Modeling and Analysis

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Monitoring sustainable biomass flows: General methodology development

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Abstract: Transition to a bio-based economy will create new demand for biomass, e.g. the increasing use of bioenergy, but the impacts on existing markets are unclear. Furthermore, there is a growing public concern on the sustainability of biomass. This study proposes a methodological framework for mapping national biomass flows based on domestic production-consumption and cross-border trade, and respective share of sustainably-certified biomass. A case study was performed on the Netherlands for 2010-2011, focusing on three categories: (i) woody biomass, (ii) oils and fats, and (iii) carbohydrates. Between 2010-2011 few major shifts were found, besides the increasing biofuel production. The share of sustainably-certified feedstock is growing in many categories. Woody biomass used for energy amounted to 3.45 MT, including 1.3 MT imported wood pellets (>85% certified). About 0.6 MT of oils and fats and 1.2 MT (estimation) of carbohydrates were used for biofuel production. It is assumed that only certified materials were used for biofuel production. For non-energy purpose, more than 50% of woody biomass used was either certified or derived from recycled streams. Certified oils has entered the Dutch food sector since 2011, accounted for 7% of total vegetable oils consumption. It is expected that carbohydrates will also be certified in the near future. Methodological challenges encountered are: inconsistency in data definitions, lack of coherent cross-sectorial reporting systems, low reliability of bilateral trade statistics, lack of transparency in biomass supply chains, and disparity in sustainability requirements. The methodology may be expanded for future projection in different scenarios. © 2013 Society of Chemical Industry and John Wiley & Sons, Ltd

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Keywords: Bio-based economy; Monitoring; Biomass; Sustainability; Trade; Certification

Introduction

Over the years, many countries have shown a growing interest in and ambition for the transition to a bio-based economy, i.e. increasing the use of biomass to substitute fossil fuels and materials. This could create new demand for biomass resources, which has already been reflected in the increasing production and trade of biomass for energy use over the last few years. Biodiesel, bioethanol, and wood pellets currently

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constitute the large majority of these international trade flows.[1,2] Minimizing negative impacts of producing and utilizing biomass has become increasingly important. As a response to the public's concerns, biomass producers from the private sector as well as governmental and non-governmental organizations (NGOs) have initiated various efforts to define criteria for 'sustainable biomass production and utilization'. In recent years, dozens of biomass and biofuel sustainability certification and verification systems have been developed or implemented by a variety of private and public organizations.[3,4] These systems may cover biomass production sectors (e.g. forests, agricultural crops), bioenergy products (e.g. wood fuels, ethanol, biodiesel, electricity), and whole or segmental supply chains (e.g. production system, chain of custody from growers to energy consumers).

A bio-based economy involves diverse forms of raw materials, intermediates, products, and by-products that go through different processes in different sectors, and flow in two dimensions, i.e. domestic and cross-border input and output. Understanding biomass flows is considered to be of high importance for the following reasons. First, a clear mapping of biomass flows is essential for policymakers in introducing a bio-based economy in multiple sectors. Due to the complexity of existing biomass flows, the potential and risks of switching to a bio-based economy are still unclear, such as direct and indirect substitution effects in supply chains. Shifting biomass from their original capacity to other purposes (e.g. for energy use) will directly and/or indirectly alter existing biomass flows (both intranational and international), possibly leading to increased utilization of other biomass to fill the demand gap created in the original sectors. Second, monitoring and quantifying international sustainable certified biomass flows is crucial in the context of global climate change policies. There is a need to distinguish biomass certified with sustainability schemes for greenhouse gas (GHG) emission analysis. This is complicated with the mushrooming of sustainability certifications and labels which have different scopes and purposes and are unevenly applied across sectors and along supply chains.

Capturing and mapping biomass flows is always fraught with difficulties, as both directions and quantity of many biomass flows are rarely entirely clear and may also change from year to year. A number of studies on cross-border bioenergy trade flows have been conducted,[2,5,6] but these studies did not assess the mass flows within the countries. In this regard, a monitoring body, usually an industrial association, a governmental agency, or a non-profit institution, covers more detail of the products' mass flows within the country or region. However, these activities usually lack information on cross-sectoral flows. Knowledge of relevant cross-market mechanisms and trade flows is relatively limited. Recent studies by Heinimö[7] and Kalt and Kranzl[8] reported on the direct and indirect trade of both wood-based fuels and non-fuel products, taking Finland and Austria as case studies, respectively. However, other important biomass categories like oils and fats and carbohydrates are inadequately addressed.

On the other hand, a comprehensive quantitative inventory of sustainable certified biomass flows for a variety of end-uses is currently absent from the sustainability discussions. Often there are reports on the production by certification bodies (e.g. FSC, RSPO) that do not involve trade directly but focus more on the production side. On the consumption side, reporting of liquid and solid biofuels leads in this respect, but until 2012 only a few countries had annual reporting systems that indicate volume and origins of the biofuels used and corresponding sustainability schemes employed. Goh *et al.*[4] examined trade flows and market development of certified solid and liquid biofuels taking the forerunners in biofuels certification, i.e. the UK and the Netherlands as two case studies. Again, these reports did not intend to cover cross-market monitoring.

The main goal of this study is to propose a methodological framework for monitoring and mapping biomass and bioenergy by quantifying both cross-border trade and domestic cross-sectoral flows, and examining the share of sustainable certified biomass in different markets, taking 'country' or 'trade block' (e.g. the EU) as the base unit. To demonstrate the framework, a first quantitative assessment of sustainable biomass and bioenergy flows in the Netherlands was carried out as a case study. Due to limited domestic biomass resources, the Netherlands is competitive in biomass trade with its leading ports, traders, logistics, and market systems. Similar to other manufacturing industries, the Dutch biomass industry relies heavily on secondary processing and trade in both directions. However, domestic agricultural products also contribute a significant share to the market. The Netherlands is also the forerunner in promoting sustainability certification of biomass and bioenergy. Furthermore, data availability seems high for the Dutch case with various monitoring systems and statistics in the country. Therefore, the country is considered a suitable example to illustrate its intra- and international sustainable certified biomass flows using the proposed methodological framework. A number of countries also possess similar characteristics, such as Belgium and the UK.

This paper describes the methodology underlying this study and then presents the setting and results of the case study. It includes methodological discussion, conclusions, and recommendations.

Methodology

Scope of study

In view of the large diversity in biomass, this study limited the scope to three main categories: (i) woody biomass, (ii) oils and fats, and (iii) carbohydrates. Woody biomass includes timber, wood products, paper and cardboard, wood fuels, and their waste streams. Oils and fats include oil seeds, vegetable oils, animal fats, and biodiesel. Carbohydrates include grains, starch, sugars, and a possible connection to bio-ethanol. Only biomass that falls under these three categories was investigated. This selection was based on three characteristics:

- They are relatively large streams with a clear distinction compared with other biomass groups.
- They are relevant to the bio-based economy – they are either long-chain polymers (such as starch and lignocellulose) or high-quality monomers (such as fatty acids and sugars) and have high potential to substitute fossil materials.
- They are closely related to bioenergy carriers – wood pellets, biodiesel, and bioethanol (also considering their large share in waste streams that may end up in energy production).

The other biomass categories with large volumes in the Dutch economy, for example flowers, vegetables, fruit, meats, and processed food are not included in the case study. Nevertheless, waste streams from this biomass might be significant as bioenergy carriers. Data about this organic biomass in municipal waste streams usually can be derived at a highly aggregated level. However, the framework can also be expanded to the other biomass categories based on the three criteria. For example, agriculture residues could be very relevant to countries with a large agriculture industry, such as Malaysia and Indonesia.

Building mass flow diagrams

The framework consists of three dimensions: (i) cross-border input and output (import and export), (ii) domestic input and output (production and consumption), and (iii) share of sustainable certified biomass. The results are presented in the form of mass flow diagrams. The mass flow diagrams were built in three steps:

Step 1: Creating biomass chains and sustainability certification schemes inventory

First, an inventory of biomass supply chains was created. This inventory should cover in as much detail as possible inputs of raw materials to secondary, tertiary, and end users and finally releases of materials to the environment. Sustainability certification schemes applied to these chains were also identified based on literature reviews.

Step 2: Setting system boundaries

Due to the relatively broad aims, this monitoring framework is unlikely to cover the whole life cycle, but largely depends on data availability and feasibility. It should be noted that the boundaries may change with time as the industry is developing rapidly. The system boundaries for the three selected categories were set at different degrees. For woody biomass, the flows of materials could be identified more clearly due to consistent chemical composition in the stream (little or without chemical processing), and therefore near to full life cycle of the biomass can be illustrated (from raw wood to combustion). For oils and fats, the end-uses were identified as for human consumption, animal consumption, for technical purposes, and for energy use. For carbohydrates, the biomass was assumed to be mostly consumed as food and feed, and therefore no further categorization was made.

