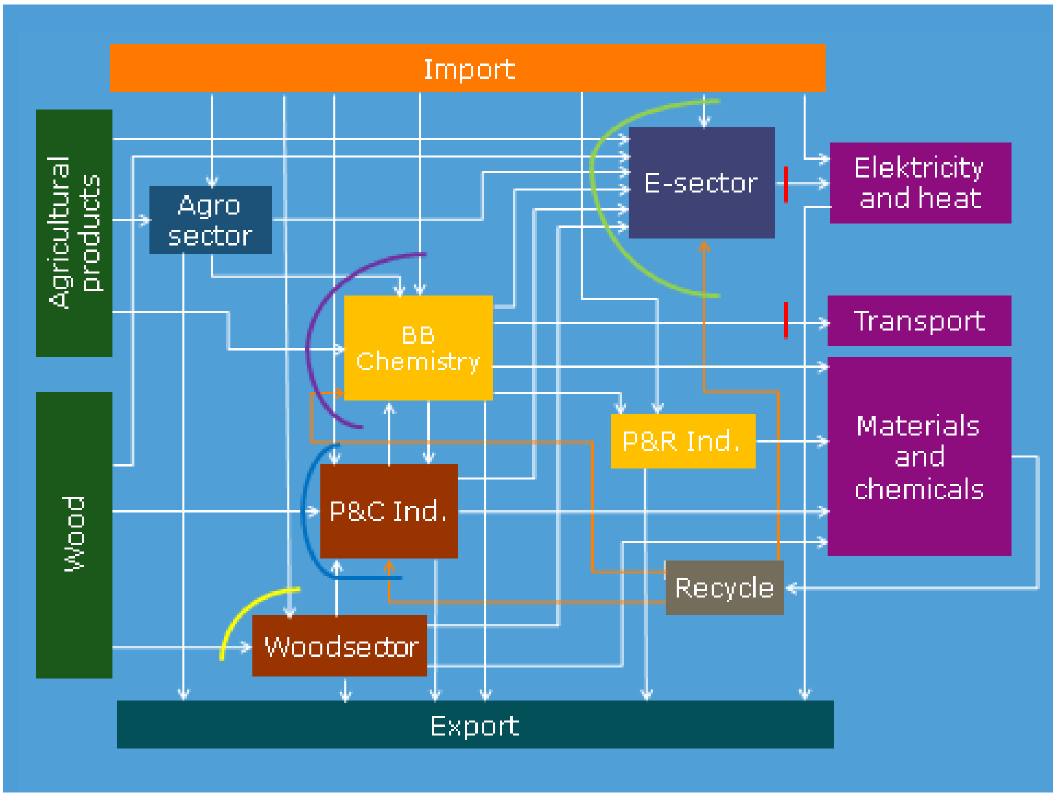

Figure 14, Measurement points for the Monitor Biobased Economy

4.2.1 Blending obligation

The blending obligation keeps track of the volume of biofuel sold in the Netherlands for use in road transport for passengers and goods (=use in the transport sector). As far as biofuels are concerned, the majority of fuel sold in the Netherlands will also be used in the Netherlands. This monitor answers questions 1, 2, 3, and 5 (paragraph 1.5) for the transport sector. If the same method is used in all member states, simply adding the numbers together will equal the total use of biofuel in the EU (question 6, paragraph 1.5).

4.2.2 Renewable energy monitor

The renewable energy monitor reports on the quantity of renewable energy (electricity and heat) produced in the Netherlands. A substantial amount of electricity is imported and exported, and each country has an individual profile in terms of the production of electricity. The consumed electricity therefore has a different profile compared to the produced electricity. The renewable energy monitor provides an answer to questions 1, 3, and 5 (paragraph 1.5) for the electricity and heat sector. The current measurement point does make it possible to calculate the total European production of renewable electricity (and, as long as import and export outside the EU is relatively small, also consumption) by adding together all individual countries (question 6, paragraph 1.5). The quantity of renewable energy is calculated by using the quantity of raw materials entering the power stations. Actually, it thus involves a measurement point at the front of the heat and energy sector (green line in Figure 14), where the measured results are converted to the measurement point used in the report.

4.2.3 Other sectors

A measurement point right before consumption is not feasible for the chemical industry, the timber industry or the paper industry. While only two products are involved in the production of renewable energy (heat and electricity) and no more than 10 different products in biofuels (bioethanol, biodiesel, bio ETBE, bio MTBE, bioCNG, bioLNG, etc.), the chemical, timber and paper industries involve thousands of distinct products and these products are often composites. A considerable portion of these products is exported and sometimes re-imported. This makes it impossible, in terms of the measurement point, to connect to existing statistics. It seems more apparent to do the measurement at the point of entry to the chemical, timber, and paper industries (also refer to Chapter 3). The number of different raw materials is still relatively limited at this point (starch, sugar, vegetal/animal oil and fat, protein, bioethanol, bioethylene, succinic acid, lactic acid, wood, cellulose, lignin, acetic acid, etc.). The monitor will then only answer question 1. For the chemical industry, the measurement point is show with the purple line in Figure 14.

4.3 International agreements

Right now, activities are underway in various locations in which the volume of the biobased economy is investigated (Bio-observatory, Carus *et al.*, (2013), Chun *et al.* (2012), Meesters *et al.* (2013)). Agreements have not yet been made in this regard, nor have protocols been established. The intention is to register this protocol with the bio-observatory as a starting point for further discussions.

At the same time, agreements have been made at a European level with regard to blending (paragraph 4.2.1) and renewable energy (paragraph 4.2.2). This protocol will fit in with these agreements.

4.4 Practical feasibility of measurement point for production sectors

The chemical industry, plastic and rubber processing industry, timber industry, and paper and cardboard industry cannot monitor the outgoing streams due to the multitude of possible products (refer to paragraph 4.2.3). The number of different raw materials is still limited at the point of entry to these industries, and the monitor should therefore measure at these points. This can also be done in two other ways: at the point of exit from the supply companies (the agricultural industry) or at the point of entry to the chemical industry and other sectors within the BBE. It is not a good idea to select both measurement points because it may lead to double-counting and additional administrative burdens.

Point of exit from supply companies

For carbohydrates, the supply balance sheets for sugars, grains, and potatoes show the quantity of carbohydrates applied in the non-food industry (and therefore in the chemical industry). WUR-LEI depends on product boards for the statistics related to these supply balance sheets. Many product boards might cease to exist as their government support was recently stopped. Therefore it is not yet clear whether comparable statistics can be pursued.

Not just the Dutch supply, but also the import of raw materials must be measured. The statistics from Statistics Netherlands (environmental, MFA) report major imports and exports for many products. An important part thereof involves re-export or transit (export of imported goods without changing the goods in any way). Re-export should be filtered out, because it must not be included in the Monitor Biobased Economy. The sectors in which the imported raw materials are actually being applied cannot be derived from the environmental accounts at this time. Additional data is available from Statistics Netherlands, but need to be verified.

