Monitoring the flows of biomass residues in the Netherlands

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De Materiaalmonitor van het CBS toont fysieke materiaalstromen (zoals mineralen, staal, biomassa) van, naar en binnen de Nederlandse economie voor een bepaald jaar, maar hierin zijn stromen van biomassaresten nauwelijks zichtbaar. Het doel van deze KB1-1B-studie is om het aanbod en de vraag van de belangrijkste biomassaresten, evenals hun inhoudsstoffen (zoals C, N, P), te kwantificeren en data daarover te implementeren in de Materiaalmonitor. Dit geeft inzicht in ongewenste lekken naar het milieu (bodem, lucht, water) die samenhangen met het aanbod en gebruik van biomassa, en laat ook kansen zien voor nieuwe, circulaire businesscases om biomassaresten efficiënter te benutten.

The Material Flow Monitor of CBS shows how different sorts of materials (e.g. minerals, steel, biomass) flow to, within and from the Dutch economy; however, flows of especially biomass residues are insufficiently captured. The aim of this KB1-1B study is to quantify the supply and use of the main biomass residues, as well as the individual components they consist of (such as C, N, P), and embed these details in the Material Flow Monitor. This increases the insight into unwanted leakages to the environment (soil, air, water) due to the supply and use of biomass, and shows opportunities for potential new circular business cases to use biomass residues more efficiently.

Key words: biomass flows, residues, circularity, material flow monitor

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Preface

The KB34-001-001 programme has developed a conceptual assessment framework to determine if the technical, ecological and socio-economic systems are moving towards a circular and climate-neutral society. It has a focus on the bioeconomy and is meant to provide structure to different projects within the KB34 programme and helps to find answers for WUR and its clients. The transition of current linear production chains in the bioeconomy to climate-positive and circular production chains requires a system data analysis tool for monitoring and impact evaluation.

This KB-1B study, being part of the KB34-001-001 programme, has taken the Material Flow Monitor of Statistics Netherlands as starting point for developing a tool that can monitor circularity in the bioeconomy. That Material Flow Monitor shows how different sorts of materials flow to, within and from the Dutch economy, but has as drawback that flows of biomass residues are hardly captured and therefore the Material Flow Monitor is insufficiently capable to monitor the development towards a circular bioeconomy. Our KB-1B study has identified and quantified the supply and use of biomass resources and associated residues, and developed an approach to embed such new information in the existing Material Flow Monitor of Statistics Netherlands. As a result, the developed WUR version of the Material Flow Monitor increases the insight into wanted or unwanted leakages to the environment (soil, air, water) due to the production, processing and consumption of biomass, and can better identify potential circular business cases that use biomass residues more efficiently.

We would like to thank Statistics Netherlands colleagues for sharing their approach with WUR and giving access to an aggregated digital version of their Material Flow Monitor. We are also grateful for their time to discuss with us options how and where to bring in more detail on biomass flows in the Material Flow Monitor.

The identification, gathering and quantification of technical and socio-economic data on a heterogeneous set of biomass resource flows has been a joint effort of sector and data experts from Wageningen Environmental Research, Wageningen Marine Research, Wageningen Plant Research, Wageningen Livestock Research, Wageningen Economic Research, and Wageningen Food and Biobased Research.

Finally, we would like to thank Jan Broeze from Wageningen Food and Biobased Research for the review and useful comments, the KB34 MAST programme (KB34-004-001) for funding the publication process, and everyone who has further contributed to the preparation of this report.

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Summary

S.1 Introduction

The increasing global demand for food, feed, biomaterials and bioenergy resources could lead to exacerbating pressures on natural resources and demand/supply conflicts. The International Bioeconomy Working Group (FAO, 2019) sees the application of circularity to a biomass value chain as the only way forward to make the bioeconomy sustainable. It follows the 9R approach which refers to (Ellen MacArthur Foundation, 2013):

- A useful application of materials (recover and recycle).
- An extended lifespan of products and their parts (repurpose, remanufacture, refurbish, repair, re-use).
- A smarter product use and manufacture (reduce, rethink, refuse).

A biomass value chain is considered to be sustainable if all components in the produced, collected, processed and consumed biological resources are reused, recycled and/or recovered and the waste is reduced to a minimum. These components can consist of materials, nutrients, water and energy. Increased circularity would help to mitigate the environmental impacts of increasing demand for biomass by easing the competition between different biomass applications, reducing greenhouse gas emissions associated with material use and correcting geographical imbalances in nutrient and carbon flows.

To get insight into which biological resources are supplied and used sustainably and which bring unwanted leakages to the environment it is essential to understand where and how biomass types flow through an economy and which features these types inherit. Statistics Netherlands (CBS) has developed a Material Flow Monitor (MFM) for the Netherlands that shows how different sorts of materials flow to, within and from the Dutch economy. PBL, CBS and RIVM use it as tool for monitoring the development towards the *circular economy* in the Netherlands (Potting et al., 2018). However, when it comes to monitoring the development of the *circular bioeconomy*, an MFM is less applicable because flows of biomass residues are hardly captured. The aim of our KB-1B study is to identify, quantify and store supply and use data for a wide range of biomass resources and associated residues, and to develop an approach to embed such additional information in the existing MFM of CBS. The resulting WUR version of the MFM can provide better insight into wanted or wanted leakages to the environment (soil, air, water) due to biomass resources, and identify potential new circular business cases that use biomass residues more efficiently and reduce waste to a minimum.

S.2 Main results

A procedure has been developed that partitions biomass over organs to the full possible detail, for example crops are partitioned over amongst others fruits, leaves, stems and roots. This level of detail is essential for identifying and quantifying the important types and amounts of primary residues produced in the Dutch primary sector. It also shows how policy and business could respond in strengthening the development of a sustainable circular bioeconomy.

Newly identified biomass residue sub-categories, not yet reported in public statistics, are coded via a hierarchical system that:

- Builds on existing CPA coding system, which fits international standards of coding products, but has been extended with extra digits to specify detailed product residues connected to the raw biomass product at stake. These extra digits express the rich biomass data detail available at WUR.
- Contains connections to the industry that supplies the biomass considered, similarly as CPA codes.
- Fits preferred reporting detail on crops, animal products and aquatic products.

- Captures not only the raw, processed and retailed biomass products, but also its connected residue products (respectively primary residue products, secondary residue products and tertiary residue products).
- Includes the full possible detail of biomass products in concept, though in practice it depends on data availability whether a product can be quantified, e.g. in terms of production volume or price. Furthermore, if data collection about a particular product is not yet taking place, it may appear within statistics in the future in case the product becomes more important.

The supply and use of newly identified and coded biomass residue sub-categories are estimated by connecting existing statistics on the main product (reported by CBS and Eurostat) with conversion factors or shares (mostly obtained from literature) to estimate different types and amounts of product residues as well as their components. These estimated values of the new biomass residues are stored in a data warehouse, and can next be transferred into the MFM or be used for other projects.

The MFM of WUR is consistent, transparent, comparable, balanced and replicable, which all are relevant requirements for a monitoring system. Furthermore, it contains indicators that measure circularity in the bioeconomy, as well as indicators that can analyse the impacts of the circular bioeconomy on sustainability dimensions.

Finally, the developed approach has been illustrated for *straw*, which is the main cereal residue in the Netherlands. It departs from the calculation of aboveground residual biomass production, and takes into account import and export of straw, and the main uses and related end-of life uses of straw. Detailed straw flow data are stored in the data warehouse and accordingly transferred into the MFM. Circularity options of straw are visualised via Sankey diagrams. The same procedure is applicable for any biomass residue type.

S.3 Methodology

CBS has developed an MFM that shows how different sorts of materials (e.g. minerals, steel, biomass) flow to, within and from the Dutch economy. This KB-1B study takes the MFM as backbone for generating a framework that can monitor biomass flows in particular and make it useful for business and policy analysis. Before the tool can be assessed for that purpose, efforts must be undertaken to incorporate more detailed bioeconomy-related flows as especially *biomass residues* are hardly captured in the original MFM. The left-hand side of Figure S-1 shows the existing framework of the CBS version of the MFM. The right-hand side shows the WUR version of the MFM which should also cover flows of detailed biomass products and associated residues.

The process of getting an enhanced MFM consists of the collection, quantification and storage of data on type and amount of 1) primary crop, animal and aquatic residues produced in the Dutch primary sector and 2) secondary and tertiary residues produced by industries and households. Data on primary residues are not systematically collected at the level required for business and policy perspectives, and a good quantification system is absent. Likewise, the systematic collection of data on secondary residues is incomplete, inaccessible and not systematically collected either. For tertiary residues which includes mostly waste, the information is collected at both national and municipal level. This is usually classified according to fixed predefined categories, but information on the exact composition of waste, particularly the organic and non-organic share is missing.