Step 3: Quantitative analysis

In the final step, each flow was quantified in as much detail as possible. An overview of data sources are presented later. First, each mass flow was examined quantitatively in both dimensions (i) and (ii). The flows of the three selected categories are presented in three different mass flow diagrams. The diagrams consist of two pairs of axes, where the top and bottom axes indicate import and export, and the left and right axes indicate domestic input and output of the chain. All streams were drawn in ratio to their actual volume. For countries with huge transhipment volume due to their trading hub nature, such as the Netherlands, net trade balances (i.e. net import and export excluding transhipment) can be used to improve the visualization of mass flows. Finally, dimension (iii) was also assessed quantitatively in as much detail as possible.

Overview of data sources: availability and quality

Data quality is the main factor that determines the reliability of the analysis and therefore needs to be defined explicitly. As no single data source covers all required information, various data sources were identified and evaluated. When more than one source available was available, data was selected based on the following order:

(i) ***Own data collection directly from the market actors***: In some extreme cases, when reliable data of certain important biomass streams is not available anywhere, data can only be collected directly from industry in the form of surveys and interviews. Direct information collected from the industry is regarded as the most reliable first-hand source of information. However, many companies tend to withhold trade information to protect their business interests. Own data collection is considered the most time-consuming and difficult way, and it is only carried out when the particular flow is of very high importance (i.e. have high potential to substitute fossil fuels and/or materials) and other data sources are not available.

(ii) ***Monitoring bodies and general statistics portals***: The core data contributors are usually monitoring bodies and general statistics portals. A monitoring body can be a governmental department or agency, an industrial association, or a non-profit institution that monitors the products' mass flows within the country or region. Some countries may have official general statistics systems that gather data from these monitoring bodies and/or directly from the industry. However, in this methodological framework, trade statistics collected at customs are separated as another category. The difference between these two sources can be viewed from two aspects: coverage and nature. Trade statistics portals capture trade flows at trading hubs, such as seaports, mainly at international level. Meanwhile monitoring bodies and general statistics portals may cover the flow of raw materials in secondary processing, post-processing and post-consumption (i.e. waste and residues) within a country or region. In terms of data nature, trade statistics are normally actual physical data (often the monetary values of physical goods) gathered directly from trading hubs, while monitoring bodies and general statistics portals may have various reporting systems that collect data for administrative purposes which do not necessarily equal the actual flows at a particular time due to various administrative reasons. A noticeable example is the consumption data of liquid biofuels that are reported in the EU to fulfil mandates. This kind of 'administrative data' has a policy dimension in the context of carbon mitigation policies, and therefore has a priority in data selection when there are discrepancies between data sources. An inadequacy of this data source is that a monitoring body usually has a very specific scope and interest in certain biomass or specific products, and seldom covers cross-sectoral flows.

(iii) ***Trade statistics portals***: Trade statistics portals cover a large range of products categorized using combined nomenclature (CN) codes. Table A1 in the Appendix lists CN codes for woody biomass, oils and fats, and carbohydrates. A number of studies on bioenergy trade flows have been conducted mainly using trade statistics.[2,5–8] This type of effort is often fraught with difficulties in differentiating the actual flows given that a number of different trade codes may be applied to similar products based on small differences in product nature, but they do not differentiate the end-uses of the materials explicitly. For example, ethanol can be imported under several different CN codes in different forms and blending levels, but it is not known how much has actually been used for energy purposes. Nevertheless, the CN system has been continuously improved; for example a new code has been introduced for energy pellets in recent years. Another weakness is that there are significant discrepancies between bilateral trade statistics reported by exporting and importing countries due to differences in timing, level of details, and classification.[5,9] In this work, data reported by the case study country was given priority, to ensure a consistent set of data was used when trade flows were linked to biomass flows within the country.

(iv) ***Mass balance deductions***: This category is placed at higher order than (v) when the base data comes from (i), (ii) and (iii). Volume of certain streams such as by-products, waste, and recycling streams can be deducted through mass balance calculations. Indicators from scientific literature can be used to complete the calculations. An example is the use of ratio method in derivation of glycerol flows, using the ratio of glycerol to monoalkyl esters proposed by scientific literature.

(v) ***Fragmented data, assumptions, and data aggregation***: Data may also be found scattered in many public available sources, such as press releases, news, reports by companies, or other organizations, and scientific literature. These pieces of information mostly come in fragments, and lack comprehensive descriptions and definitions. To complete the picture, assumptions can be made based on information fragments, related facts, extrapolation or interpolation, and other appropriate ways. For example, the sustainable share of certain

biomass streams in the Dutch market might be assumed to be equal to that of the European market, as the country possesses the largest trading hub in Europe with a very active and complex intra-European trade, making identifying the final destination of sustainable products extremely difficult. The drawback of this data source is that it often lacks scientific justification and consistency, and therefore it is ranked lower. Ultimately, if there are still some missing details in the mass flow diagram, streams or part of the chain that data is not available for at a high level of detail can be merged to increase the efficiency of the study. For example, paper and cardboard were not separated into individual streams but considered as one general product group, as the specific type and volume of paper and cardboard recycled or combusted is unknown. Besides, streams with less distinction and small volumes, such as different forms of wheat powder, can also be grouped together to improve visualization. However, the conditions might change from one case study to another, depending on specific objectives.

This list shows that there are many discrete analyses and data available, but mostly in different forms, and not every single biomass flow is monitored. The main idea of this framework is to overcome these challenges by matching all data together, supplementing each one to illustrate the big picture of biomass flows. When there is more than one set of data available, only data with the highest rank is used. ***Harmonization of data*** should be performed to ensure a consistent set of metrics when data comes in different units, such as volume, mass, energy, and monetary values. Table A2 shows the conversion factors for biomass, as well as moisture contents. All units should be harmonized to a consistent unit to give meaningful comparisons, for example million tonnes (MT) in this study.

Results

Case study setting

Table 1 lists the data sources employed in this case study, while more details of data sources for biomass streams are shown in Table A3 in the appendix.

Quantitative mass flows

Woody biomass

Figure 1 illustrates the flows of woody biomass in the Netherlands in 2010 and 2011. The moisture content may vary depending on humidity and therefore it is neglected in this study (Table A2). In the middle of the diagram there is a box indicating wood products, which represents the storage of woody biomass in the form of buildings, furniture, and other types of wood products that are non-consumable or not short-lived. In 2010 and 2011, the Netherlands produced considerable amounts of round wood, but about half of that was exported. On the other hand, a relatively large amount of sawn wood and wood panels was imported, mostly originating from adjacent countries. There were also significant imports of paper and cardboard into the Dutch market. A large amount of wood pellets was consumed in utilities. About 90% of

Table 1. Data sources for this case study.

	Sources	Woody biomass	Oils and fats	Carbohydrates
i	Own data collection directly from the market actors	Wood pellet buyers	–	–
ii	Monitoring bodies and general statistics portals	Probos	Product board Margarine, Fats, Oils (MVO); Task Force of Sustainable Palm Oil, Sustainable Trade Initiative (IDH); Liquid biofuels - Dutch Emission Authority	–
		Waste - Afval database van Agentschap NL; General - Central Bureau of Statistics of the Netherlands (CBS)		
iii	Trade statistics portals	• The Netherlands - Central Bureau of Statistics of the Netherlands (CBS); • EU level - EUROSTAT; • International level – FAOSTAT; UN COMTRADE; USDA Foreign Agricultural Service		
iv	Mass balance deductions	Derivations from the other sources		
v	Fragmented data, assumptions, and data aggregation	Various sources like press releases, news, reports by companies or other organizations, and scientific literature		

(Note: See details for each streams in Table A3 in Appendix).