Point of entry to the chemical industry and other sectors of the BBE

Each year, MVO publishes usable data on vegetal and animal oils and fats used in the oleochemical industry (MVO, 2013). MVO represents the oleochemical industry and MVO's data is therefore reliable. Such an umbrella organisation does not exist for the use of carbohydrates. The data on carbohydrates is therefore less reliable.

The chemical industry has an interest in a greener image. During the workshop, three representatives of a few large chemical companies indicated their willingness to provide information on the application of biobased raw materials for the manufacture of their products.

Based on the observations formulated above, the point of entry to the BBE seems to be the best point for measurement.

4.5 Preventing double-counting

The Dutch BBE is part of a large international network of activities. The monitor for biobased raw materials must keep track of relevant biobased chains and products and the conversion of biobased resources involved. To determine the volume of the BBE, the choice was made to measure the quantity of raw materials passing through the point of entry to the BBE (refer to the purple line in Figure 14). This prevents streams within the chain from being counted double (like being counted for the first time as vegetal oils being delivered to the chemical industry and then a second time as vegetal oil derived chemicals to the paint industry).

However, the selected system boundaries will lead to double-counting in the following two cases:
1. when adding the numbers together per sector to obtain a global number for the Dutch BBE
2. when adding the numbers together per EU member state to obtain a global number for the EU

This double-counting means that condition 6, as stated in paragraph 1.4, is not complied with. This can be solved in the manner explained in paragraphs 4.5.1 and 4.5.2.

4.5.1 Adding numbers together for NL sectors, to obtain the NL number

The volume of the Dutch biobased economy cannot be quantified by simply adding the different sectors together. After all: the timber industry and the chemical industry supply the energy sector and the transport sector. For the energy sector and the transport sector, the supply from Dutch supplying sectors should be deducted in order to avoid double-counting (the arrows circled in Figure 15).

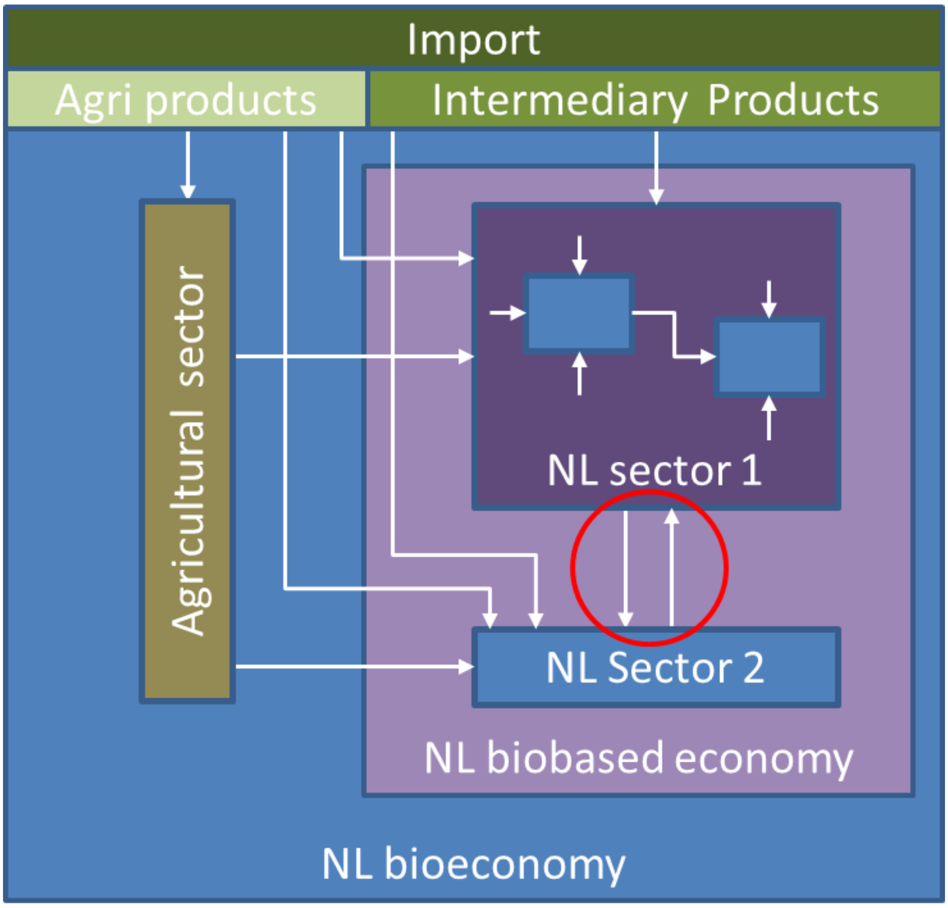

Figure 15, Streams in the NL biobased economy (double-counting shown in the red circle)

4.5.2 Adding numbers together for member states, to obtain the EU number

Double-counting will also take place when adding together the numbers for the BBE for the different member states of the EU, to obtain one number that represents the volume of the BBE in the EU. This double-counting can be prevented by way of separate administrations for imports from outside and within the EU. When adding the numbers together, only the imports from outside the EU should be included, mutual deliveries between EU countries (arrows in the red circle) should not be taken into account (refer to Figure 16).

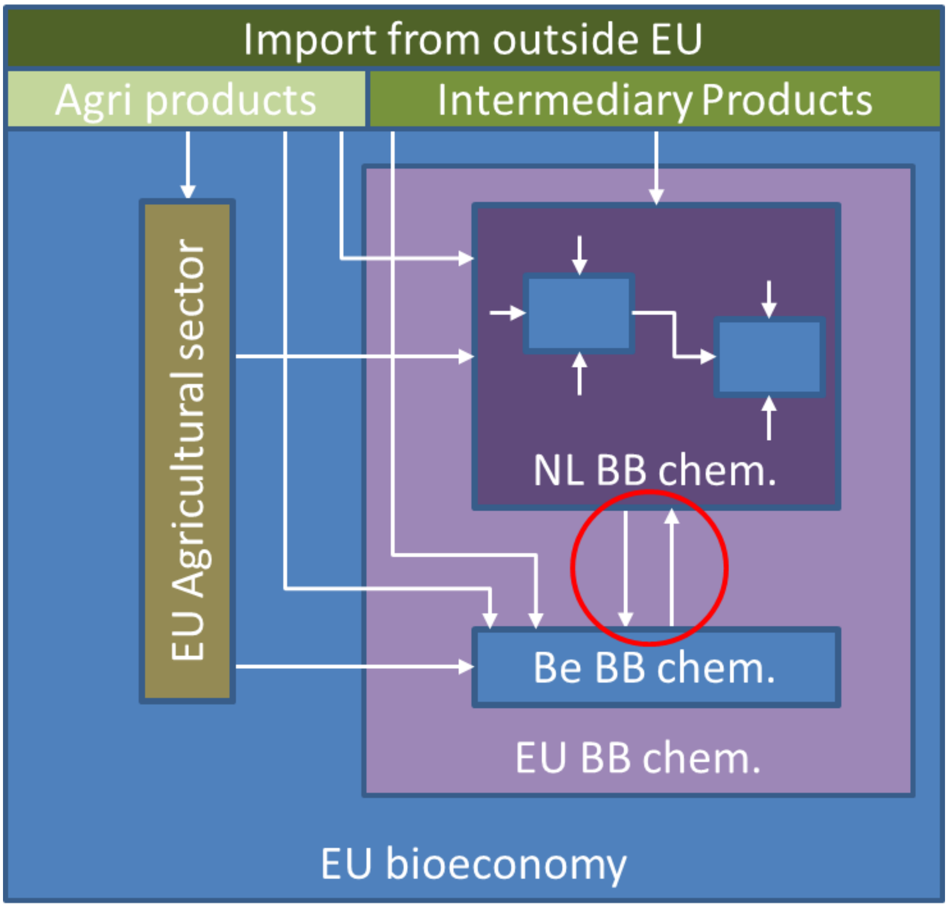

Figure 16, Streams in the EU biobased economy (double-counting shown in the red circle)