Our conceptual approach starts with the systematic partitioning of biomass over organs to the full possible detail, for example crops are partitioned over leaves, stems and roots. This detail is essential for identifying and quantifying the important types and amounts of primary residues produced in the Dutch primary sector. Consequently, several new biomass residue sub-categories are identified, which are not yet in statistics but should get numbers. The second step of the approach is to code these new biomass categories via a hierarchical system that aligns with existing international product coding standards (especially NACE and CPA). Third, the quantification of the new biomass products takes existing statistics on the main product (reported by CBS) as starting point and connect these to conversion factors or shares (from literature) to estimate different types and amounts of product residues. Finally, both the newly identified biomass sub-categories and calculation rules to give numbers to the new products are systematically stored in a data warehouse. Tailor-made programs guarantee a smooth and gradual transfer of the CBS version of the MFM into the WUR version of the MFM that has more detail on supply and demand of biomass residues. Apart from this, the storage in a warehouse ensures regular data updates that can be conveyed for a wider use in studies that monitor the progress of the circular bioeconomy.

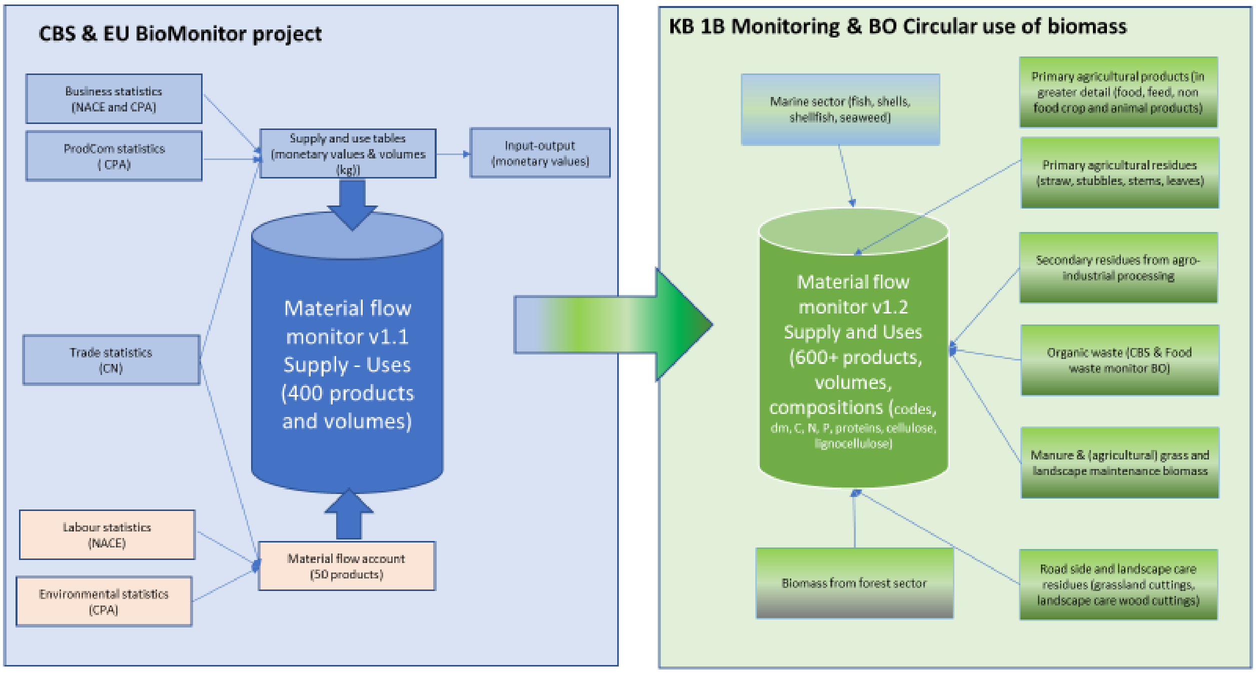

Figure S-1 *MFM development towards a wider and more detailed coverage of the bio-based economy*
Source: Authors.

Samenvatting

S.1 Inleiding

De toenemende wereldwijde vraag naar voedsel, diervoeders, biomaterialen en bio-energie vergroot de druk op natuurlijke hulpbronnen en hoe die het efficiëntst te benutten. Rekening houdend met de 9R-benadering van de Ellen MacArthur Foundation (2013) ziet de International Bioeconomy Working Group (FAO, 2019) ziet het circulair maken van biomassawaardenketens als kansrijke manier om de bio-economie te verduurzamen via:

- Het nuttig toepassen van materialen (terugwinnen en recyclen).
- Het verlengen van de levensduur van producten en hun onderdelen (hergebruik, revisie, renovatie, reparatie).
- Een efficiënter aanbod en gebruik van producten (verminderen, heroverwegen, weigeren).

Een biomassawaardeketen is duurzaam als alle componenten van geproduceerde, verzamelde, verwerkte en verbruikte biologische hulpbronnen worden hergebruikt, gerecycleerd en/of teruggewonnen en afval tot een minimum wordt beperkt. Voorbeelden van die componenten zijn materialen, voedingsstoffen, water en energie. Bij een toenemende vraag naar biomassa kan circulariteit resulteren in lagere milieueffecten. Vanwege een verminderde concurrentie tussen verschillende toepassingen van materialen zullen broeikasgasemissies regionale nutriënten- en koolstofoverschotten verminderen. Om te weten welke hulpbronnen duurzaam worden geproduceerd en gebruikt en waar er ongewenste lekken naar het milieu zijn, is kennis nodig over hoe biomassa door een regionale economie stroomt en wat de kenmerken van biomassa zijn. Het Centraal Bureau voor de Statistiek (CBS) heeft voor Nederland een Materiaal Monitor ontwikkeld die laat zien hoe verschillende soorten materialen naar, door en vanuit de Nederlandse economie stromen. PBL, CBS en RIVM gebruiken deze Materiaal Monitor als instrument om de ontwikkeling naar de *circulaire economie* in Nederland te monitoren (Potting et al., 2018). Voor het monitoren van de *circulaire bio-economie* is de Materiaal Monitor echter minder geschikt omdat het weinig inzicht geeft in de stromen van biomassaresiduen. Het doel van de KB-1B-1-studie is het identificeren, kwantificeren en opslaan van aanbod- en gebruiksgegevens voor een breed assortiment aan biomassa soorten en aanverwante residuen. Dit rapport beschrijft de ontwikkelde methodiek om dergelijke informatie te integreren in de CBS-versie van de Materiaal Monitor. De uitgebreide WUR-versie van de Materiaal Monitor geeft zo inzicht in de stromen van een breder assortiment aan biomassasoorten, en brengt ook nauwkeuriger de (on)gewenste milieulekken (naar bodem, lucht en water) in kaart die met aanbod en gebruik van biomassa samenhangen. Daarnaast identificeert het kansen voor circulaire bedrijfsmodellen om biomassa(residuen) efficiënter te gebruiken en afval tot een minimum te reduceren.

S.2 Belangrijkste resultaten

Een methode is ontwikkeld die biomassasoorten partioneert naar onderdelen; bijvoorbeeld gewassen zijn gespecificeerd naar onder andere vruchten, bladeren, stengels en wortels. Een dergelijk detail is belangrijk voor goede identificatie en kwantificatie van soorten en hoeveelheden primaire residuen geproduceerd door de Nederlandse primaire sector.

Een methode die biomassatypes (zoals residuen) waarover openbare statistieken nog niet rapporteren, een unieke productcode geeft via een hiërarchisch systeem. Dat systeem:

- Bouwt voort op het bestaande CPA-coderingssysteem, welke voldoet aan internationale normen voor het coderen van producten.[1] De hiërarchische productcodeopbouw is uitgebreid met extra cijfers voor elk specifiek biomassaresidue met verwijzing naar het aanverwante hoofdproduct. Dit geeft tegelijkertijd inzicht in de brede kennis en beschikbaarheid over aanbod en gebruik van biomassa bij bij WUR.

[1] https://www.cbs.nl/nl-nl/onze-diensten/methoden/classificaties/producten/classification-of-products-by-activity--cpa--

- Bevat linken met de industrie die een bepaalde biomass levert en/of gebruikt, die passen binnen het CPA-coderingssysteem.
- Past bij het gewenste rapportagedetail over gewassen, dierlijke producten en aquatische producten.
- Bevat niet alleen het ruwe, verwerkte en in de detailhandel verpakte biomassaproduct, maar ook de daaraan verbonden residuproducten (respectievelijk primaire, secundaire en tertiaire residuen).
- Omvat, in concept, de diepst mogelijke details van biomassaproducten. In de praktijk kan informatie voor een bepaalde nieuw product ontbreken en blijft het buiten de analyses. Als in de toekomst wel cijfers beschikbaar komen, dan kunnen die eenvoudig aan het product worden toegewezen.

Rekenregels zijn opgesteld om het aanbod en gebruik van de nieuw geïdentificeerde en gecodeerde biomassaresiduen te kwantificeren. Dit gebeurt door gegevens uit bestaande statistieken over het hoofdproduct (gerapporteerd door bijvoorbeeld CBS en EUROSTAT) te koppelen aan conversiefactoren en/of fracties (meestal verkregen uit de literatuur). Dit geeft ook informatie over een aantal componenten (zoals nutriënten) in de producten.