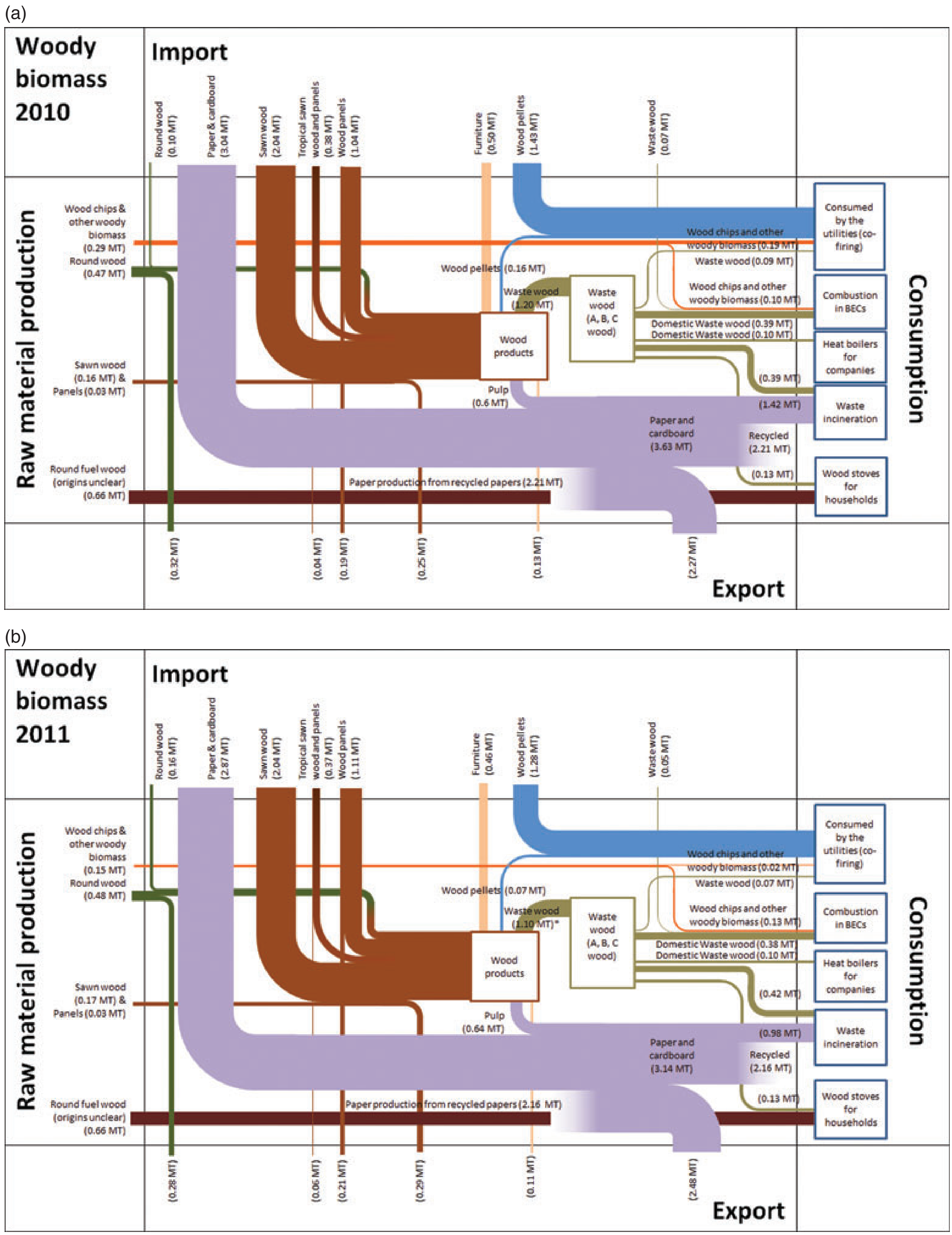
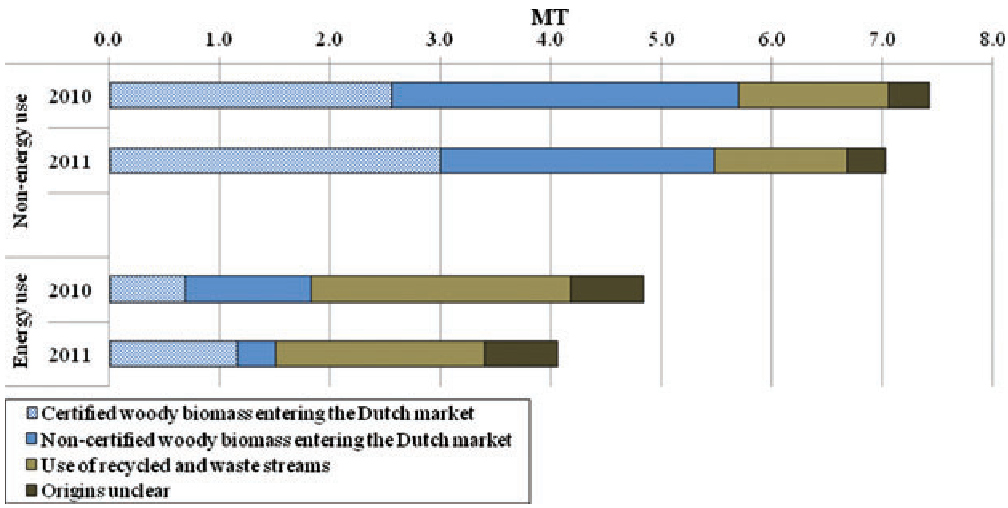


Figure 1. Mass flow diagram of woody biomass in the Netherlands in 2010 and 2011 for material and energy purposes.

 | *Biofuels, Bioprod. Bioref.* **8**:83–102 (2014); DOI: 10.1002/bbb



a. 'Use of recycled and waste streams' includes all waste wood, waste incinerations and recycled paper and cardboard.
b. 'Origins unclear' covers 'Furniture' in non-energy use and 'Round fuel wood' in energy use.
c. 'Certified-' and 'non-certified woody biomass entering the Dutch market' include all woody biomass excluding the aforementioned two categories.

Figure 2. Use of certified, non-certified, recycled and waste woody biomass in the Netherlands.

wood pellets were imported. A considerable amount of woody biomass and paper and cardboard was incinerated to generate electricity and heat. Overall mass flows did not change much between 2010 and 2011.

Figure 2 shows the share of sustainability certified woody biomass in the Netherlands in 2010 and 2011. The use of woody biomass can be divided into two main markets based on end-use:

- ***Non-energy use***: The market share of certified wood products (sawn wood and panels) for non-energy use increased from 33.5% in 2008 to 65.7% in 2011 (23.7% FSC certified and 42% PEFC certified).[10] In 2011, sawn softwood recorded the highest certified percentage: 86% of the market volume (46% in 2008), as most of this sawn softwood came from countries where 60–97% of the forest area was certified. About 57% of the certified sawn timber and 73% of the certified wood based panels was consumed by the construction sector and civil engineering. On the other hand, the share of certified paper and paperboard in the Dutch market has increased to 32.8% in 2011.[10] Most of the paper and cardboard consumed in the Netherlands was separated for recycling purposes. However, there was still a large portion of woody biomass and paper and cardboard that could not be separated and ended up in waste incineration.
- ***Energy use***: A significant change between 2010 and 2011 would be the increase of certified woody biomass for energy purpose. In 2011, most of the wood pellets were certified with sustainability schemes. Figure 3 shows the origins and the share of sustainable certified biomass used by utilities. Most of the certified wood pellets came from Canada, the USA, the Baltic states, Russia, and southern Europe. However, still more than one-third of wood pellets from western Europe was not certified. There are a few industrial sustainability schemes currently available for solid biomass, particularly for wood pellets, but many of them primarily serve the companies which developed them, such as Green Gold Label and Laborelec Label. New systems, such as NTA 8080 and ISCC PLUS, were not yet being widely applied. In the last few years, industrial pellet buyers (mainly utilities) have been working together to develop a harmonized sustainability system for wood pellets, namely IWPB*.

*IWPB is a working panel grouping the major European utilities firing wood pellets in large power plants GDF SUEZ, RWE, E.On, Vattenfall, Drax Plc, and Dong, as well as certifying companies SGS, Inspectorate, and Control Union. Laborelec participates in this work panel as a technical expert. Available at http://www.laborelec.be/ENG/initiative-wood-pellet-buyers-iwpb/

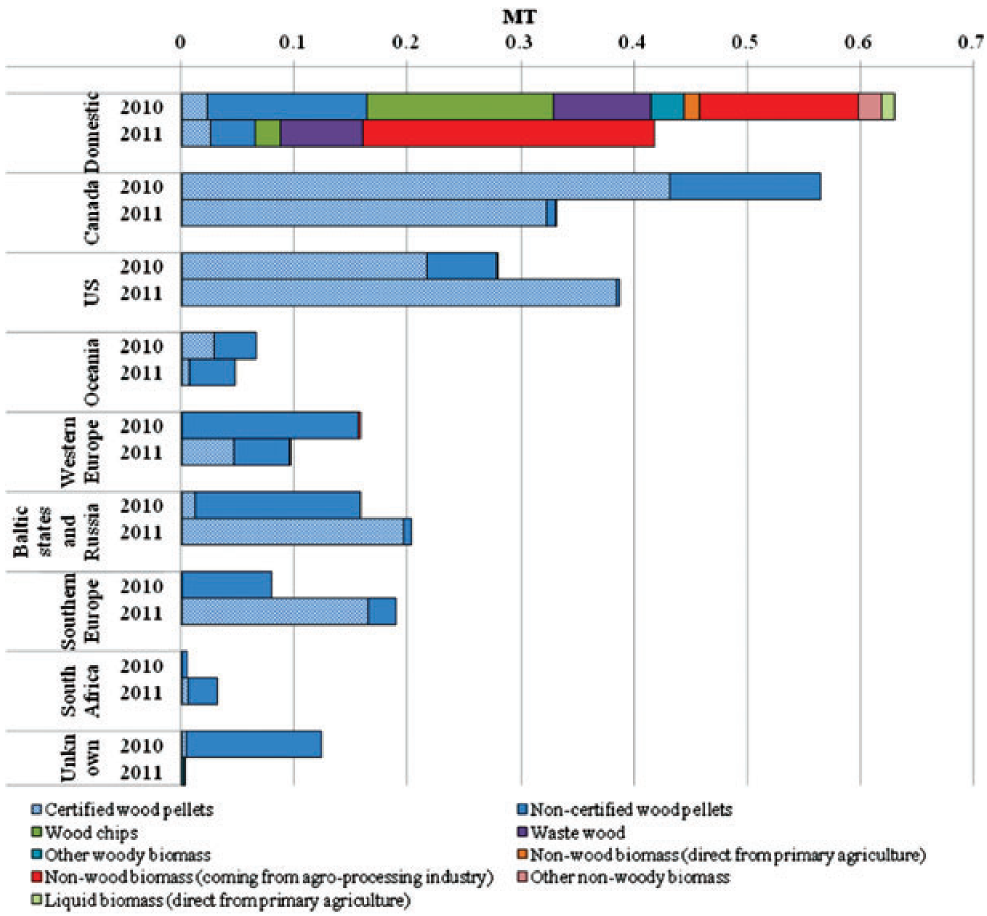


Figure 3. Biomass co-fired in the Dutch utilities in 2010 and 2011 (Source: Surveys with the utilities;[27]).