4.6 Conclusions

With respect to the transport sector, a connection has been achieved with the data made available through the renewable energy monitor. It is therefore measured by the volume of biofuel that is blended for use in road traffic.

For the electricity and heat sector, a connection has been achieved with the data made available through the renewable energy monitor. The quantity of biobased raw materials that is combusted for the production of electricity and heat is measured.

The consumption of materials and chemicals cannot be tracked, due to the multitude of different products. It does seem feasible, however, to measure the input of biobased raw materials for the production of chemicals and materials. The point of entry to the producing sectors seems to be the best point of measurement.

Double-counting can be neutralised by avoiding the inclusion of internal flows (in the red circles) in the calculation. However, additional administration will be needed for this purpose.

5 Definitions

In order to achieve an adequate 'Protocol for Monitoring of the Biobased Economy', it is important that agreement is reached on the definitions for relevant terms. In this chapter, propositions are made with regard to the definitions to be used. Adaptations of these definitions might be required over time in order to ensure that definitions correspond to policy, statistics or European standards and agreements, to a better extent. The BBE content is not covered through the replacement of fossil raw materials by equivalent products and materials from renewable raw materials.

5.1 Bioeconomy

Economic activity based on vegetal or animal raw materials.

5.2 Biobased economy (BBE)

Economic activity based on biomass, with the exception of human food and feed. The biobased economy is based on recently captured carbon (refer to 5.5).

5.3 Biobased products

Biobased products are all non-food or non-feed products, produced from biomass (CEN/TC/411).

5.4 Biomass

Material of biological origin, with the exception of material included in geological formations and/or fossilised material (pursuant to CEN/TC/411).

5.5 Recently captured carbon / renewable carbon

Carbon which was recently captured from the atmosphere through the growth of plants or phototrophic organisms (algae/cyanobacteria), or through other reactions which capture carbon (carboxylation reactions); as opposed to fossil carbon, which was taken from the atmosphere millions of years ago.

5.6 Renewable raw materials

Renewable raw materials are natural raw materials, obtained through recent cultivation or natural growth. Renewable raw materials are a source of renewable carbon (refer to 5.5).

5.7 Commodities or commercial goods

Commodities are raw materials, products or intermediary products that are traded across the globe. The composition is well known. Commodities can usually be stored for a long time and contain very little moisture. Think of: grain, flour, sugar, soybeans, soybean oil, and wood.

5.8 Composite goods

Composite goods are often consumer products. They often contain fossil, mineral, and renewable components. Provision of the actual composition is therefore cumbersome to ascertain. Think of: cars, clothing, and so forth.

5.9 Monitor Biobased Economy

Objective observation of the application of renewable raw materials in the BBE, at multiple successive points in time. The Monitor Biobased Economy (BBE) measures the input of biomass used for the production of energy, fuel, chemicals and materials (input for food or feed is excluded).

5.10 Sustainable

A working method that does not lead to the depletion of natural resources.

6 Parameters and units

For an adequate monitor it is important that proper parameters and units are established. Many parameters and units are possible, each with its advantages and disadvantages.

6.1 Added value, euro (€)

- Provides a direct insight into the economic valuation of products and streams
- Sensitive to price fluctuations (crop failure, economic situation, political tension)
- Resource efficiency (added value in € per kg of material used) differs per application

6.2 Weight, tonnes of product (1 tonne = 1000 kg)

- Well known
- Clear to all straightaway
- Fresh products will be accentuated over dry products (misrepresentation)
- There is no law of 'conservation of product'. This is due, in particular, to the fact that products may be holding a considerable amount of water. Water may be added or removed (drying) during processing of the product. This makes it difficult to establish conclusive balances.
- No indication of possible added value

6.3 Weight, tonnes of dry matter (dm)

- Often well known
- The absolute law of conservation of dry matter does not apply for conversion processes (for example: starch + water → sugars and sugar → ethanol + CO_2); the differences are much smaller than in the case of 6.2 and are stoichiometric; if the reactions are known, then proper balances can be established
- No indication of possible added value
- Can easily be converted to energy or carbon (C)

6.4 Weight, tonnes of C

- Can be estimated on the basis of the composition and dry matter content
- Not clear to all right off the bat
- The law of conservation of C will apply (when nuclear reactions are ignored); sometimes CO_2 is incorporated or expelled but this can be taken into account as the reactions are well known
- No indication of possible added value

6.5 Energy, GJ/tonne

- Can be estimated on the basis of the composition and dry matter content
- Less relevant for applications other than those involving generation of energy and heat

6.6 Discussion

The added value of the biobased economy is an extremely relevant economic parameter. However, major problems will arise when measuring the added value of the biobased economy. The greatest added value is formed at the end of the chain, where fossil, mineral, and renewable components are composed to form a consumer product. Allocation of the added value to the individual components will therefore always be debatable. Many processes used at the end of the chain (like injection moulding, for instance) are often identical for fossil and renewable raw materials. Allocating added value for these processes is therefore problematic.

6.7 Conclusion

The most practical parameter for the monitor is therefore the weight of the applied biobased raw materials measured in tonnes of dry matter. It was pointed out during the workshop that this involves the application of renewable carbon. Since the carbon content of raw materials is mostly known, the application of renewable carbon can also be calculated easily on the basis of these numbers. In a parallel research project, CE Delft will attempt to express the contribution of the biobased economy in monetary units and derivatives thereof (turnover, added value, job opportunities).

7 Calculation method for computing the volume of the biobased economy per sector

7.1 Energy sector

Statistics Netherlands reports the renewable energy produced in the Netherlands, on the basis of data from the Dutch Emissions Authority (*Nederlandse Emissie Autoriteit, NEA*) and CertiQ, amongst other sources.