De nieuw geïdentificeerde en gecodeerde biomassaresiduen, alsmede de rekeningsregels voor kwantificering van hun aanbod en gebruik, worden systematisch opgeslagen in een datawarehouse. Op maat gemaakte computerprogramma's verzorgen de overgang van CBS versie naar WUR versie van de Materiaal Monitor, waarbij de laatste dus meer details rapporteert over biomassareststromen. Bijkomend voordeel van de opslag in een datawarehouse is dat informatie ook toegankelijk wordt voor andere WUR projecten gericht op monitoren en analyseren van de circulaire bioeconomie.

De WUR versie van de Materiaal Monitor is consistent, transparant, uitbreidbaar en repliceerbaar. Dit zijn belangrijkste vereisten voor een goed monitoringsysteem. Verder levert het indicatoren om circulariteit in de bioeconomie meten, evenals indicatoren die inzicht geven in duurzaamheidseffecten van de circulaire bioeconomie.

Tot slot is de ontwikkelde methodiek geïllustreerd voor *stro*, het belangrijkste graanresidu in Nederland. Uitgangspunt is de berekening van de bovengrondse biomassarestproductie. Verder wordt rekening gehouden met de in- en uitvoer van stro, de belangrijkste toepassingen en het gebruik van stro aan het einde van de levensduur. Gedetailleerde informatie over strostroom is opgeslagen in de datawarehouse, en vervolgens zijn delen daarvan geimplementeerd in de Materiaal Monitor. Het circulaire gebruik van stro is gevisualiseerd via een Sankey-diagram.

S.3 Methode

Het CBS heeft een Materiaal Monitor ontwikkeld die laat zien hoe verschillende soorten materialen (bijvoorbeeld mineralen, staal, biomassa) van, naar, binnen en uit de Nederlandse economie stromen. Onze KB-1B-studie neemt deze Materiaal Monitor als basis voor de ontwikkeling van een systeem dat met name biomassareststromen kan monitoren, en inzetbaar is voor bedrijfs- en beleidsanalyses rondom circulaire bioeconomie. De originele CBS-versie van de Materiaal Monitor is hiervoor niet direct geschikt, omdat het onvoldoende inzichtelijk maakt hoe de stromen van *biomassaresiduen* binnen de Nederlandse economie lopen. Het linkerdeel van Figure S-2 toont het bestaande raamwerk van de CBS-versie van de Materiaal Monitor. Het rechterdeel projecteert de WUR-versie van de Materiaal Monitor, met daarin stromen van gedetailleerde biomassaproducten en bijbehorende residuen en hun specifieke kenmerken (zoals inhoudstoffen).

Het proces om tot een verbeterde Materiaal Monitor te komen start met het verzamelen, kwantificeren en opslaan van gegevens over 1) primaire gewas-, dierlijke en aquatische residuen geproduceerd door de Nederlandse primaire sector, en 2) secundaire en tertiaire residuen die beschikbaar komen bij respectievelijk industriële productieprocessen verder in de keten en huishoudens. Gegevens over primaire en secundaire residuen worden niet systematisch verzameld waardoor een goed kwantificeringssysteem ontbreekt, evenals voldoende cijfermatige onderbouwingen voor beleids- en bedrijfsanalyses. Over tertiaire residuen, voornamelijk afval, wordt informatie verzameld op zowel nationaal als gemeentelijk niveau. Dit wordt meestal ingedeeld naar vooraf gedefinieerde categorieën, maar informatie over de exacte samenstelling van afval, met name het organische en niet-organische aandeel, ontbreekt.

Over biomassaresiduen wordt nog nauwelijks gerapporteerd in de statistieken, terwijl behoefte aan informatie daarover toeneemt. Onze methode start met het systematisch partioneren van biomassa over onderdelen, bijvoorbeeld gewassen worden verdeeld over bladeren, stengels en wortels. Dit detail is belangrijk voor het identificeren en kwantificeren van de belangrijke soorten van biomassaresiduen die de Nederlandse primaire sector produceert. De tweede stap van onze aanpak is om de geïdentificeerde biomassaresiduen een unieke productcode te geven op basis van een hiërarchisch systeem dat aansluit bij bestaande internationale coderingsnormen (met name NACE en CPA).[2] In de derde stap worden rekenregels opgesteld om het aanbod van en de vraag naar nieuwe biomassaresidueproducten te schatten. Hierbij worden bestaande statistieken over het hoofdproduct (gerapporteerd door CBS of EUROSTAT) als uitgangspunt genomen en gekoppeld aan bijvoorbeeld conversiefactoren of aandelen die veelal afkomstig zijn uit de literatuur. Vervolgens worden de verzamelde informatie over de biomassaresidueproducten, evenals de rekeningsregels, systematisch opgeslagen in een datawarehouse. Tot slot is een computerprogramma ontwikkeld dat specifieke informatie uit het datawarehouse haalt, bewerkt en implementeerd in de Materiaal Monitor.

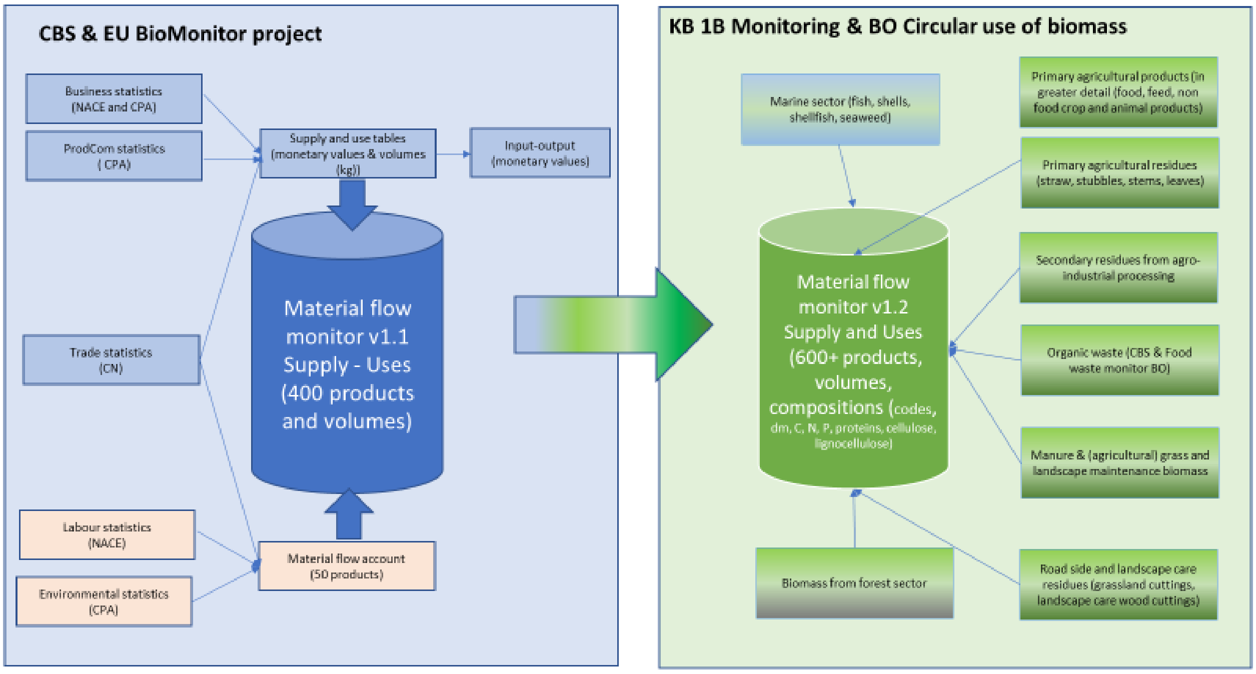

Figure S-2 *Ontwikkeling van een MFM met meer detail over de bio-based economy*
Bron: Auteurs.

[2] https://www.cbs.nl/nl-nl/onze-diensten/methoden/classificaties/producten/classification-of-products-by-activity--cpa--

1 Introduction

1.1 Background

The increasing global demand for food, feed, biomaterials and bioenergy resources could lead to exacerbating pressures on natural resources and demand/supply conflicts. The International Bioeconomy Working Group (FAO, 2019) sees the application of circularity to a biomass value chain as the only way forward to make the bioeconomy sustainable. It follows the 9R approach which refers to (Ellen MacArthur Foundation, 2013) with regard to:

- A useful application of materials (recover and recycle).
- An extended lifespan of products and their parts (repurpose, remanufacture, refurbish, repair, re-use).
- A smarter product use and manufacture (reduce, rethink, refuse).

In all stages of a biomass value chain which consists of biomass production and collection to biomass end of life in which all components of bioproducts are either reused, recycled and/or recovered and waste is reduced to the minimum. These components can consist of materials, nutrients, water and energy. Increased circularity would help to mitigate the environmental impacts of increasing demand for biomass by easing the competition between different biomass applications, reducing greenhouse gas emissions associated with material use and correcting geographical imbalances in nutrient and carbon flows.