Table 2 shows the market share of sustainability schemes in each selected categories in the Netherlands. It is expected that the share of certified wood products will grow steadily. The recent focus in this category is the energy use of woody biomass by utilities, particularly wood pellets. In 2011, the percentage of certified pellets in the market was very high (almost 90%), dominated by Green Gold Label (51.8%) and Laborelec Label (33.5%).

Oils and fats

Figure 4 shows the mass balance for oils and fats flows in the Netherlands in 2010 and 2011. Different from woody biomass, the top and bottom axes indicate net import and net export instead of actual volume, to avoid the diagram becoming overcrowded with the large volume of vegetable oils transhipment. As shown in Fig. 4, soybean has the largest mass flow in this group. Strictly speaking, soy is not primarily an oil crop but used mainly as a protein source. Therefore, a relatively small portion of oil was produced while most of the mass remained as meal after processing, mainly used as animal feeds. Palm oil was the largest oil source followed by rapeseed oil, soy oil and sunflower oil. Human consumption was the most important application of vegetable oils, recording about 67% in 2011, while about 17% was used for energy purpose, about 11% for animal consumption, and the rest for technical purposes. Rapeseed oil contributed the largest share in biodiesel production. From 2010 to 2011, there were no dramatic changes in the net flows of oil seeds and vegetable oils, but substantial increase in animal fats import owing to increasing demand for biodiesel in 2011. Production of biodiesel from these streams was favored due to the double counting mechanism.[†4]

[†]The double counting mechanism is generally applied for biofuels produced from wastes, residues, non-food cellulosic material, and lignocellulosic material. These biofuels are counted double for the annual obligation of renewable transport fuels.

  | *Biofuels, Bioprod. Bioref.* **8**:83–102 (2014); DOI: 10.1002/bbb

Table 2. Market share of sustainability certification schemes in the Netherlands in 2011.

Type of biomass	Sustainability schemes	Market share (% of certified biomass per particular products group in the market)
Woody biomass: Sawn timber and wood based panels[10]	FSC PEFC	23.7% 42.0%
Woody biomass: Paper and cardboard[10]	FSC PEFC	23.9% 8.9%
Woody biomass: Wood pellets used by utilities (Self collection)	Green Gold Label Laborelec Label	51.8% 33.5%
Oils and fats: Total vegetable oils[11,12]	RSPO (Palm oil) RTRS (Soy bean)	6.7% 0.3%
Carbohydrates: Grains	VVAK Stichting Veldleeuwerik	Starts in 2012/13 Starts in 2012/13
Biodiesel[14]	ISCC 2BSvs RTRS Others	48.4% 4.9% 1.8% 9.6% The rest is double counting or unknown
Bioethanol[14]	ISCC RBSA Others	84% 4% 12%

Note:
FSC: Forest Stewardship Council.
PEFC: The Programme for the Endorsement of Forest Certification.
VVAK: Voedsel- en Voederveiligheid Akkerbouw.
RSPO: The Roundtable on Sustainable Palm Oil.
RTRS: The Round Table on Responsible Soy.
ISCC: International Sustainability and Carbon Certification.
RBSA: The RED Bioenergy Sustainability Assurance Standard.

Figure 5 illustrates the consumption trend of oils and fats for different purposes since 2008. In the Netherlands, production companies have an obligation to provide these data to Product Board for Margarine, Fats and Oils (MVO). A steady increase was observed in the total consumption volume, mainly attributed to the increasing energy use of oils and fats, i.e. biodiesel production.

Figure 6 depicts the trade balance of oil seeds and oils and fats by country or region. Net import of oil seeds reached the lowest in 2009 but bounced back in 2011. On the other hand, trade volume of oils and fats has been decreasing since 2008. Over the last few years, Brazil and the USA were the main suppliers of soybean, while Malaysia and Indonesia were the biggest suppliers of palm oil to the Netherlands. However, it was not entirely clear where the sustainable certified vegetable oils come from. Significant palm oil certified by RSPO and soybean certified by RTRS entered the Dutch market only in 2010/2011. However, the industrial players have set ambitious targets to completely shift to certified palm oil and soybean within a few years. On the other hand, starting from 2011, the Dutch government accepts only biofuels certified with sustainability schemes accepted by the Dutch government or originated from waste.

Figure 7 shows the use of certified and non-certified vegetable oils, used cooking oil (UCO) and animal fats, and fatty acids in the Netherlands. To some extent, the year 2011 can be regarded as the starting year for the significant use of sustainable certified vegetable oils in the Dutch market. In 2011, the Dutch food and feed industry imported the first batch of RTRS certified soybean, amounted to 85 ktonnes.[11] Many Dutch food manufacturers also started to import RSPO-certified palm oil with ambitious targets in the next few years. The Dutch Task Force Sustainable Palm oil (2012)[12] reported that 21% of total palm oil consumed for food purpose (about 81 ktonnes out of 385 ktonnes) in the Netherlands in 2011 was sustainable certified. It should be noted that an assumption was made in Fig. 7 that all vegetable oils used for biodiesel production in the Netherlands were 100% sustainable certified (including RSPO-certified palm oil which is not accepted by the EC but accepted in the Netherlands to demonstrate sustainability). With this assumption, about one-third of total palm oil and

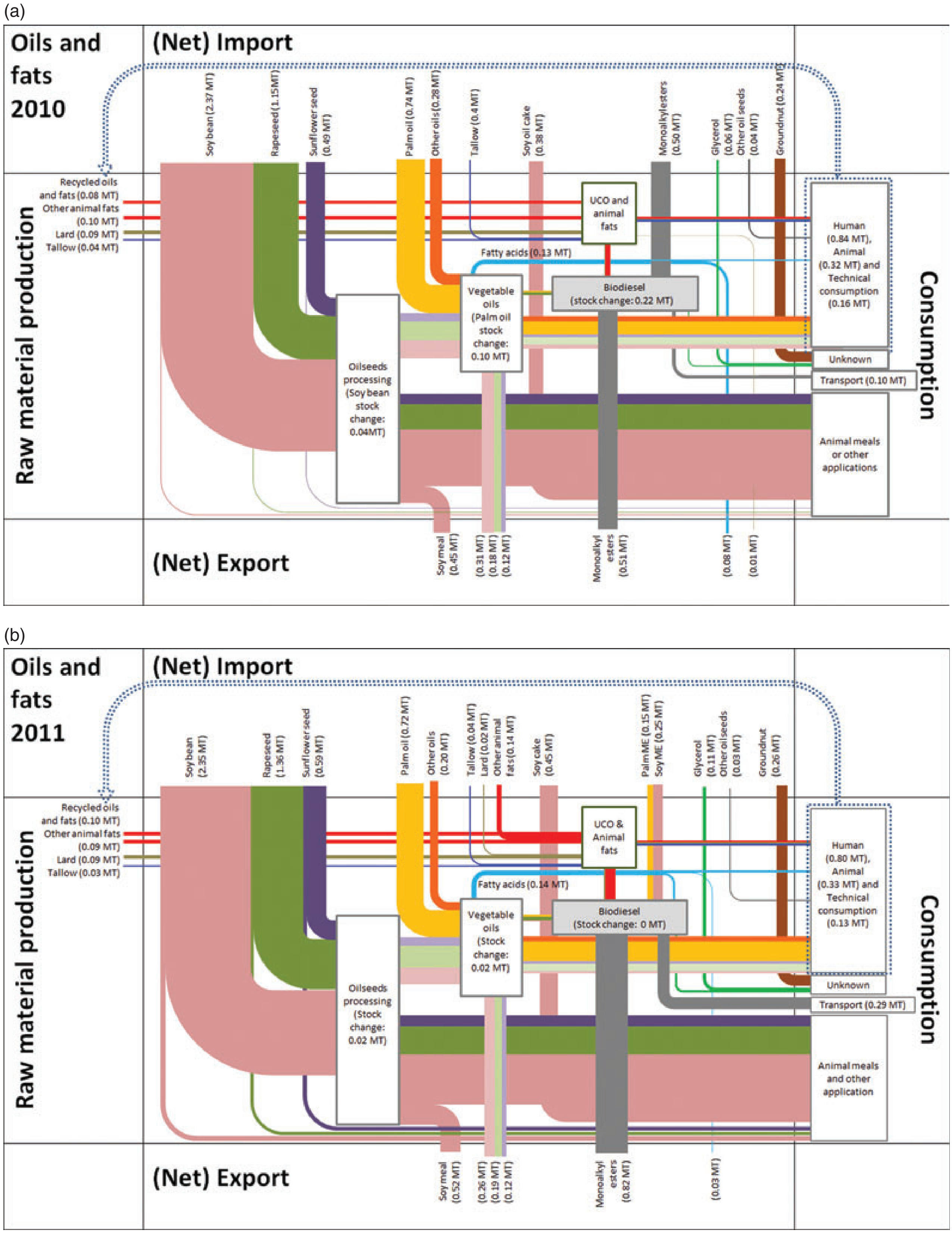


Figure 4. Mass flow diagram of oils and fats in the Netherlands in 2011 for food, fuel and other purposes.