7.1.1 Municipal solid waste incinerators (MSWI)

Statistics Netherlands reports yearly on the amount of energy obtained through combustion of biogenic waste in MSWI (CBS, 2013[b]). The Renewable Energy Protocol Monitoring update 2010 (AGNL, 2010) is used for this report. The quantity of renewable energy is estimated by determining a number of sorting fractions per waste category (refer to table B3.4, AGNL, 2010). For each sorting fraction, the biogenic calorific value is determined by multiplying the fraction's LHV (lower heating value) by the fraction of biogenic material in the respective sorting fraction (table B3.5, AGNL, 2010). The energy content for the waste category is then determined by multiplying the mass fraction of each sorting fraction by the respective biogenic calorific value. The total energy content is calculated by adding together the masses of the various waste categories, multiplied by the biogenic energy content for each waste category:

$$Q_{wasteBBE} = \Sigma\ \Phi_i \text{ x } \Sigma\ f_{i,j} \text{ x } f_{B\_i.j} \text{ x } LHV_{i,j}$$

Where:

i	= 1 to number of waste categories
j	= 1 to number of fractions
$Q_{wasteBBE}$	= energy content of waste (kton)
Φ_i	= quantity of waste from waste category i (kton)
$f_{i,j}$	= size of sorting fraction j of category i (-)
$f_{B\_i,j}$	= biogenic fraction of sorting fraction j of waste category i (-)
$LHV_{i,j}$	= calorific value of sorting fraction j of waste category i (GJ/tonne)

The same methodology can largely be followed for the Monitor BBE. The biogenic dry matter content is determined for each waste category, by multiplying each sorting fraction by the dry matter content of the fraction (= 1- moisture content, table B3.3, AGNL, 2010) and by the biogenic material fraction in the relevant fraction (table B3.5, AGNL, 2010). The total dry matter is calculated by adding together the mass of the different waste categories, multiplied by the biogenic dry matter of each waste category:

$$\Phi_{wasteBBE} = \Sigma\ \Phi_i \text{ x } \Sigma\ f_{i,j} \text{ x } f_{B\_i.j} \text{ x } f_{DM\_i,j}$$

Where:

i = 1 to number of waste categories
j = 1 to number of fractions
$\Phi_{wasteBBE}$ = waste contribution to BBE (kton)
Φ_i = quantity of waste from waste category i (kton)
$f_{i,j}$ = size of sorting fraction j of category i (-)
$f_{B\_i,j}$ = biogenic fraction of sorting fraction j of waste category i (-)
$f_{DM\_i,j}$ = dry matter content of sorting fraction j of waste category i (-) (= 1 - moisture content)

7.1.2 *Biomass co-combustion in power stations*

The Statistics Netherlands report on renewable energy in the Netherlands (*Hernieuwbare energie in Nederland 2012*) (CBS, 2013[b]) conveys the volume of the renewable raw material streams for production of electricity and heat. The reported data is obtained by multiplying the input of biomass per power station by the energy content of the biomass. Likewise, the reported input of biomass can be multiplied by the relevant dry matter content:

$$\Phi_{co\text{-}combustionBBE} = \Sigma\Phi_i \times f_{DM\_i}$$

Where:

i = 1 to number of plants
$\Phi_{co\text{-}combustionBBE}$ = contribution from co-firing plants to BBE (kton)
Φ_i = biomass input in plant i (kton)
f_{DM_i} = dry matter content of biomass burnt in plant i (-)

7.1.3 *Wood-burning stoves at companies*

The Statistics Netherlands report on renewable energy in the Netherlands (CBS, 2013[b]) (table 9.4.1) reports on the use of wood in industry. A calorific value of 16.5 GJ/tonne is used in the calculation. This corresponds to a dry matter content of roughly 85 %. The input of wood can be multiplied by the dry matter content to achieve the input of biomass for industrial wood-burning stoves.

$$\Phi_{woodBBE} = \Phi_{wood} \times f_{DMwood}$$

Where:

$\Phi_{woodBBE}$ = contribution from wood-burning to BBE (kton)
Φ_{wood} = wood burnt in stoves (kton)
f_{DMwood} = dry matter content of wood (-)

7.1.4 Wood-burning stoves in households

The report by Statistics Netherlands and TNO on renewable energy in the Netherlands (CBS, 2013[b]) table 9.5.1) reports on the use of wood in wood-burning stoves in households. A calorific value of 15.5 GJ/tonne is used in the calculation. This corresponds to a dry matter content of 80 %. The input of wood can be multiplied by its dry matter content to achieve the input of biomass for wood-burning stoves at households.

The same formulas from paragraph 7.1.3. apply.

7.1.5 Landfill gas and biogas from WWTPs

Statistics Netherlands reports on the use of landfill gas and biogas from WWTPs (*Hernieuwbare energie in Nederland 2012* (CBS, 2013[b]) table 9.8.1 and 9.9.1). Based on the data in this table, the weight of the usefully applied biogas can be calculated as follows:

$$E_{applied} = E_{production} - E_{flared}$$
$$\Phi_{biogasBBE} = E_{applied}/LHV_{biogas}$$

Where:

E_{useful} = usefully applied energy from biogas (TJ)
$E_{production}$ = produced biogas (TJ)
E_{flare} = flared biogas (TJ)
$\Phi_{biogasBBE}$ = biogas contribution to BBE (kton)
LHV_{biogas} = biogas energy content (GJ/tonne)

The energy content is roughly 15.2 GJ/tonne for landfill gas and 22.4 GJ/tonne for biogas from WWTPs.

The weight of the biogas formed is equal to the weight of the biomass used to produce it (water produced by hydrolysis is ignored).

7.1.6 Biogas (co)digestion

Statistics Netherlands reports on the use of biogas from co-digestion (*Hernieuwbare energie in Nederland 2012* (CBS, 2013[b]) table 9.10.1). Based on the data in this table, the volume of biogas can be calculated as follows:

$$\Phi_{biogasBBE} = E_{prim}/LHV_{biogas}$$

Where:

$\Phi_{biogasBBE}$ = biogas contribution to BBE (kton)
E_{prim} = production and input for electricity production (TJ)
LHV_{biogas} = biogas energy content (GJ/tonne)

The biogas energy content is roughly 14.8 GJ/tonne.

The weight of the biogas formed is equal to the weight of the biomass used to produce it (water produced by hydrolysis is ignored).

7.1.7 Other biomass combustion

Combustion of other biomass waste streams (category C residual wood, chicken manure, and paper sludge) contributes substantially to renewable energy. Dedicated installations have been designed, where the emission of toxic components (such as NO_x or fly ashes) is prevented. The volume of raw materials applied for the generation of electricity and heat, is reported in the report on renewable energy in the Netherlands (CBS, 2013[b]) table 9.7.1. The reported data is obtained by multiplying the input of biomass per power station by the energy content of the relevant biomass (similar to the method used for co-firing in power stations, refer to paragraph 7.1.2). For the Monitor BBE, the reported use of biomass can be multiplied by the relevant dry matter numbers (same formulas as 7.1.2.).