1.2 Objective

To understand how the Netherlands progress to a more circular bioeconomy, it is important to better understand the flows of biomass in the bioeconomy. An important aspect in this respect is the flow of biomass resources and the individual components they consist of in agriculture. The crop, livestock and fish sectors produce large amounts of primary products and primary residues. The main/targeted products are mostly going to food and feed production and the supply and uses are well known through existing statistics and other regularly collected information systems. For primary residues (e.g. field residues in case of crops, manure in case of livestock) data are not systematically collected at the level required for action perspectives, and a good quantification system is absent. Moving along the food and feed value chains, there are also secondary residues (e.g. potatoes steam peels, beer brush, beet pulp in case of processed crops, animal fats or blood meal in case of processed livestock products, or fish meal in case of processed fish), and tertiary residues at the end-of-life stage (e.g. municipal waste, household food waste). Like for primary residues, the systematic collection of data on secondary and tertiary residues is incomplete, not accessible and not systematically collected. Setting up such a quantification approach will significantly improve the understanding of the flow of biomass and of the components this biomass consists of (e.g. nutrients, carbon) through the bioeconomy. Furthermore, this information will support our understanding of how to make the bioeconomy more circular to reach high greenhouse gas mitigation and carbon capture targets and optimal circulation of crucial nutrients and overall higher sustainability.

1.3 Approach

CBS has developed the Material Flow Monitor (MFM) that shows how different sorts of materials (e.g. minerals, steel, biomass) flow to, within and from the Dutch economy. The KB1 project has acknowledged the usefulness of CBS's MFM for identifying inter-relations of suppliers and users of resources, and has embraced it as framework for monitoring biomass flows. However, it noticed that flows of especially biomass residues are insufficiently captured and need to be better visualised within the system. The left-hand side of Figure 1-1 shows the existing framework of the MFM developed by CBS. The right-hand side shows the conceptual MFM that KB-1B study is developing with a more detailed coverage of biomass flows (including residues) to, within and from the economy. This should become a base for better monitoring of the supply and use of biomass flows in terms of kilotonnes of dry matter (KT DM), as well as carbon, nutrients and greenhouse gas emissions connected to the biomass supply and use. Also, it should provide better knowledge on a more efficient use of biomass and potential new business cases to minimalise unwanted leakages to the environment (soil, air, water).

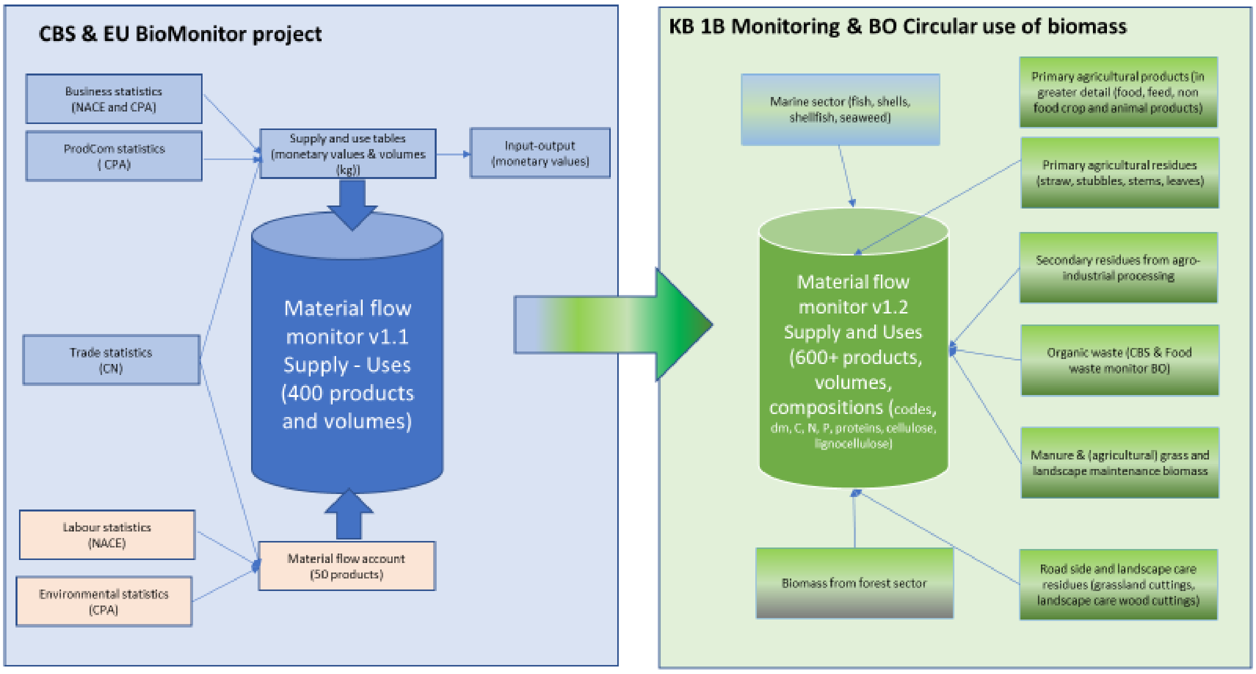

Figure 1-1 *MFM development towards a wider and more detailed coverage of the bio-based economy*
Source: Authors.

This report presents an approach to quantifying on a regular basis the type and amount of primary crop, animal and aquatic residues produced in the Dutch primary sector as well as the amount of tertiary residues generated by industry and households. The approach builds on existing work and experience, and uses existing statistical data sources to enable regular updates in time so that the data can be wider used in monitoring for circularity. The secondary residues which are mostly produced in the processing sectors are not fully covered in this report. Not because these residues are regarded as unimportant, rather the contrary, but given data and time limitations, they could not be directly included.

1.4 Structure of this report

The chapters in this report are structured along six defined factsheets that can be read separately depending on reader's interest. The first five chapters/factsheets have a focus on a specific biomass residue type and outline scope, classification, coding, and data sources. Chapter 2 presents the conceptual framework for monitoring biomass from crops and their residues. Chapters 3 and 4 do the same for respectively biomass from animal and aquatic sources and their residues. The focus of Chapter 5 is on secondary and tertiary biomass residues. Chapter 6 shows an example of how to trace straw throughout the regional economy. The last chapter/factsheet describes an approach how to embed the forementioned biomass residues in the Material Flow Monitor (Chapter 7). Finally, conclusions and recommendations are presented in Chapter 8.

2 Biomass from crop residues

2.1 Scope and size: production structure

This section highlights the production volume structure of crops in the Netherlands, with specification of main product categories within the sector. In the Netherlands the total agricultural area amounts to 1.8m hectares of land (2021). Of this area 29% is arable land and 43% is covered with permanent grassland (Table 2-1). About 6% is used for horticultural production, of which the main share is covered by vegetables and fruit trees. The largest amount of primary crop residues comes from arable land. The crops that can deliver primary residues at large quantities are cereals, potatoes, and sugar beet (Table 2-2).

Table 2-1 *Agricultural land use in the Netherlands (ha for total, and % per type in total)*

	Entity	2005	2010	2015	2016	2017	2018	2019	2020	2021
Arable	%/UAA	31	29	27	28	28	28	29	29	29
Horticulture	%/UAA	4	5	5	5	5	5	5	5	5
Greenhouses	%/UAA	1	1	0	1	0	0	1	1	1
Green fodder crops	%/UAA	12	13	13	12	12	12	11	11	11
Permanent & natural grassland	%/UAA	41	43	42	41	41	42	42	43	43
Utilised Agricultural Area (UAA)	Ha	1,937,700	1,872,320	1,845,750	1,815,870	1,818,590	1,822,370	1,816,320	1,814,450	1,811,910

Source: CBS Landbouwtelling, different years (https://opendata.cbs.nl/statline/#/CBS/nl/dataset/ 81302ned/table?ts=1671033133850).

Table 2-2 *Main arable crop categories in the Netherlands (ha for total, and % per type in total)*

	Entity	2005	2010	2015	2016	2017	2018	2019	2020	2021
Cereals	%/UAA	37	40	39	36	32	32	34	33	33
Potatoes	%/UAA	26	29	31	31	32	32	31	31	30
Sugar beet	%/UAA	15	13	12	14	17	17	15	15	15
Industrial crops	%/UAA	3	3	3	3	3	3	3	3	3
Oil crops	%/UAA	0	0	0	0	0	0	0	0	0
Arable land	Ha	604,050	542,070	505,670	503,660	509,150	515,950	531,930	526,840	525,750

Source: CBS Landbouwtelling, different years.[3]

Only for cereals, especially for wheat and barley, it is now common to partly remove the residues from the field and use them for own animal production or sell them. For all other primary residues, it is most common to leave them on the field where they will (partly) contribute to soil organic matter and the carbon capture in the soil, depending on soil, the C/N ratio, climatic circumstances and further land management practices (Wang et al., 2017; Hansen et al., 2020). Incorporation of crop residues in the soil may help to capture carbon in the soil, but there is also a higher risk of nitrous oxide emissions (Lesschen et al., 2012). The effectiveness of the measure for organic matter depends on the type of crop. Generally, crop residues with a higher C/N ratio are less easily broken down, for example, beet tops are broken down faster than cereal straw (Lesschen et al., 2012).

3 https://opendata.cbs.nl/statline/#/CBS/nl/dataset/ 81302ned/table?ts=1671033133850

2.2 Classification and quantification

This section summarises the biomass partitioning over plant organs (leaves, stems, roots) which is needed to identify and quantify the important types and amounts of primary crop residues produced in the Dutch primary sector for being integrated in the WUR version of the MFM.