Biofuels, Bioprod. Bioref. **8**:83–102 (2014); DOI: 10.1002/bbb

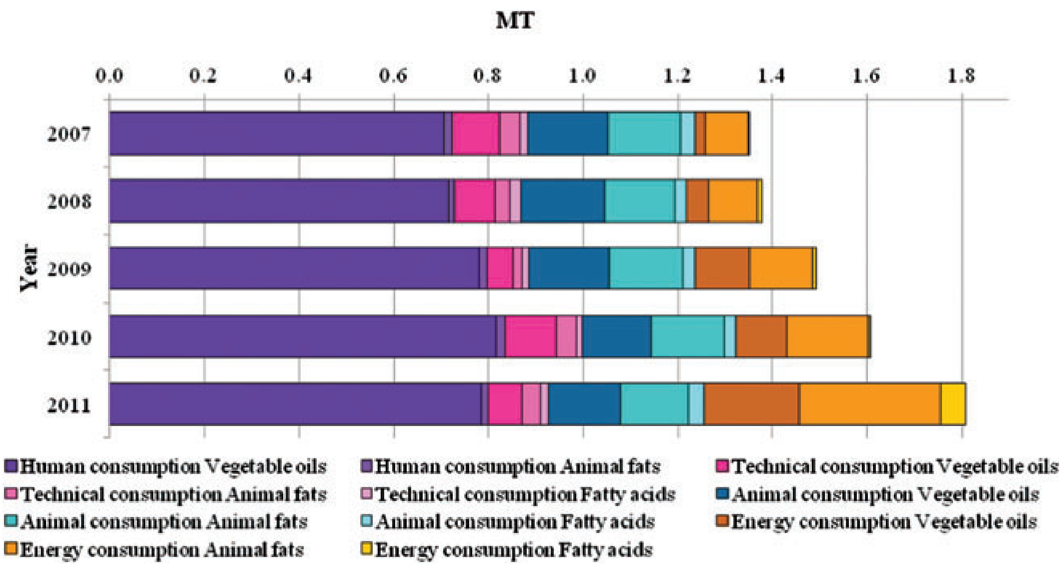
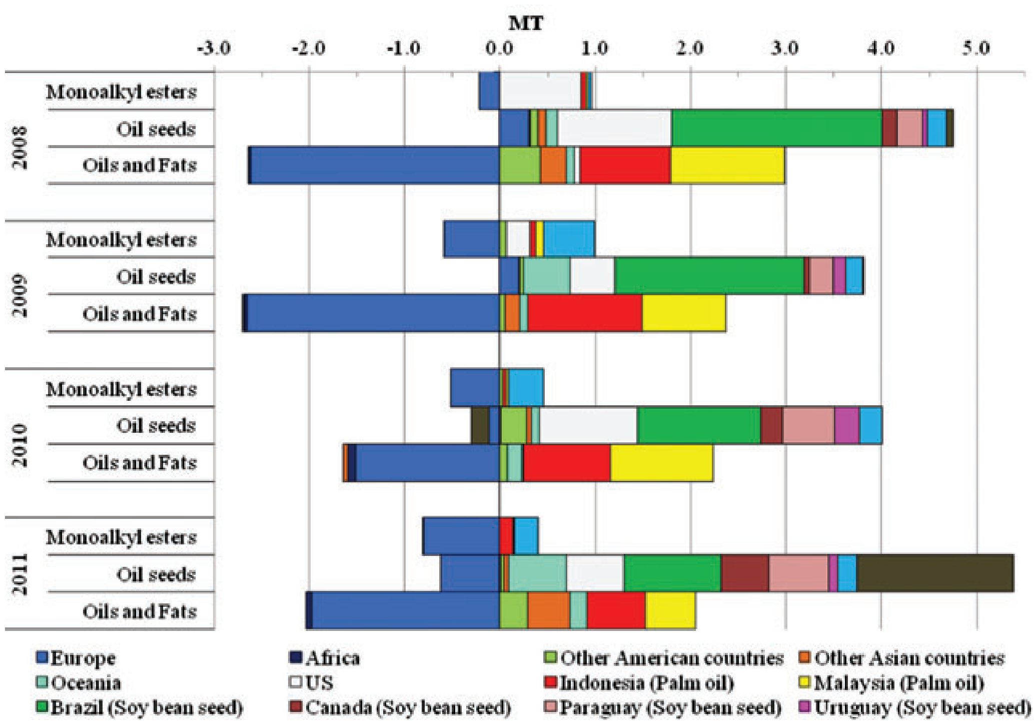


Figure 5. Consumptions of oils and fats for different purposes in the Netherlands (Source: MVO)[28] (Note: Animal fats include UCO).



a. Countries with small net trade volumes were omitted
b. Monoalkyl esters: CN 38249091(Monoalkyl esters of fatty acids, with an ester content of 96.5%vol or more esters (FAMAE))
c. Oil seeds: CN 12xxxxxx (Oil seeds and oleaginous fruits)
d. Oils and fats: CN 15xxxxxx (Animal or vegetable fats and oils and their cleavage products; prepared animal fats; animal or vegetable waxes)

Figure 6. Monoalkyl esters, oil seeds and oils and fats trade flows (net by regions) for the Netherlands from 2008 – 2011 (Source: CBS)[23].

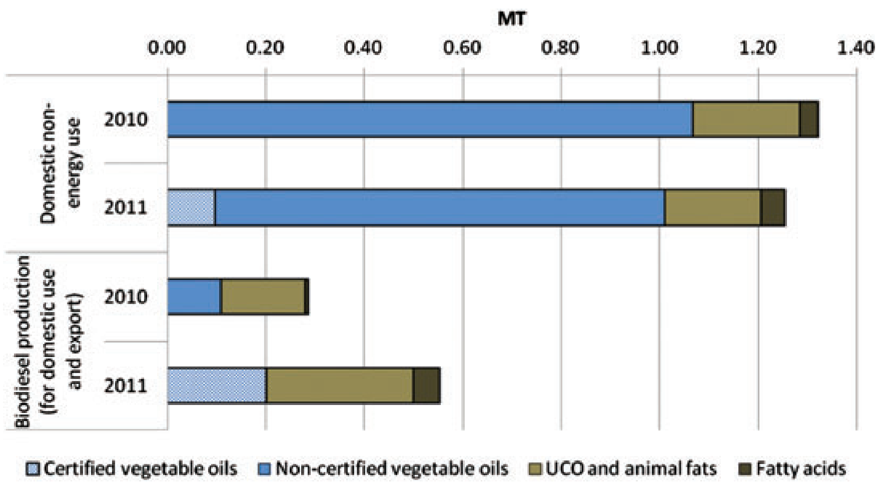


Figure 7. Use of certified and non-certified vegetable oils, UCO and animal fats, and fatty acids in the Netherlands.

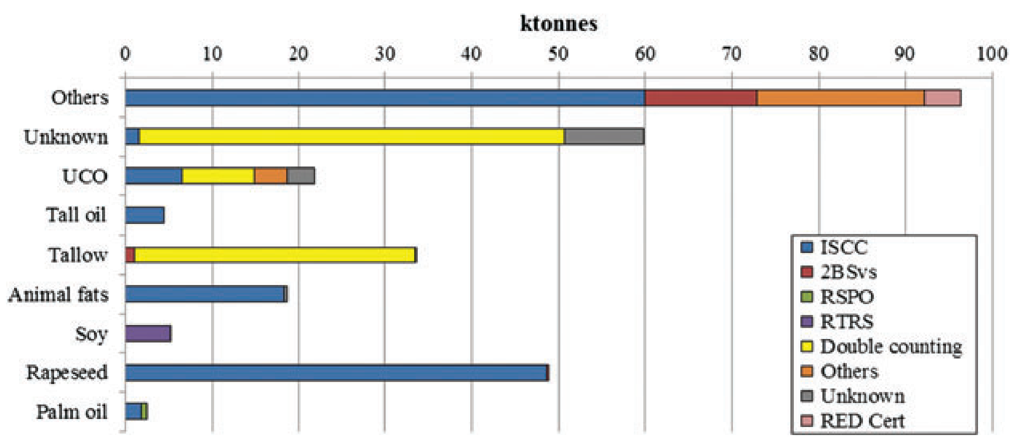


Figure 8. Sustainable certified biodiesel consumed in the Netherlands in 2011 by sustainability schemes (Source: NEa)[14].

rapeseed oil imported into the Netherlands was sustainable certified. Data for certified vegetable oils used for biodiesel production in 2010 was not available. Since there was no mandatory requirement, it was assumed that all vegetable oils used for energy purposes in 2010 were not certified.