7.2 Transport sector

The reported figures on blending of road trasnport fuels cannot be used as a starting point for the transport sector. A considerable part of the percentage consists of so-called double-counting. In figure 6 of NL Agency's Bioenergy Status Document 2011 (AGNL, 2012), the different biofuels are split out (biethanol, bioETBE, bioMTBE, biomethanol, biodiesel). The input for the various products can be divided by their respective energy content, to achieve the input for tonnes of biofuel. For bioETBE, bioMTBE, and biodiesel, a correction must be applied for fossil derived parts of the molecule.

$$\Phi_{transportBBE} = \Sigma\, Q_i / LHV_i \times f_{BBi}$$

Where:

i	= 1 to number of components
$\Phi_{transportBBE}$	= renewable transport fuel contribution to BBE (kton)
Q_i	= combustion heat of component i (TJ)
LHV_i	= lower heating value of component i (GJ/tonne)
f_{BBi}	= biobased component fraction i

7.3 Timber industry

Probos collects data on harvest and import for the timber industry. From these numbers the quantity of wood processed in the Dutch timber industry may be derived.

Harvest

Probos collects data on the volume of roundwood harvested in the woods and forests of the Netherlands (Probos, 2012). The volume of roundwood is expressed in m^3. The harvested dry matter can be estimated by multiplying the density (ρ_{rwe}) and dry matter fraction (f_{DM}):

$\Phi_{harvest}$ $= Q_{harvest} \times \rho_{rwe} \times f_{DM}$

Where:

$\Phi_{harvest}$ = harvested weight (tonne)
$Q_{harvest}$ = harvested volume (m^3)
P_{rwe} = weight per volume (tonne/m^3)
f_{DM} = dry matter content (tonne/tonne)

The following applies for Dutch roundwood: $\rho_{rwe} = 0.836$ and $f_{DM} = 0.5$ (Probos 2012, Appendix 1).

Branches and top wood are mostly left behind in the woods/forests. The volume of branches and top wood is estimated at 5 % of the harvested roundwood.

Import

Probos collects data on the volume of imported wood purchased in the Netherlands by members of the *Vereniging van Nederlandse Houtondernemingen, VVNH (*Netherlands Timber Trade Association). The members of the VVNH cover approximately 80 % of the overall wood trade. The import data is split into 3 categories: softwood, hardwood, and boards. The data (reported in m^3) must be converted to dry matter by multiplying by density (ρ_{rwe_i}) and dry matter fraction (f_{DM_i}). For the incomplete coverage, a correction is done with an extrapolation factor (f_E) of 1.25 (=1/80 %).

Φ_{import} $= f_E \Sigma Q_{harvest\_i} \times \rho_{rwe\_i} \times f_{DM\_i}$

Where:

i = 1 to number of categories
Φ_{import} = weight of imported wood (tonne)
$Q_{harvest\_i}$ = import volume category i (m^3)
ρ_{rwe_i} = weight per volume (tonne/m^3)
f_{DM_i} = dry matter content of category i (-)
f_E = extrapolation factor for unsurveyed wood trade (-)

	ρ_{rwe} (tonne/m^3)	**f_{DM} (tonne/tonne)**
Soft roundwood	0.78	0.5
Hard roundwood	0.9	0.5
Tropical roundwood	1.181	0.78
Boards	0.65	0.85

Probos 2013, Appendix 1

Use of wood in BBE

$\Phi_{woodBBE} = \Phi_{harvest} + \Phi_{import}$

Where:

$\Phi_{woodBBE}$ = wood contribution to BBE (tonne)
$\Phi_{harvest}$ = harvested weight (tonne)
Φ_{import} = imported weight (tonne)

It is important that we remain vigilant of the following: a considerable part of the wood which is burnt for heat and energy is not obtained through the wood trade, as surveyed by Probos, but is purchased directly from municipalities (prunings) or the state forestry department, or is imported from abroad. This is not an immediate problem for the monitor, because this use of the wood is captured by the energy sector monitor (paragraph 7.1).

7.4 Paper and cardboard industry

For the paper and cardboard industry, the consumption of raw materials can be calculated using the annual paper production and the application of recycled paper (published annually by the VNP, *Koninklijke Vereniging van Nederlandse Papier en kartonfabrieken* (the Royal Association of Dutch Paper and Cardboard). The production of fresh pulp can be calculated from this as follows:

$\Phi_{fresh\ pulp} = \Phi_{production} - \Phi_{rec}$

Where:

$\Phi_{fresh\ pulp}$ = production of fresh paper pulp (dry matter) (tonne)
$\Phi_{production}$ = production of paper pulp (dry matter) (tonne)
Φ_{rec} = recycled paper (dry matter) (tonne)

During the production of paper pulp from wood, 15 to 20 % mineral components are added. The required volume of wood pulp was therefore lower. The recycled paper can also be included in the calculation as a raw material for the biobased economy.

$\Phi_{P\&CBBE} = \Phi_{fresh\ pulp}$ x 87.5 % (+ Φ_{rec})

Where:

$\Phi_{P\&CBBE}$ = paper and cardboard industry's contribution to the BBE (dry matter) (tonne)
$\Phi_{fresh\ pulp}$ = production of fresh paper pulp (dry matter) (tonne)
Φ_{rec} = recycled paper (dry matter) (tonne)

7.5 Chemical industry

Data is published annually by MVO (MVO, 2013) on the application of vegetal and animal oils and fats in the chemical industry. For starch, numbers are provided in the supply balance sheets for grains, potatoes, and sugar for industrial application of carbohydrates (WUR-LEI). Supply balance sheets are not prepared for protein or wood. For many intermediary products from biological raw materials, the statistics (from Statistics Netherlands, for instance) do not make a distinction between biobased products and identical products from fossil sources.

The proposal is to arrive at a usable number by posing questions to the chemical industry. To prevent double-counting, the following 2 questions must be answered:

1. What is the import of chemicals produced from renewable raw materials (sugar, starch, vegetal and animal oils and fats, lignin, glycerol) in tonnes per year?
2. What is the conversion of renewable raw materials (sugar, starch, vegetal and animal oils and fats, lignin, glycerol) for the production of chemicals in tonnes per year?

For raw materials with a fossil and renewable component, the renewable portion can be included in the report, according to the DIN 1206 /CEN/TR 15932 standard.
It is perhaps appropriate to differentiate between a few categories during the questioning phase: 1. oils and fats, 2. starch and sugars, and 3. other products (alcohol, organic acids, amino acids). These groups differ considerably on calorific values, C:H:O ratio and agricultural origin. Such a separate administration will allow for the results to be converted to tonnes of carbon or energy at a later stage.

$$\Phi_{chemBBE} = \Phi_{import} + \Phi_{NL}$$

Where:
$\Phi_{chemBBE}$ = Chemical industry’s contribution to the Dutch BBE (tonne)
Φ_{import} = Weight of the imported intermediary products (tonne)
Φ_{NL} = Conversion of biobased raw materials to intermediary products in NL (tonne)

7.6 Plastic and rubber processing industry

The plastic and rubber processing industry has not yet been worked out in detail. This industry could also be considered part of the chemical industry. In any event, the approach will be similar.

7.7 Textile, clothing, and leather industry

A method has not yet been developed for this industry. It might not be necessary either, since it involves extremely small volumes.