2.2.1 Concept of biomass partitioning over plants

When crops grow, they convert water and carbon dioxide into assimilates and partition that towards different plant organs such as roots, stems, leaves and reproductive organs and/or storage organs. Some of the assimilates are respired through maintenance respiration. Storage organs refer to fruits, grains, tubers and bulbs that are mostly harvested as the main product, often referred to as the *economic yield*. The partitioning to storage organs depends on the growth stage of the plant. Figure 2-1 presents an example (simulation by WOFOST model)[4] of assimilates or dry matter biomass partitioning in the above-ground organs in relation to the development stage of barley in the Netherlands.

The partitioning rate to the leaves determines the increase in the leaf area which leads to higher light inception potential if it exceeds leaf death rate, and therefore shows higher potential growth of the plant (higher assimilation rate), if sufficient light, water and nutrients are available. When leaf area expands, growth of the plant is exponential until all incoming light is intercepted by the leaves after which the growth becomes constant. A fraction of the assimilates is assigned to the roots first, the remainder is divided over the above-ground organs (including below-ground storage organs such as tubers). At later development stages (DVS), this partitioning shifts in the favour of other crop organs. The partitioning of biomass to the storage organs is usually largest in the final growth stage (Figure 2-1), with DVS=0 for sowing/planting, DVS=1 for flowering, and DVS=2 for crop maturity.

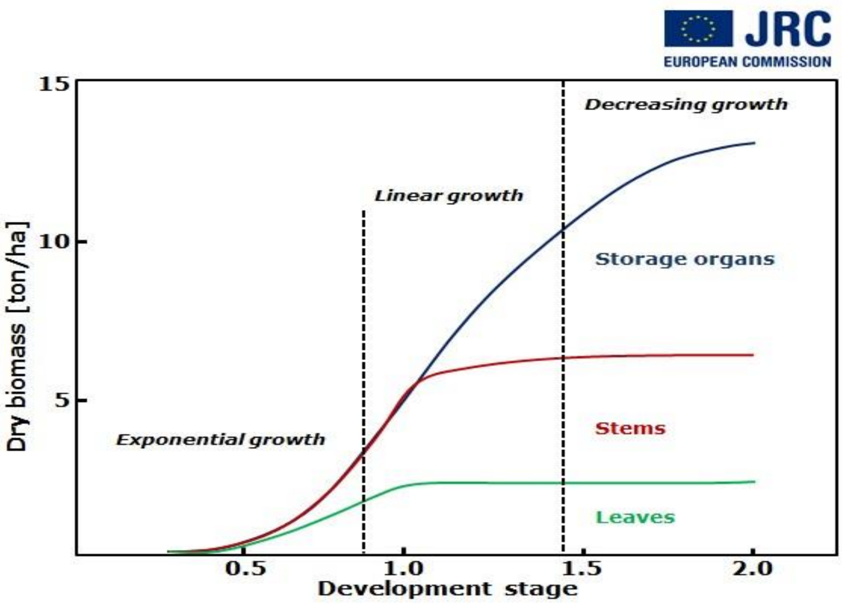

Figure 2-1 *Partitioning of biomass over crop organs in barley in development stage stages, the Netherlands Source: Marswiki.*[4]

From this crop growth partitioning pattern, it is also logical to assume that there is a relationship between the amount of economic yield and the amount of the rest of the biomass which we can call the residual biomass. Therefore, many approaches to assess the residual biomass potentials use functions that express the relationship between the economic yield and residue biomass. These crop specific empirical conversion factors can be based on the simple assumption that there is a fixed partitioning between economic yield (Y) and

[4] https://marswiki.jrc.ec.europa.eu/agri4castwiki/index.php/The_Wofost_model

residues not influenced by weather or changes in management (e.g. de Wit and Faaij, 2008). Other more advanced approaches assume a correlation between economic yield (Y) and the amount of biomass going in the partitioning to other plant components. In those approaches empirical regression models are used to predict the relation between economic yield and residue product ratio (RPR) or the harvest index (Scarlat et al., 2010; Montforti, 2013; and Garcia-Condado, 2019). However, if a crop fails to produce economic yield because of biotic and/or abiotic stresses, a considerable amount of residue biomass may be available.

To understand better the relation between economic yield and residue yield a study by Scarlat et al. (2010) was performed in which a literature review was done to collect information on the RPR and the economic yield of the main cereal and oil crops in Europe. From this, best fit curves were plotted and regression models were derived to predict the relationship between economic yield and RPR. This work started by Scarlat et al. was further elaborated by Garcia-Condado et al. (2019) to improve the logarithmic models of Scarlat et al (2010) predicting the RPR from the economic yield. For this purpose, a dataset of 1,580 experimental observations of economic yield (Y), residue biomass yield (R) and Harvest Index (HI) was generated from 84 scientific publications. Equation 2-1 defines HI as follows:

$$HI = Y/(Y + R)$$ *Equation 2-1*

Where Y denotes the economic yield, R is above-ground residue yield (expressed in tonne dry matter per hectare). These factors were then processed statistically to derive predictive regression models for a set of 10 arable crops (wheat, barley, grain maize, rice, sorghum, rapeseed, soybean, sunflower, potato, sugar beet). which make up the largest share of arable crops grown in the EU, in terms of production volume and acreage. These 10 crops could be divided into two groups in the way the economic yield and the biomass partitioning (and thus the HI and the RPR) are related.

The first group of crops, consisting of wheat, barley, rapeseed, sunflower and rice, have a relatively stable HI which is weakly correlated with Y. When looking at specific crops in group 1, sunflower shows an almost complete independence between HI and Y (Figure 2-2). This means that if Y is high, also R is high. For especially cereal crops, the distribution between R and Y is more heteroscedastic than for sunflower which implies that if Y is high, R can still be ranging more between low and high so large differences occur in amount of residue produced.

The second group of crops, which consists of grain maize, sorghum, soybean, potato, and sugar beet, shows a large variability in HI that is strongly correlated with economic yield (Figure 2-3). This correlation is especially pronounced for grain maize, sorghum and sugar beet. The relationship between economic (Y) and residue yield (R) is stronger than in the first group. If Y increases, then HI increases stronger than in first group and this is at the cost of residue biomass, of which relatively less becomes available. The situation for soy in Figure 2-4 needs some more explanation as it gives - in green - the true and apparent HI. The economic yield can be related to either the organs available before the plant is fully mature and still has its leaves and petioles, or after maturity when the residual biomass is smaller because the leaves and petioles have fallen off. Garcia-Condado et al. (2019) also assessed the influence of varieties (cultivars), use of irrigation/water stress and nitrogen fertilisation on the plant partitioning. The effect was largest from irrigation on biomass partitioning which is strongly positively correlated with economic yield and harvest index. This relationship is particularly strong in grain maize, wheat and barley.

Equations 2-2 and 2-3 show empirical regression models to assess the HI of 10 crops generated by Garcia-Condado et al. (2019, p. 814). For the parameters per crop see Table 2-3.

$$\hat{P} = \frac{\lambda}{2}\left(\frac{1 - e^{-\frac{\widehat{P_t} - \gamma}{\delta}}}{1 + e^{-\frac{\widehat{P_t} - \gamma}{\delta}}} + 1\right) + x_i$$ Equation 2-2

$$\hat{P} = \frac{\lambda}{2}\left(e^{\frac{\widehat{P_t}\,\gamma}{\delta}} - \frac{1}{e^{\frac{\widehat{P_t}\,\gamma}{\delta}}}\right) + x_i$$ Equation 2-3

$$\widehat{P_t} = aY + b \pm CI$$ Equation 2-4

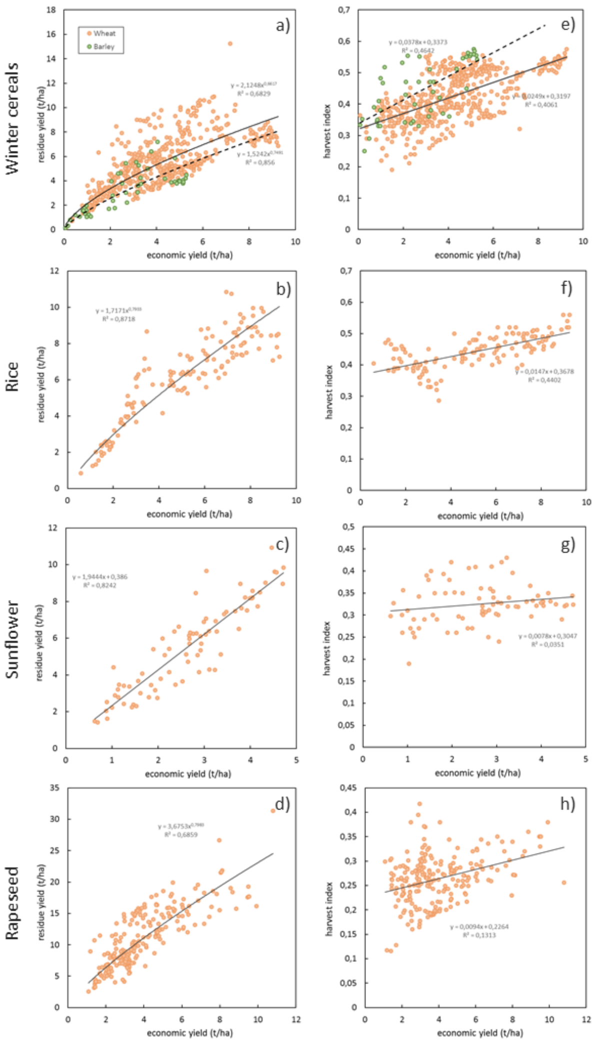

Figure 2-2 *Regression between economic and residue yields (a-d) and economic versus harvest index (e-h); observations collected from scientific literature for winter cereals (wheat, barley and triticale), rice, sunflower and rapeseed*
Figure copied from: Garcia-Condado et al. (2019).