Figure 8 shows the quantity of sustainable certified biodiesel consumed in the Netherlands in 2011 by sustainability schemes. The total consumption volume amounted to 0.1 MT and 0.29 MT, respectively, in 2010 and 2011. Biofuels consumption in the Netherlands is monitored by NEa. Data for 2010 published by NEa was reported at a highly aggregated level due to a confidentiality agreement with industrial actors.[13] The nominal share of biodiesel in total Dutch diesel consumption was 4.62% in 2011, but note that this value includes double-counted biodiesel.[14] The Dutch biodiesel market relied heavily on double counting, as double-counted biofuels contributed 40% of the compliance with the annual requirement of 4.25% for renewable energy in transportation in 2011. The largest sources of feedstock used were domestic UCO and tallow from Germany. It is unclear whether the 'Unknown' category includes UCO or not, but more than 80% of this category was counted double, and most of the 'Unknown' was reported to have Dutch origin.

Carbohydrates

Carbohydrates are widely used food staples, which can be directly used for food and animal feed, or processed to make food (bread, biscuits), beverages (beer) and feed, or industrial products such as ethanol. In addition to food and feeds, carbohydrates can also be feedstock for textiles, adhesives, and energy. Figure 9 illustrates the quantified mass flows of carbohydrates in the Netherlands in 2010 and 2011. Basically the Netherlands was able to self-supply more than half of its total carbohydrates consumption. Other carbohydrates products and sugars (e.g. white sugars) have very little flows. Maize (corn) turned out to be the largest Dutch carbohydrates source. Although the Netherlands produced relatively large amounts of maize, considerable amounts of maize were imported. Potatoes, sugarbeet, and barley were the other important sources of carbohydrates. A significant change in 2011 is that about 1.2 MT of maize and wheat were processed in the Netherlands to produce bioethanol. However, the connection shown in Fig. 9 was only for indication because the exact feedstock and destination are unknown. Besides bioethanol, it can also be used as feedstock for biogas. About 0.36 MT of maize was fermented into biogas in 2010, but this figure dropped to 0.18 MT in 2011.

Figure 10 shows the trend of ethanol trade flows. The major supplying countries were the USA, Brazil, and Guatemala. Net imports from the EU were relatively very low. The import of ethanol under the groups CN 22071000 and CN 22072000 has plummeted since 2008. The main reason lay within the CN code swap of US ethanol. Since 2009, there has been a steep increase in US ethanol entering the EU. These products were found to leave the USA as denatured (CN 22072000) or undenatured ethanol (CN 22071000), but most of those exports entered the EU as chemical compounds (CN 38249097) with lower tariffs. On the EU side (most likely on shore), petrol was added to the ethanol (the percentage of petrol varies between 10 and 15). The problem with CN 38249097 is that it is an 'other' and 'other' category, so the CN code did not clearly state what good was being classified. This means that the ethanol blend might be counted together with other goods. Hence it was difficult to trace back how much ethanol/petrol blends had really entered.[4,15] These operations and imports have happened mainly in the Netherlands, the UK, and Finland. In 2012, these bioethanol blends were reclassified to a higher tariff rate, and trade of ethanol from the USA to Europe slowed dramatically. However, it was not sure in the long term how this would impact imports from the USA, due to the fact that in 2012 EU domestic production was still insufficient and Brazilian ethanol was more expensive for the EU market.[16]

For carbohydrates, which differ from woody biomass and oils and fats, there were no specific sustainable certifications over the years, although sustainability schemes were applied to bioethanol derived from carbohydrates. Most carbohydrates consumed in the Netherlands originated from Europe and mostly produced according to the EU's environmental regulations, and therefore the demand for separate sustainability certification was not so strong (the focus was on the other concerns, such as organic food labels). In recent years sustainability has been an important consideration in the Dutch food industry, and included in the procurement policies of many food companies. Companies generally purchased sustainable supplies through bilateral agreements by providing suppliers with a set of rules and criteria to follow. However, in 2012, there were efforts to put sustainability certification on Dutch grains (more precisely on farming practices), namely VVAK and Stichting Veldleeuwerik.[17,18] It is expected to see some sustainable certified grains in the Dutch market in the near future. For the energy use of carbohydrates, bioethanol derived from carbohydrates was mainly imported. Similar to biodiesel, starting from 2011, only sustainable certified bioethanol enters the Dutch market. In addition to the co-digestion of maize, small-scale biogas production from potatoes was also observed in the Netherlands under the Green Deal, but the involvement of certification schemes is not expected in the near future.

Figure 11 illustrates the Dutch bioethanol consumption in 2010 and 2011 by schemes. Differing from biodiesel, which has a diverse source of feedstock and origins, the majority of the bioethanol consumed in the Netherlands originated from US maize. Maize ethanol dominated with about 40% and even 90% of market share in 2010 and 2011, respectively. This was followed by ethanol made from Brazilian sugarcane and French wheat, but in 2011 both streams plummeted drastically. This was mainly because the Brazilian domestic bioethanol market had absorbed most of the Brazilian sugar cane ethanol. Meanwhile the decrease of French wheat ethanol was probably caused by bad harvest in 2011 – feedstock price was high and production of bioethanol from cereal was less attractive.[16,19] The Netherlands may continue to become a hub for biofuels blending and further distribution, as well as production since its large seaports provide easy access to feedstock. Abengoa Bioenergy's bioethanol plant in Rotterdam can produce 480 million liters of bioethanol annually from 1.2 MT of maize or wheat cereal as feedstock. It also produces 0.36 MT of distilled grains and solubles (DGS) which can be used as animal feed.[20] On the other hand, in 2012, Cargill also added 380 million liters of annual