8 Determining the volume of the biobased economy according to protocol

8.1 Energy sector

8.1.1 Municipal solid waste incinerators (MSWI)

The method described in 7.1.1 cannot be implemented by WUR-FBR, because the underlying data is confidential. Statistics Netherlands received this data subject to confidentiality. Statistics Netherlands could perform the proposed calculations and the result could be published without confidentiality issues. A proper estimate for the processing of biogenic waste in MSWI can be obtained on the basis of the report on renewable energy in the Netherlands (*Hernieuwbare energie in Nederland 2012* (CBS, 2013[b]). The total amount of waste burnt in 2012 was 7555 kton (table 9.2.1 (CBS, 2013[b])). The share of biobased waste burnt in MSWI is estimated at 54 % for 2012 (table 9.2.2 (CBS, 2013[b])). The moisture content for the biobased fraction is approximately 45 % (table B3.3 (AGNL, 2010)). The total volume of biomass burnt in 2012 was therefore roughly:

$\Phi_{wasteBBE}$ = 7555 kton x 54 % x (1 - 45 %) = 2243 kton.

8.1.2 Biomass co-combustion in power stations

As described in the above paragraph, the method described in 7.1.2 cannot be implemented by WUR-FBR either, because the underlying data is confidential. Statistics Netherlands received this data subject to confidentiality. Statistics Netherlands could perform the proposed calculations and the result could be published without confidentiality issues. A proper estimate for co-firing in power stations can be obtained on the basis of the report on renewable energy in the Netherlands (CBS, 2013[b]). In 2012, 26049 TJ was used for co-firing in power plants (table 9.3.1 (CBS, 2013[b])). Assuming a combustion energy of 16.5 GJ/tonne and dry matter content of 85 % (same numbers as those used for wood-burning stoves at companies), it adds up to a supply of 1342 kton for co-fired dry biomass.

$\Phi_{co\text{-}combustionBBE}$ = 26049 TJ /(16.5 GJ/tonne) x 85 % = 1342 kton

8.1.3 Wood-burning stoves at companies

In 2012, 174 kton biomass was burnt in wood-burning stoves at companies (provisional figure) (CBS, 2013[b]).

$\Phi_{woodBBE}$ = 174 kton x 85 % = 148 kton

8.1.4 Wood-burning stoves in households

In 2012, 817 kton biomass was burnt in wood-burning stoves in households (provisional figure) (CBS, 2013[b]).

$\Phi_{woodBBE}$ = 817 kton x 80 % = 654 kton

8.1.5 Landfill gas and biogas from WWTPs

Based on the data from (*Hernieuwbare energie in Nederland 2012* (CBS 2013[b]), table 9.8.1 and 9.9.1), the biomass used for the production of landfill gas and biogas from WWTPs can be calculated as follows:

$\Phi_{landfill\ gasBBE}$ = (1596 TJ – 366 TJ) / (15.2 GJ/tonne) = 81 kton
$\Phi_{WWTPBBE}$ = (2388 TJ – 167 TJ) / (22.4 GJ/tonne) = 99 kton

8.1.6 Biogas (co)digestion

Based on the data from (*Hernieuwbare energie in Nederland 2012* (CBS, 013[b]), table 9.10.1), the biomass used for the production of biogas through co-digestion can be calculated as follows:

$\Phi_{co\text{-}digestionBBE}$ = (1596 TJ – 366 TJ) / (14.8 GJ/tonne) = 374 kton

8.1.7 Other biomass combustion

As described in paragraph 8.1.1 and 8.1.2, the method described in 7.1.7 cannot be implemented by WUR-FBR either, because the underlying data is confidential. Statistics Netherlands received this data subject to confidentiality. Statistics Netherlands could perform the proposed calculations and the result could be published without confidentiality issues. A proper estimate for the application of other biomass for the production of renewable energy can be obtained on the basis of the report on renewable energy in the Netherlands (*Hernieuwbare energie in Nederland 2012* (CBS, 2013[b]). The applied biomass can be estimated by dividing the reported production of heat (table 9.7.1 (CBS, 2013[b])) by the average calorific value for manure, fibre, and wood (approximately 15 GJ/tonne DM). In 2012, 13985 TJ of biomass was used for combustion of other biomass (manure, scrap wood, paper sludge). This corresponds with 932 kton dry biomass matter (assuming combustion energy of 15 GJ/tonne).

$\Phi_{otherBBE}$ = 13985 TJ / (15 GJ/tonne) = 932 kton

8.2 Transport sector

As described in the top paragraph, the method described in 7.2 cannot be implemented by WUR-FBR either, because the underlying data is confidential. Statistics Netherlands received this data subject to confidentiality. Statistics Netherlands could perform the proposed calculations and the result could be published without confidentiality issues. The results from this approach are provided by Statistics Netherlands in the report on renewable energy in the Netherlands (CBS, 2013[b]), table 9.12.1:

Use of biogasoline: 192 kton

Use of biodiesel: 229 kton

The other fuels (bioLNG and bioCNG) are not reported in this publication. The volumes for these fuels will, in any event, be extremely small compared to biogasoline and biodiesel.

$\Phi_{transportBBE}$ = 192 kton + 229 kton = 421 kton

8.3 Timber industry

The production of roundwood in 2011 was 1.0 million m^3 (Probos, 2012). The dry matter content is calculated as follows:

$\Phi_{harvest}$ = 1.0 x 10^6 m^3 x 0.836 tonne/m^3 x 0.5 tonne/tonne x 0.001 kton/tonne= 418 kton

The import of wood in 2012 by the timber industry affiliated with VVNH has been reported by Probos (Oldenburger *et al.*, 2013): 1166 million m^3 in the form of softwood, 313 million m^3 in the form of hardwood, and 613 million m^3 in the form of boards. The imported volume of dry matter for the entire timber industry is thus estimated as follows:

Φ_{import} = 1.25 x (1166 x 10^6 m^3 x 0.78 tonne/m^3 x 0.5 tonne/tonne + 313 x 10^6 m^3 x 0.9 tonne/m^3 x 0.5 tonne/tonne +613 x 10^6 m^3 x 0.65 tonne/m^3 x 0.85 tonne/tonne) x 0.001 kton/tonne =1168 kton

The total volume of wood used in the timber industry is therefore:

$\Phi_{timber\ industryBBE}$ = 418 kton + 1168 kton = 1586 kton

8.4 Paper and cardboard industry

In 2011, the production of paper was: 2748 kton dry matter (VNP, 2013). Paper in the Netherlands is made mostly out of recycled paper. In 2011, 2159 kton recycled paper was used. In other words: 2748 kton – 2159 kton = 589 kton paper was produced from fresh pulp. The portion of mineral fillers and additives (glue, fillers, pigments) for some types of paper, such as coated paper and print paper, can be anywhere between 15-20 %. In other words, roughly (100 %-17.5 %) x 589 kton = 486 kton wood pulp is needed to manufacture this paper.

$\Phi_{P\&CBBE}$ = 486 kton + 2159 kton = 2645 kton

8.5 Chemical industry

The method described in paragraph 7.5 cannot be implemented within the current project. However, data is available which provides an overview of the volume of the biobased chemical industry.