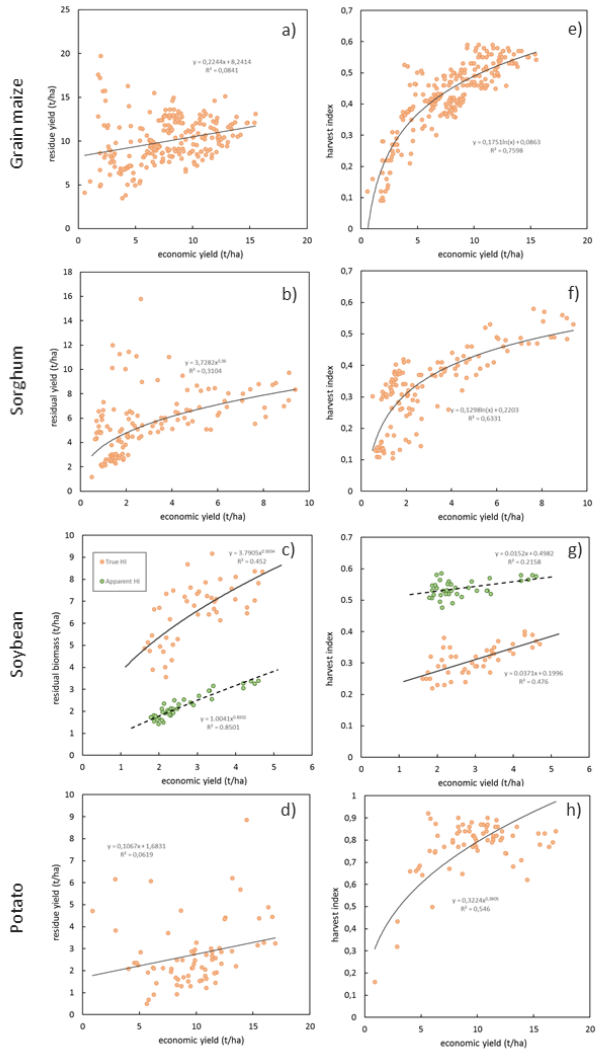

Figure 2-3 *Regression between economic and residue yield (left) and economic versus harvest index (right); observations collected from scientific literature for grain maize, sorghum, soybean and potato*
Figure copied from: Garcia-Condado et al. (2019).

Table 2-3 specifies the equation factors per crop and shows which of the equations to apply to which crop to estimate the residue amount. The residue amount can be calculated directly (in Equation 2-2 and Equation 2-3) or indirectly via de HI assessment in Equation 2-4 as presented in the former.

Table 2-3 *Parameter values of empirical regression model for estimation of harvest index of crops with relatively stable HI (Figure 2-2) which is weakly correlated with the economic yield (Y). (Parameters to be used in the equations 2-2, 2-3 presented on former page)*

Crop	Predicted Variable	Transformation of	Transformation parameters				Linear regression parameters		
			γ	δ	xi	λ	a	b	CI
Wheat	HI	LT (Equation 2-2)	-0.2551	1.0835	0.2034	0.4006	0.3093	-1.2958	1.5067
Barley	HI	LT (Equation 2-2)	-0.0705	0.5421	0.2817	0.3063	0.3319	-0.8631	1.1952
Rice	HI	LT (Equation 2-2)	-1.6054	2.3282	0.0687	0.5663	0.2823	-1.431	1.4469
Sunflower	HI	HS (Equation 2-3)	-0.3057	3.8491	0.3111	0.1717	0.1715	-0.4522	1.9114
Rapeseed	HI	HS (Equation 2-3)	0	3.2858	0.2637	0.1575	0.188	-0.7453	1.8212
Maize	HI	LT (Equation 2-2)	-1.6992	1.2752	-0.2218	0.8428	0.2509	-1.9424	1.105
Sorghum	HI	LT (Equation 2-2)	-0.553	1.3866	-0.1036	0.7427	0.3446	-1.0251	1.2173
Soybean	HI	LT (Equation 2-2)	-0.0819	1.0113	0.191	0.2299	0.7659	-2.2731	1.3811
Sugar beet	R	HS (Equation 2-3)	0.5345	2.8868	6.0578	2.8308	-0.1067	1.8538	1.7528
Potato	R	LT (Equation 2-2)	2.6877	1.2031	0.6951	16.7831	0.0617	-0.5178	1.7609

Source: Garcia-Condado et al. (2019).

The approach to predict crop residue potentials by Garcia-Condado et al. (2019) is scientifically robust and covers the 10 main crops grown in the EU. It can only be used to assess the residual aboveground biomass for a selection of arable crops. For the remainder crops, not covered by Garcia-Condado et al. (2019) the study by Monfreda et al. (2008) can provide the harvest index data. Monfreda et al. (2008) performed a literature review to identify the Harvest Index, the dry matter fraction of the main product and the aboveground biomass fraction for 175 main crops grown in the world. The approach does not develop equations to predict the relation between main product and harvest index such as Garcia-Condado et al. (2019) but provides expert based average factors. An important addition by Monfreda et al. (2008) regards the systematically collected information on the aboveground biomass fraction. This fraction can be used to deduct the belowground biomass.

Table 2-3 shows the equations and factors from Garcia-Condado et al. (2019) and Table 2-4 presents the equations for above and below-ground residues calculation from the study of Monfreda at al. (2008). The parameters to be used in the calculation specific per crop are presented in Appendix 2 and were derived from Monfreda et al. (2008).

Table 2-4 *Factors per crop and equations for above-ground and below-ground residues (for the values per crop from Monfreda et al., 2008 see Appendix 2)*

What?	Item	Explanation and unit in ()	Equation for calculation
Factors and equations for calculation of above and below-ground residues:	Yfw	*Economic yield fresh matter (FW, tonne per ha)*	-
	Res,abvgr	*Residue in dry matter (tonne DM per ha) above ground*	
	Res,blwgr	*Residue in dry matter (tonne DM per ha) below ground*	
	Ydm	*Economic yield dry matter (DM, MT per ha)*	*Yfw * Dry_Matter Fraction*
	Res,abvgr	*Residue in dry matter (tonne DM per ha) above ground*	*Ydm / (HI*%dm) - Ydm*
	Res,blwgr	*Residue in dry matter (tonne DM per ha) below ground*	*(Ydm + Res,abvgr) / (Abvgr_fraction) - (Ydm + Res,abvgr)*
Factors derived per crop:	Harvest Index (HI)	% factor	$HI = Yfw/(Yfw + Res,abvgr)$
	Dry matter fraction of economic yield (DMF)	% dry matter	-
	Abvgr_fraction	% dry matter	-

FW=Fresh weight, DM= Dry Matter, HI=Harvest Index, DMF = Dry Matter fraction.

Source: Monfreda et al., 2008).

For the assessment of crop residues in the Netherlands it is proposed to take the predictive equations of Garcia-Condado et al. (2019) (Equations 2-2, 2-3 and 2-4, in the former). For crops not covered in this study the factors provided by Monfreda et al. (2008) are to be used (see Table 2.4 and Appendix 2). Finally, Monfreda et al. (2008) is also the base for estimating the below-ground biomass for all crops in the Netherlands (see Appendix 2).

2.2.2 Quantification of crops and main residues that are harvestable or remain in the field

For making a full biomass and C balance it is important to understand the total biomass, what is removed from the field and what remains in the field and in the soil. From above it is clear that both the equations developed by Garcia-Condado et al. (2019) and the factors from Monfreda et al. (2008) are needed to estimate the above-ground and below-ground plant biomass and the division of this in economic yield and residual products. Appendix 1 gives an overview of what source information is to be used to estimate the different types of biomass potentials and production factors per crop.

The next aspect to consider, is what type of storage organs and plant residues there are and whether this biomass is removed from the field or not and, if removed, how much. For the below-ground biomass per crop, apart from economic yield (such as potato tubers, (sugar) beet, onions, carrots, bulbs etc.) we assume that this is left in the soil and adds to the carbon and nutrient pools in the soil. For the above-ground residual biomass, the fractionation to organs is more complicated to assess. It is not commonly known how much crop biomass is lost during crop growth, and how much residue is lost during harvest, and how much is left behind after the harvest process. This depends on several factors such as type of crop, soil and harvest management practice and timing chosen by the farmer, and possibly other factors. Second, above-ground residual biomass loss is crop specific, e.g. cereals produce straw and chaff and sugar beet produce leaves.