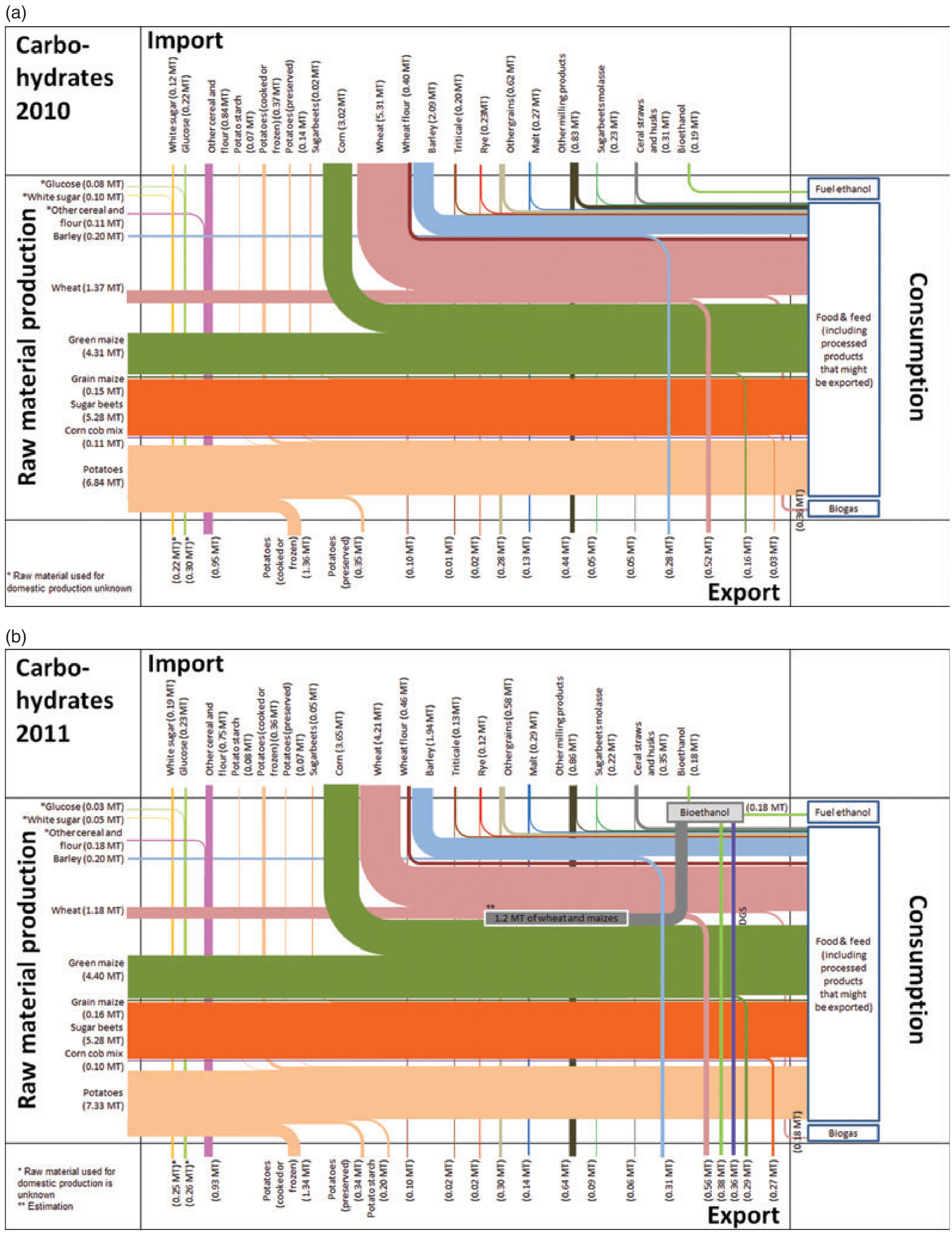
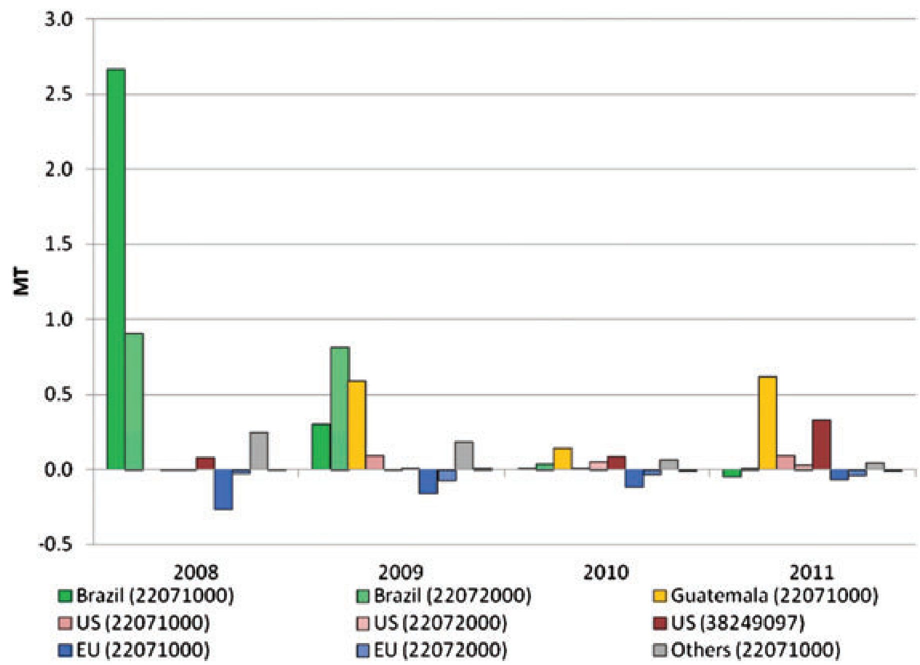


Figure 9. Mass flow diagram of carbohydrates in the Netherlands in 2010 and 2011.

 | *Biofuels, Bioprod. Bioref.* **8**:83–102 (2014); DOI: 10.1002/bbb



a. CN 22071000: Undenatured ethyl alcohol of actual alcoholic strength of >= 80%
b. CN 22072000: Denatured ethyl alcohol and other spirits of any strength
c. CN 38249097: Fuel ethanol from the USA was found registered as 38249097 upon arriving in the EU.

Figure 10. Ethanol trade balances (net) of the Netherlands for 2008 – 2011. (Source: CBS)[23].

starch-based ethanol production capacity to its wheat wet-mill in Bergen op Zoom. The facility can process 0.6 MT of wheat annually.[21] Unfortunately, it is not publicly known where they source the raw materials and where they supply the bioethanol to.

Discussion, conclusions, and recommendation

Case study summary

Woody biomass

As the use of woody biomass for energy purpose is getting more important in the Netherlands, a number of monitoring activities have been carried out. Among the woody biomass streams, the large-scale use of wood pellets by power companies is easier to monitor due to its large volume and small number of users. Furthermore, starting from 2013, there will be a mandatory reporting system on the sustainability of biomass used for large-scale energy generation through the Green Deal agreement between the government and the power companies.[22] However, it seems more difficult to assess the other streams due to the lack of proper reporting systems (smaller and more complicated flows), especially the waste wood streams. The measurement of municipal waste streams composition is also outdated and less reliable. In terms of sustainability assessment, the share of certified woody biomass for non-energy use is only known for 2008 and 2011, given the fact that the market study performed by Probos is not continuous.[10] Nevertheless, with the available information, (near to) complete cradle-to-grave (raw wood to combustion) flows of woody biomass can be illustrated.

Oils and fats

The use of oils and fats in the country has been monitored by MVO in the past few years at a relatively high level of detail. Companies in the oils and fats sector have a legal obligation to provide statistical data about their international trade in oils and fats products. The Netherlands has also been actively promoting sustainability certification of vegetable oils through various initiatives such as IDH, and the latest development is available publicly on the website. The biggest challenge at the moment lies within the connection between the administrative biofuels data

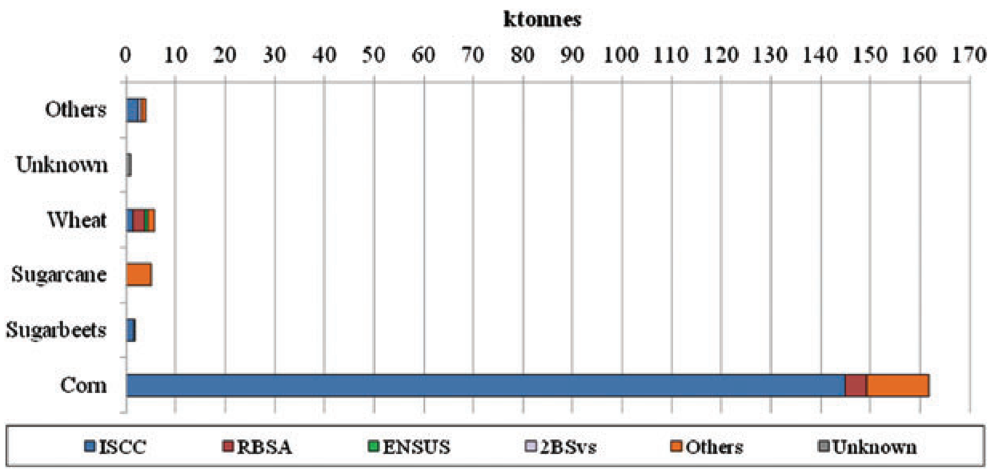


Figure 11. Sustainable certified bioethanol consumed in the Netherlands in 2011 by schemes (Source: NEa)[14].

reported for renewable fuels targets and the feedstock flows. Also, it is not entirely clear how monoalkylester streams recorded in the trade statistics can be linked to the biofuel streams.

Carbohydrates

Due to difficulties in quantifying specific biomass components after secondary processing, assessment of this category was limited to primary feedstock only. Most data can be found on national statistics (CBS) (both general agriculture and trade statistics). The sustainability certification of carbohydrates is still in its infancy, except for specific streams used as feedstock for bioethanol. Similar to oils and fats, the biggest challenge is to link the feedstock streams to the bioethanol streams. There are also some issues with the trade statistics of ethanol.[4]

Methodological discussion and conclusions

Seeing the need to understand not only the mass flows but also the share of sustainable certified biomass, five major challenges that need to be addressed were identified through this work:

(i). Data definitions: administrative data versus actual physical data

Data collected for administrative purposes do not necessary equal the actual physical flows due to various administrative reasons:

- Definitions used are different from the CN codes
- Definitions differ between organizations
- Definitions differ as the administrative rules change over time
- Delayed or early reporting
- Considerations of indirect trade flows (administratively reporting the origins of goods as either where the goods are produced, or where the goods are imported from through re-export/transhipment)
- Other internal or external considerations

These phenomena are rather prominent for biofuels, reflected in the discrepancies found between data reported by different monitoring bodies. Currently, the reported consumption of liquid biofuels is different from the actual physical situation. First, for administrative purposes, companies are allowed to carry over their physical efforts to later years. Second, companies may administratively allocate a low-blend biofuel to the Dutch market, but physically (part of) this low blend is exported. For comparison, CBS reported biodiesel consumption at 0.11 MT and 0.20 MT (in 2010 and 2011, respectively),[23] whereas the monitoring body NEa reported 0.10 MT and 0.29 MT (in 2010 and 2011, respectively).[13,14] Sustainability of biomass and bioenergy is important in the context of carbon mitigation policies. This phenomenon causes potential barriers to assessment of GHG emission reduction at sectoral or national level especially when it involves large trade volumes consisting of both sustainable certified and non-certified biomass. The risk of confusion seems very high due to data inconsistency between countries and sectors when different reporting systems are employed.