The MVO data (MVO, 2013) can be used for the application of oils and fats in the chemical industry. MVO differentiates between technical applications and energy applications. Use as vehicle fuel (biodiesel) is considered an energy application. The data represented here are the numbers for 2012.

Table 1, application of vegetal and animal oils and fats

Application	kton
Technical application of vegetal and animal oils and fats	135 kton
Energy application of vegetal and animal oils and fats	1212 kton
Technical application of fatty acids	10 kton
Energy application of fatty acids	54 kton
Total for technical and energy applications of oils and fats	**1411 kton**

For carbohydrates, the supply balance sheets for sugars, grains, and potatoes can be used (Table 2, column 2). Based on the dry matter content (Table 2, column 3), the volume of dry matter can be estimated from this (Table 2, column 4).
These supply balance sheets indicate what volume of sugar, grain, and potatoes is used in industrial (non-food) applications.

Table 2, Application of biobased raw materials in industrial (non-food) applications according to supply balance sheets (season 2010/2011)

Raw material	kton	dry matter	kton (dry)
Sugar	0	100 %	0
Sugar molasses	340	50 %	170
Potato starch	246	100 %	246
Grains	628	80 %	565
Total			**981**

The extent to which the supply balance sheets actually form a reliable source for the Monitor Biobased Economy is not clear. Many product boards might cease to exist as their government support was recently stopped. Therefore it is not yet clear whether comparable statistics can be pursued.
As a check, a few large-scale users were studied.
Abengoa Rotterdam can process 1200 kton wheat and corn into bioethanol. Abengoa Rotterdam produces 360 kton DDGS. In other words, 840 kton carbohydrates are used for the production of bioethanol. This is more than the application of grains according to the supply balance sheet. However, the installation was only started up in the middle of 2010. Full capacity is generally not reached in the first production year. This might explain the lower reported number.

Nedalco (Cargill) produces 500,000 hectolitres (35 kton) of alcohol from grains. Roughly 78 kton grain is needed for this. This number is relatively small compared to the volumes processed by Abengoa.
AVEBE processes roughly 2 million tonnes of potatoes a year. These contain 18 % starch, of which 65 % is derivatised (Rotink, 2013, Bruinenberg, 201x). In other words, this equals 254 kton carbohydrates. This corresponds rather well to the number in the supply balance.
AKZO uses 10-50 kton dissolving cellulose per year for the production of CMC. Dissolving cellulose is not covered in the supply balance sheets.

In any event, the volume of carbohydrates applied in the chemical industry exceeds 1352 kton (= 170 + 840 + 78 + 254 + 10).

The aforementioned list of companies is certainly not complete. Some of the missing companies that use a significant volume of carbohydrates for chemical products include: ADM, Unilever, Cosun, and AKZO Nobel. It is recommended that these companies should also be included in the overall picture.

The total biobased chemical industry therefore exceeds:

$\Phi_{\text{chemical industryBBE}} > 1411 \text{ kton} + 1352 \text{ kton} = 2763 \text{ kton}$

8.6 Plastic and rubber processing industry

A method has not yet been developed within this project for the plastic and rubber processing industry.
In 2010, 110 kton natural rubber was imported and 86 kton was exported (Statline, 2013). The processing of natural rubber therefore comes to 24 kton.
An estimate of the processing volume for bioplastics in the plastic processing industry could be obtained based on the consumption of bioplastics in the Netherlands. An estimate for this can be obtained by multiplying the overall global production of bioplastics (Europe bioplastics data 2011) by the Dutch contribution to the global GDP. The global production (including biodegradable plastics on the basis of petrochemical raw materials) currently amounts to 1100 kton. For the Netherlands, this therefore equals 1100 kton x 1.2 % (NL share of global GDP) = 13.2 kton per year. The extent to which the Dutch plastic processing industry contributes in this regard is not known.

8.7 Textile, clothing, and leather industry

A method has not yet been developed for this industry.

9 Overview of the biobased economy

The table below provides a summarised look at the numbers from Chapter 8. Table 3, Application of renewable raw materials in various production sectors, most from the year 2012* indicates the application of biobased raw materials in the biobased economy (the flow through the green, purple, blue, and yellow lines in Figure 14). Measuring therefore takes place at the point of entry to the biobased economy; the point where biomass and agricultural raw materials are supplied to the biobased economy.

Table 3, Application of renewable raw materials in various production sectors, most from the year 2012*

		kton	kton	kton
Energy sector	MSWI	2243		
	Co-firing	1342		
	Wood-burning stoves at companies	148*		
	Wood-burning stoves in households	654		
	Landfill gas	81		
	Biogas from SWPs	99		
	Biogas from co-digestion	374		
	Other combustion	932		
	Subtotal		**5725**	
Timber industry	Harvested wood	418		
	Imported wood	1168		
	Subtotal		**1586**	
Paper and cardboard industry	New wood pulp	589		
	Recycle	2159		
	Subtotal		**2748**	
Chemical industry	Oils and fats	1411		
	Carbohydrates	>1352		
	Subtotal		**>2763**	
Total application of raw materials				**≈12822****

*Wood-burning stoves in industry are often fed with residual wood from the main process. In this table, the number is therefore not added, because it would result in double-counting.

**This number will include a slight degree of double-counting, because the energy and heat sector processes residual products from other sectors: think of saw dust and residual fatty acids, for instance.

Table 4 provides information on the application (consumption) of biobased products (the flow through the red lines in Figure 14). Measurement therefore takes place at the point of exit from the biobased chemical industry; the point where products are supplied to consumers and local and foreign industry.

Table 4, Application of biobased products in the Netherlands, most from the year 2012*

		TJ_e	TJ_{th}	TJ_{tot}
Energy sector	MSWI	6264	7341	**13605**
	Co-firing	9940	658	**10598**
	Wood-burning stoves at companies		2445	**2445**
	Wood-burning stoves in households		7501	**7501**
	Landfill gas	263	67	**330**
	Biogas from WWTPs	633	138	**771**
	Biogas from co-digestion	1829	447	**2276**
	Other combustion	3200	2327	**5527**
	Total	**22129**	**20924**	**43053**
		kton		
Transport**	Biogasoline	192		
	Biodiesel	229		
Materials and chemicals***		**>0**		
Total application	**Total**	**>421**		

* Energy is supplied in the form of electricity (TJ_e) and heat (TJ_{th}). In the European system for renewable energy, these numbers are added together to get the applied renewable energy (TJ_{tot}). The numbers were adopted from the report on renewable energy in the Netherlands (*Hernieuwbare energie in Nederland 2012*) (CBS, 2013b)

** The Dutch production of transport fuels is hardly related to the application of biofuels. There is a major production, major import, and also major export of biofuels.

*** Since this involves a very large number of different products, this number cannot be determined. This explains the choice to measure at the point of entry to the biobased economy.