For main crops such as cereals and oil crops that produce grains or seeds as storage organs, the residual aboveground biomass consists of straw, including stems and leaves and also husks (Figure 2-4). The storage organs grow at the end of the stems. In the Netherlands the grains of cereals are harvested with a combine that also harvests part of the straw. How much of the straw is removed differs between regions, year, farmer’s choice, etc. What is common practice in different regions can be derived from publications such as KWIN or the BINTERNET database for the Netherlands. This however is an average situation and does not apply to every farmer.

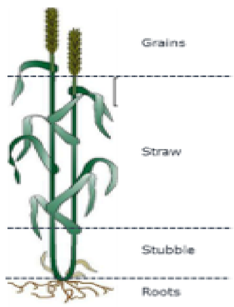	
Crop organs overview for wheat, where the straw consists of stems and leaves. *Note that a stubble is the bottom part of stems and leaves, and that the amount of them is determined by management settings of harvesting machinery.*	Potato plant, location of storage organs and field residues consisting of leaves, stems and flowers (source: https://www.123rf.com/photo_127097338_stock-vector-potatoes-plant-growing-process-from-seed-to-ripe-vegetables-on-plants-isolated-on-white-background-p.html

Figure 2-4 *Illustration of economic products (storage organs) and residual above-ground and below-ground biomass of wheat (left) and potatoes (right)*
Source left figure: Authors.

For tuber plants such as potatoes, sugar beet, but also for vegetables such as onions, which are very common and widely cultivated in the Netherlands, the storage organs are below ground, and the primary residues consist mostly of stems and leaves growing above ground (see Figure 2-4). For potato it is common practice to kill the above-ground biomass consisting of stems and leaves two weeks before the harvest of the tubers in the field. So the residue is not harvestable anymore because of this practice. For sugar beet it is most common to separate the beet from the rest of the biomass and only remove the beet from the field. For onions it is common practice to harvest it by pulling them out of the soil and let them dry on the land until the above-ground biomass is dried up and has shrunk to a minimum. Despite this, the amount of above-ground residue can be quantified, but the removable potential or the potential that is currently removed is likely to be practically zero. All these specific morphological characteristics and management practices make it very difficult to estimate the real harvestable crop residue.

Figure 2-5 shows the scheme to be assessed for a systematic quantification of all primary crop residues.

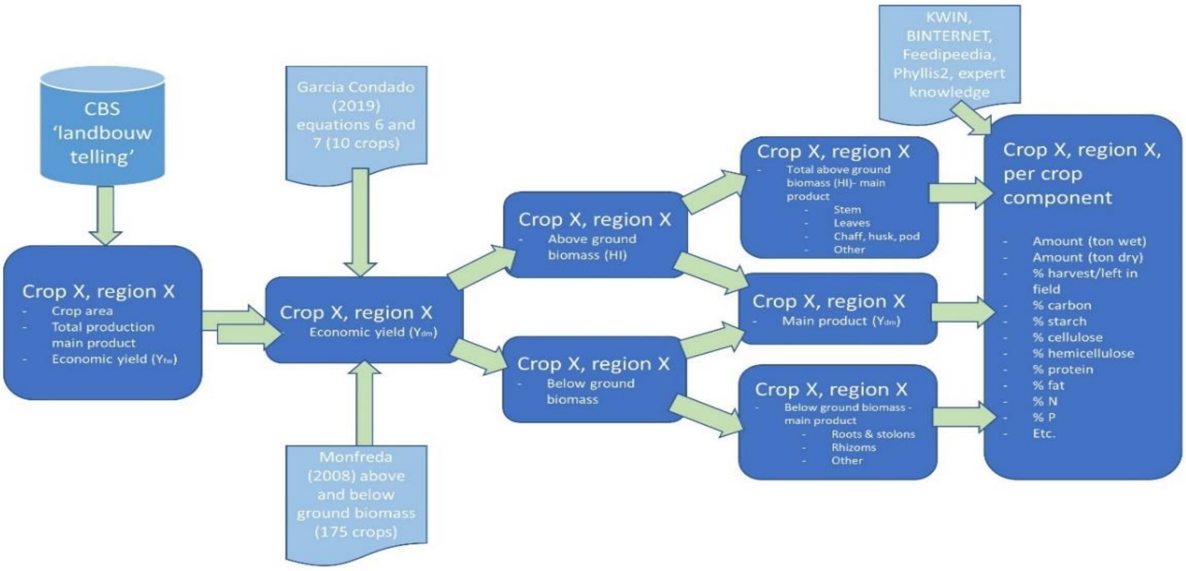

Figure 2-5 *Assessment steps from statistical data towards estimated primary crop residues and their attributes*
Source: Authors.

To assess the primary residual biomass availability for arable crops in the Netherlands, a calculation protocol which takes the data from Statistics Netherlands (CBS) is the starting point. It then applies the factors of Garcia-Condado et al. (2019) and Monfreda et al. (2008) (see Appendix 1 and 2.2) to calculate the total above-ground and below-ground biomass per crop. The main product is then subtracted to calculate the total residual biomass, aboveground and belowground.

The crop main product (yield) is subtracted, and partition factors (if available) are applied to estimate the distribution of the total residual biomass over different types of residual plant components. This then results in a final estimate of total residual biomass that can technically be harvested and what remains in the field. Whether the biomass is harvested in practice is then the next question and requires new sources of information which will be discussed for wheat and barley straw in Chapter 6.

To illustrate the approach Table 2-5 shows results on quantities of main product and above-ground biomass for barley and wheat taking the CBS data on area and production in the Netherlands.

Table 2-5 *Total above-ground biomass production volumes for wheat and barley in the Netherlands (tonne DM) per province, 2011-2020*

Row Labels	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Drenthe (PV)	146	162	169	149	158	148	126	135	131	115
Flevoland (PV)	248	252	256	237	236	205	210	204	221	203
Fryslân (PV)	109	114	120	112	108	90	93	94	100	86
Gelderland (PV)	115	125	131	105	99	82	83	86	99	91
Groningen (PV)	517	559	555	572	573	495	493	478	522	455
Limburg (PV)	123	136	137	138	141	108	109	108	132	123
Noord-Brabant (PV)	203	209	212	188	196	166	158	153	193	170
Noord-Holland (PV)	141	146	156	149	157	121	124	120	130	111
Overijssel (PV)	39	39	40	31	32	28	26	30	37	33
Utrecht (PV)	6	11	8	8	6	4	4	4	6	4
Zeeland (PV)	471	501	506	502	528	452	418	423	472	405
Zuid-Holland (PV)	224	228	238	232	243	193	196	177	195	170
Grand Total	2,342	2,482	2,528	2,423	2,477	2,092	2,040	2,012	2,238	1,966

Source: Based on CBS Landbouwtelling and own calculation.

Between 2016 and 2020 on average 1 million tonnes of residues per year from barley and wheat were produced in the Netherlands (Table 2-6). This is the amount of residues produced on field, consisting of straw (800 KT) and chaff (200 KT). Chapter 6 discusses the removal rates for this straw and chaff.

Table 2-6 *Estimated total residual biomass production volumes for wheat and barley in the Netherlands (tonne DM) per province, 2011-2020*

Provinces	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Drenthe (PV)	73	77	80	71	76	70	61	64	63	56
Flevoland (PV)	122	120	122	114	113	100	99	97	103	97
Fryslân (PV)	56	57	59	55	53	45	44	45	47	42
Gelderland (PV)	59	61	64	52	49	42	41	43	48	45
Groningen (PV)	259	272	271	273	277	245	237	231	251	220
Limburg (PV)	61	65	66	65	67	56	54	52	62	59
Noord-Brabant (PV)	104	103	104	91	94	83	76	74	90	83
Noord-Holland (PV)	73	72	77	72	75	60	59	59	62	55
Overijssel (PV)	20	19	20	16	16	14	13	15	18	17
Utrecht (PV)	3	5	4	4	3	2	2	2	3	2
Zeeland (PV)	239	249	249	243	253	226	202	204	220	196
Zuid-Holland (PV)	112	113	115	111	115	96	93	86	91	83
Grand Total	1,181	1,213	1,232	1,167	1,191	1,039	981	972	1,058	955

Source: Based on CBS Landbouwtelling and own calculation.

2.3 Coding approach

The new biomass categories identified in Section 2.2 are coded via a hierarchical system that aligns with existing product coding standards. It ensures that the additional product detail can be smoothly and gradually transferred into the CBS version of the MFM, which will end up in the WUR version of the MFM that has more detail on biomass residues. In principle, the WUR version of the MFM aims to capture the full biomass product detail, according to WUR product and sector experts, which:

- Builds on an existing CPA coding system, which fits international standards of coding products, but has been extended with extra digits to specify detailed product residues connected to the raw biomass product at stake; these extra digits do express the rich biomass data detail available at WUR.
- Contains connections to the industry that supplies the biomass considered, similarly as CPA codes.
- Fits preferred reporting detail on crops, animal products and aquatic products.