(ii). Lack of coherent cross-sectoral reporting system

Each reporting system usually has a very specific scope and interest in certain biomass or specific products, and

  | *Biofuels, Bioprod. Bioref.* **8**:83–102 (2014); DOI: 10.1002/bbb

seldom covers cross-sectoral flows. Taking liquid biofuels as an example, although the origin of biofuel was reported, it is not known explicitly whether the biofuel was produced domestically using imported feedstock, imported directly from the feedstock-producing country, or imported from a third country. The timing of production and consumption, and their relationship with the feedstock flows remain unclear. This has resulted in the unknown composition of biodiesel flow in Fig. 4 (shown in grey), because it cannot be matched with data from the oils and fats sector. On top of that, it also causes difficulty to deduct the sustainable share of biomass flows across sectors. Although in the Netherlands some monitoring bodies that cover conventional use of biomass such as MVO (oils and fats) and Probos (woody biomass) have started to include energy use of biomass in their reports, again this is fraught with the same problems as in point (i). Overall, the data consistency of biomass flows still needs improvement, and this requires more alignment between monitoring bodies from different sectors

(iii). Reliability of bilateral trade statistics

Significant discrepancies between bilateral trade statistics of biomass reported by exporting and importing countries were noticed, especially for intra-EU trade statistics on the EUROSTAT portal. To ensure that a more consistent set of data is used, data reported by the case study country were given priority to match with other data collected in the country, but this led to different results between country analyses. Vice versa, reconciliation of the bilateral trade statistics may cause inconsistency with other data reported in the country. Besides that, in this study, international trade statistics also show significant discrepancies with other data sources. For the Netherlands, discrepancies were found in the case of wood pellets when comparing Eurostat with own data collection (directly from the industry), showing differences in net trade balance up to 55 ktons per country for the year 2011. The reasons of these discrepancies are multi-fold, but similar to those listed in point (i). The situation is even more complicated in the Netherlands considering the large volume of transhipment and re-export. Various efforts have been made to understand and reconcile the discrepancies in general trade statistics.[9,24] For bioenergy, a few studies have pointed out that the current CN codes do not differentiate the end-use purposes of the materials between energy use and raw material use. Moreover, more than one product might be included under one CN code. A prominent example is ethanol which is used as transportation fuel and for raw material purposes in the chemical industry. Ethanol is categorized under several different CN codes based on its forms and blending level but not the end uses.[7,8]

(iv). Lack of transparency in biomass supply chain

One of the biggest barriers to overcome is the transparency of biomass flows. Currently, the degree of transparency of supply chains is considered low, not only for bioenergy, but also for conventional biomass chains, with only a few companies willing to publicly identify their biomass suppliers.[25] Most of the companies' reports are incomplete, for example revealing only the percentage of sustainable certified vegetable oil consumed by a company in its annual sustainability report, but without giving any concrete information in volumes, origins, destinations, and timing. Companies tend to withhold information (particularly trade information) to protect their business interests. This is further exacerbated when it comes to the question of the sustainability of biomass, which is regarded as a very sensitive issue for private companies. Nevertheless, in the Netherlands, the reporting of liquid biofuels consumption is getting more transparent, as more details were revealed in 2012 compared 2011.[13,14] However, the actual situation of liquid biofuels production in the country remains unclear. There is no publicly available knowledge on the actual sources of feedstock (for bioethanol production) and supply destinations (for both bioethanol and biodiesel production), resulting in a few speculative streams in Fig. 4 and Fig. 7 (illustrated in grey). On the other hand, solid biofuels users will also have to report annually to the government on the amount of biomass they use and how sustainability is demonstrated via certification or verification systems.[22] However, the level of details of this reporting system will only be revealed when the report is published.

(v). Disparity in sustainability requirements

At present, numerous sustainability certification schemes are being developed or implemented by a variety of private and public organisations with different interests, purposes, and target groups. While there are many years of experience for certification of woody biomass with sustainable forestry management schemes, it is worthwhile pointing out that in 2011, the sustainability certification of solid biofuels, liquid biofuels, and vegetable oils for human consumption significantly increased as shown in Figs 2 and 7. However, the systems in this wide range of schemes, developed largely without coordination among the organizations involved, are mostly incompatible in many aspects, especially the measurement of GHG emissions reduction. For example, industrial schemes for wood pellets do take GHG emissions measurement along the supply chain into account, but sustainable forest management schemes do not. Similarly, certification of vegetable oils used for biofuels production does employ the Renewable Energy Directive (RED) criteria but certification of vegetable oils used in food sectors does not. There are also differences between schemes applied in different countries. This disparity in sustainability requirements makes the comparison between supply chains, sectors, and countries very challenging.

To sum up, this work has explored various issues in monitoring biomass flows for a bio-based economy by taking the Netherlands as a case study, and identifying the key challenges. Points (i) to (iii) have to be addressed mainly quantitatively, while point (iv) is a qualitative issue, and point (v) needs to be viewed from both qualitative and quantitative aspects. The case of liquid biofuels in point (i) is considered an administrative issue as it stems mainly from current legislative frameworks. The period between 2010 and 2012 is regarded as a transition period for the use of sustainable certified biofuels in the EU. Improvement in the level of detail was observed. It is recommended that in the future actual physical data should be used for reporting purposes to ensure a sound basis for further analysis. This could be achieved using a track-and-trace system through certification systems. An example is the Renewable Identification Number (RIN) system[‡] used in the USA that provides information on the volume of renewable fuel produced in or imported to the United States, allowing tracking of physical flows after going through the distribution system and ownership changes. Addressing point (ii) could be costly at the initial stage because additional efforts have to be made for data collection and compilation. However, with the wider application of sustainability certification, information should be available together with the certificates (if a track-and-trace system is applied), and hence additional efforts in collecting data can be reduced, provided the companies are willing to reveal the information. The methodology framework proposed in this work also shows possibilities in connecting cross-sectoral flows by assembling available data and conducting mass balance deduction. Point (iii) is not a new topic for trade statistics, and has already been discussed at least 30 years ago.[26] To ensure consistency for analysis across countries, it is recommended to improve the CN codes for bioenergy, and use a common reconciliation approach on bilateral trade statistics. Point (iv) could be addressed by monitoring bodies or official statistics portals through administrative dimension, such as providing guarantees for the individual business that the confidential information will not be misused in the course of creating aggregate statistics from the original records. On the other hand, social pressure has also been forcing the companies to reveal more information on biomass supply chains. Point (v) is considered the most difficult technical issue at the moment, with dozens of ongoing discussions on sustainability criteria, such as the applicability of universal criteria at local level. Moreover, in a broader scope of bio-based economy, there is also a need for harmonization of criteria regardless of end-uses. As observed in the bioenergy sector, harmonization process could be carried out with both top-down (at regulatory level) and bottom-up approach (at industrial level).

Notwithstanding the issues cited, the results of this work show the opportunity for constructing a monitoring framework at EU level by using the methodology proposed, but the aforementioned challenges have to be addressed adequately to ensure sound assessments.

Recommendations for future research

The present study provides a basic quantification methodological framework of biomass in the broader scope of a bio-based economy. Possible further research activities are recommended below:

(i) ***Benchmarking of reporting systems***: As revealed by this study, there are many shortcomings in the current biomass and biofuels reporting systems. There is a need to further address the issues of data definitions in different systems (e.g. for the case of biofuels), inconsistencies within a system (e.g. trade statistics), as well as transparency in data flows from industries and bilateral agreements, not only at the national level but also at EU level.

(ii) ***Future projection of biomass flows***: The impact of altering mass flows in a bio-based economy on existing supply chains is not known. With this methodology, scenarios can be built to display how mass flows will change when certain flows are altered, added, or removed from the big picture, and to provide insights into quantitative impacts from three aspects: cross-border flows, domestic flows, and sustainability certification.

‡A RIN is a 38-character numeric code that corresponds to a volume of renewable fuel produced in or imported into the United States. RINs remain with the renewable fuel through the distribution system and ownership changes. Once the renewable fuel is blended into a motor vehicle fuel, the RIN is no longer required to remain with the renewable fuel. Instead, the RIN may then be separated from the renewable fuel and used for RFS compliance, held for future compliance, or traded. Available at: http://www.ers.usda.gov/media/138383/bio03.pdf

  | *Biofuels, Bioprod. Bioref.* **8**:83–102 (2014); DOI: 10.1002/bbb

(iii) ***Accounting for GHG emissions associated with biomass flows***: At the moment, the substitution effects between sectors due to new demand (e.g. food versus biofuel), particularly the impacts on overall GHG emissions reduction, and are not adequately addressed in quantitative unit. Likewise, the emissions adhered to in the imported/exported biomass are not taken into account in any national emissions reporting. On top of the mass flows, this framework can be further developed to assess allocation of emissions by examining emissions attached to physical biomass flows in two dimensions, i.e. domestic and international flows. This work can also be combined with (ii) to show the impact on national emissions reduction in different scenarios.

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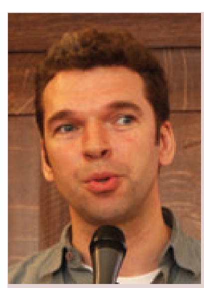

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