10 Conclusions

The Protocol for Monitoring of Material Streams in the Biobased Economy was prepared to provide a clear picture of the volume and growth of the Dutch biobased economy.
Using the current protocol, the volume of the biobased economy was established at 13 Mton biomass used. This is an understatement, because the information available on the chemical industry, in particular, is insufficient. The biobased economy is small compared to the fossil economy (roughly 5 %). Energy and heat currently form the most important pillars of the biobased economy (5.7 Mton). The timber industry (1.6 Mton) and the paper and pulp industry are also significant (2.7 Mton). The paper and pulp industry uses far more old paper (recycled) than fresh paper pulp. It was much more difficult to obtain data for the biobased chemical industry. Numbers are known for a few important players, and from these numbers it can be derived that the application of biobased raw materials for the chemical industry exceeds 2.8 Mton. The production of biofuels is dominant in this regard.

Several problems were encountered in determining the volume of the biobased economy:
1. A significant amount of different products and intermediary products are involved (particularly in the chemical industry)
2. Import and (re-)export of raw materials and intermediary products play a major role (the significant re-export volume makes it difficult to determine the volume of biobased raw materials used in the Netherlands)
3. Chemicals and materials do not disappear once used (contrary to fuels), but are transferred to successive companies (this poses a risk for double-counting)
4. Raw materials for the chemical industry are mostly obtained from the agricultural industry and can therefore also be used as food for humans and animals (food or feed are not part of the biobased economy)

The problems formulated above can be solved as follows:
1. Measurement at the point of entry to the biobased economy: what volume of biobased raw materials is processed? The number of raw material types is still relatively limited at the point of entry to the chemical industry.
2. Problem 2 can only be solved by asking companies to report the quantity of biobased raw materials that are actually processed. A similar analysis is conducted annually for the timber industry, but not for the chemical industry.
3. This problem is solved (along with problem 1) by only measuring at the point of entry to the biobased economy.
4. The fermentation industry is considered part of the chemical industry. All fermentation products are thus part of the biobased economy, even when applied in food or feed.

With the protocol in its current form, the volume of the biobased economy can systematically be assessed each year (always with a delay of 1 year to gather the necessary statistics). Small adjustments will still be required to get the protocol to correspond with the available data. Due to lack of data, the protocol cannot formulate a report on the volume of the biobased chemical industry. However, an adequate system boundary has been established for measurement of the biobased chemical industry, which fits in well with the other industrial sectors within the biobased economy. The missing data for the monitor will have to be supplied by the chemical industry. A solution must be found in collaboration with industry and Statistics Netherlands, for the supply of data and the processing thereof.

11 Symbols and abbreviations used

Table 5, Explanation of symbols used

Symbol	Explanation	Unit	Remarks
E	Energy production / consumption	TJ	(per year)
f	factor	(-)	
LHV	Lower Heating Value	GJ/tonne	
Q	Volume flow	m^3	(per year)
Φ	Mass flow	tonne	(per year)
ρ	Weight per volume	kg/m^3	=density

Table 6, Explanation of abbreviations used

Abbreviation	Explanation
AgNL	NL Agency,(*since 1-1-2014 Netherlands Enterprise Agency (RVO.nl)*)
B	Biogenic
BBE	BioBased Economy
BioCNG	Compressed Natural Gas from biogas
BioLNG	Liquefied Natural Gas from biogas
CBS	Statistics Netherlands
CMC	Carboxymethyl Cellulose
DDGS	Dried Distillers Grains and Solubles
DM	Dry Matter
ETBE	Ethyl Tert-Butyl Ether
EU	European Union
GDP	Gross Domestic Product
MFA	Material Flow Accounts
MSWI	Municipal Solid Waste Incinerator
MTBE	Methyl Tert-Butyl Ether
NL	The Netherlands
P&C	Paper and Cardboard
P&R	Plastics and Rubber
Prim	Primary
Rwe	Roundwood equivalent
WWTP	Wastewater treatment plant

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Appendix 1, Why can the monitor only be used to answer question 1 (paragraph 1.5)?

For some sectors, the monitor will only be able to answer question 1 (What volume of biobased raw materials does the Dutch industry use?). An explanation is provided below, per question, on why the relevant question cannot necessarily be answered with the monitor.

Question 2: What volume of biobased products does the Dutch consumer use?
The chemical, timber, and paper industries manufacture a very large number of different and composite products. It is impossible to follow in which country these products are used. Biopolyethylene can be exported directly, but products and foils manufactured from polyethylene can also be used or exported. Paper is used e.g. as packaging material and crosses the border in considerable quantities in this form.

Question 3: What is the BBE's contribution in reducing fossil CO_2 emissions in the Netherlands?
For biofuels, the quantity of CO_2 that would have been released if fossil fuels were used can be calculated. In the application of products from the chemical, timber, and paper industries, CO_2 is not released when the product is used by the consumer. The CO_2 is only released once the waste is processed, or may not be released at all in the event of recycling. For biofuels and also for other products, the fossil CO_2 emissions in the production chain must be taken into consideration.

Question 4: How much renewable carbon is captured in the Netherlands in non-food/non-feed products?
This question relates to that portion of the BBE which converts wood or food/feed raw materials to biobased products. However, the BBE also takes intermediary products that are manufactured abroad from wood or food/feed (such as Bioethanol and Bioethylene from Brazil, for example) as raw material. These raw materials must be deducted to obtain the answer to question 4.

Question 5: To what extent are fossil raw materials replaced through the application of renewable raw materials?
For biofuels, it is assumed that 1 GJ of bioenergy replaces roughly 1 GJ of fossil energy. However, this does not apply for products from the chemical, timber and paper industries. For those industries, 1 kg of fossil product replaces 1 kg of biobased product. For many products, the aforementioned is not a proper comparison either, because it involves the functionality of the product. If a biobased fibre is twice as strong as a fossil fibre, then 1 kg of a biobased product might replace 2 kg of a fossil product.
For the paper and timber industries, hardly any replacement of fossil raw materials takes place. Wood might be used to replace rock or steel, rather than plastics. For that matter, the reverse may also occur, such as plastic window frames, for example. For chemical products, replacement

is not always one-to-one. However, this is the case for biopolyethylene, which is identical to polyethylene from fossil sources, but not for polylactic acid, linoleum floors, lignosulfonates, etc. Answering question 5 is therefore much more difficult for products from the chemical industry than for fuels, and requires extensive knowledge of biobased products and of the fossil products that are replaced.
Another problem is associated with the fact that it is often unclear what volume of fossil raw materials is needed for the production of fossil-based chemicals. Refineries produce multiple products and the required process energy must be distributed amongst the products (allocation). Various allocation methods are available, and therefore the results are always debatable.

Question 6: What is the magnitude of the Dutch contribution to the EU biobased economy? Double-counting will take place when adding together the biobased economy volume for multiple member states. Intermediary products from one country are imported to another country, and will also be included in the tally for that country's BBE. An example of such a chain: the production of ethanol from wheat in the Netherlands, from which bioethylene is produced in Belgium and biopolyethylene is produced in Germany, from which in turn biopolyethylene foils are produced in France, which are then sold in the supermarket in the Netherlands. Question 6 can only be answered if internal streams within the EU are excluded from the tally (refer to paragraph 4.5).