- Captures not only the raw, processed and retailed biomass products, but also its connected residues, respectively primary residue products, secondary residue products and tertiary residue products.
- Includes the full possible detail of biomass products in concept, though in practice it might depend on data availability to which detail the products can be filled with numbers. Note that product detail without data at this point in time, might get data in future.

The WUR product coding system is built up of 14 digits for crop and animal products. It builds on the NACE coding system for plant and animal products which makes up the first 4 digits of the total 14-digit coding for plant and animal products and the related primary residues. Figure 2-6 explains the building up of the coding system for plant primary products and residues.

```
NACE 01. Crop and animal production, hunting and related service activities
NACE 02. Forestry and logging
NACE 03. Fishing and aquaculture
|        Crop and animal production
|        NACE 1 Growing of non-perennial crops
|        NACE 2 Growing of perennial crops
|        NACE 3 Plant propagation
|        NACE 4 Animal production
|        NACE 5 Mixed farming
|        NACE 6 Support activities to agriculture and post-harvest crop activities
|        NACE 7 Hunting, trapping and related service activities
|        Fishing and aquaculture
|        NACE 1 Fishing
|        NACE 2 Aquaculture
|        |
|        |          Crops
|        |          NACE 1. Cereals (except rice), leguminous crops and oil seeds
|        |          NACE 2. Rice
|        |          NACE 3. Vegetables and melons, roots and tubers
|        |          NACE 4. Sugar cane
|        |          NACE 5. Tobacco
|        |          NACE 6. Fibre crops
|        |          NACE 9. Other non-perennial crops
|        |          Animals
|        |          NACE 1. Dairy cattle
|        |          NACE 2. Other cattle and buffaloes
|        |          NACE 3. Horses and other equines
|        |          NACE 4. Camels and camelids
|        |          NACE 5. Sheep and goats
|        |          NACE 6. Swine/pigs
|        |          NACE 7. Poultry
|        |          NACE 9. Other animals
|        |          Fishing and aquaculture
|        |          NACE 1. Marine
|        |          NACE 2. Freshwater
|        |          |
```

Digit No.	1-2	3	4	5-6	7-8	9-10	11-12	13-14
Value	**01.-03.**	**1-7**	**1.-6., 9. Crop 1.-7., 9. Animals 1.-2. Fish & Aquaculture**	**00.-99.**	**00.-99.**	**00.-99.**	**00.-99.**	**00.-40.**

```
                                                  |         |         |          |        |
   Crops / live animals & animal products from ProdCom      |         |          |        |
              Crops / live animals & animal products from CBS*        |          |        |
                                              Crop variety / Animal breed*       |        |
                                                   Crop / Animal production system*       |
                                               Total and components of Plant / Animal product*
```

Figure 2-6 *MFM coding scheme, where digits 1-8 build on NACE, ProdCom and CBS data, and digits 9-14 identify subcategories of material flows*
Source: Authors.

Note that the CBS and additional data (digits 7-14) are coded in such a way that it can be integrated in NACE and ProdCom codes, and can be totalled over sub-categories. The first 4 digits are directly taken from the NACE coding system; digits 5-6 refer to the ProdCom coding system, and digits 7-8 to CBS (Table 2-7). Digits 9-10 (Table 2-8 Crop variety/animal breed), digits 11-12 (Table 2-9 Production system), and digits 13-14 (Table 2-10 Crop components) originate from sources indicated in the tables.

Table 2-7 *Digits 1-8 of coding scheme: product types by activity from NACE, ProdCom and CBS*

NACE (digits 1-4)	ProdCom 00-99 (digits (5-6)	CBS - Crops/live animals & animal products (digits 7-8)
01.11.	10-49 Cereals	
	10. wheat	00. wheat total
		10. winter wheat
		20. summer wheat
	20. maize	00. maize total
		10. corn maize
	30. barley, rye, oats	00. barley, rye, oats total
	31. barley	00. barley total
		10. winter barley
		20. summer barley
	32. rye	00. rye total
	33. oats	00. oats total
	...	...
	50 Cereal straw and husk	
	60-79 Leguminous vegetables	1-9: beans green, peas green, ...
	......	
01.40	10 Dairy cattle	1-9: dairy cattle different age and male & female groups
	20 Meat cattle-veal	1-9: different types of veal
	30 Young livestock - meat	1-9: different age and male & female groups

Table 2-8 *Digits 9-10 of coding scheme: variety per crop/plant, breed per animal if available from CBS or elsewhere*

Variety (digits 9-10)
00 Total
01 Variety 1
02 Variety 2
03 Variety 3
....
99 Other/unknown

Table 2-9 *Digits 11-12 of coding scheme: production system per crop/plant, breeding per animal product*

Production system (digits 11-12)
00 Total
10 Conventional
20 Organic
30 Organic in transition
...
99 Other/unknown

Table 2-10 *Digits 13-14 of coding scheme: total and components of plant/animal product*

Plants (digit 13)	**Plants (digit 14)**	**Animals (Digits 13 and 14)**
0 Total biomass	0 Total above and below biomass	00 total animals
	1 Main product (grains, fruits, tubers, beets, bulbs, whole plant	
1 Total Above ground	0 Total aboveground biomass	10 animals for slaughter
	1 Stems	
	2 Leaves	
	3 Grains	
	4 Fruits	
	5 Chaff, husk, pod	
	9 Other, ...	
2 Total Below ground	0 Total belowground biomass	20 died
	1 Roots	
	2 Bulbs	
	3 Tubers	
	4 Stolons	
	5 Rhizomes	
	9 Other, ...	
		30 milk
		40 manure

2.4 Data sources and mapping of classified crops

The biomass (residues) products identified in Sections 2.2 and 2.3 and supposed to be gradually phased into a WUR version of the MFM (Table 2-11) should provide information on a set of attributes (indicators). This section gives an overview of the data sources and literature used to collect the required data for the distinguished products.

Table 2-11 *Attributes to be monitored by the WUR-MFM*

Attributes (for crops)	Suggested data sources (with table number if available)
Year	
Area (NL, region, etc.)	
1000t production (wet)	CBS (https://opendata.cbs.nl/statline/#/CBS/nl/dataset/85636NED/table?ts=1697795109105)
1000t production (DM)	Production wet*%DM (e.g. from Monfreda et al., 2008, see Appendix 1)
1000t import (wet)	Import and export values; key figures: 70017eng
1000t import (DM)	Import and export values; key figures: 70017eng * conversion to DM
1000t export (wet)	Import and export values; key figures: 70017eng
1000t export (DM)	Import and export values; key figures: 70017eng * conversion to DM
% DM	Monfreda (2008) or Phyllis 2 (https://phyllis.nl/) (and Feedipedia.org)
% harvest/left in field	Phyllis 2 (https://phyllis.nl/) (and Feedipedia.org)
% carbon	Phyllis 2 (https://phyllis.nl/) (and Feedipedia.org)
% starch	Phyllis 2 (https://phyllis.nl/) (and Feedipedia.org)
% cellulose	Phyllis 2 (https://phyllis.nl/) (and Feedipedia.org)
% hemicellulose	Phyllis 2 (https://phyllis.nl/) (and Feedipedia.org)
% protein	Phyllis 2 (https://phyllis.nl/) (and Feedipedia.org)
% nitrogen	Phyllis 2 (https://phyllis.nl/) (and Feedipedia.org)
% phosphate	Phyllis 2 (https://phyllis.nl/) (and Feedipedia.org)

Source: Authors. Table 2-12.

Table 2-12 contains CBS tables (with links) for arable, vegetable, fruit, grass and organic animal and crop production in the Netherlands. Data are specified per available year, region and units of main products. From these values, production volumes (tonne FM total) are derived, or productivities (tonne FM per hectare) are calculated. From the CBS main product volumes (tonne FM), residual biomass availability in tonne DM and its attributes can be calculated.

Table 2-12 *CBS tables (with links) for arable, vegetable, fruit, grass and organic animal and crop production in the Netherlands*

CBSTabel	CBS Table Name	Meta-data	CBS Region Code	CBS Years	Production volume	Acreage	Productivity calculated as: (tonne FM /ha)²/³
7100oogs	Crops; production per region		NL01 (NED); 4LD; 12PV	1994-2021¹	1,000 kg FM	ha	Production/Acreage²
84296NED	Crops; preliminary and final yield estimation		NL01 (NED)	2010-2021	1,000 kg FM	ha	Production/Acreage²
37738	Vegetables; yield and acreage per vegetable type	Meta-data	NL01 (NED)	1998-2021¹	million kg FM	ha	(Production/1,000)/Acreage²
84499NED	Fruits; yield and acreage apples and pears		NL01 (NED)	1997-2021	1,000 kg FM	ha	Production/Acreage²
84075NED	Organic animal and crop production		NL01 (NED)	2015-2020¹	1,000 kg FM	?	
7140GRAS	Grassland acreage and yield		NL01 (NED); 4G+Other	1985-2020¹	million kg DM	million ha	(Production*1,000/Acreage)³

1) Preliminary; 2) tonne FM = tonne Fresh Matter; 3) tonne DM = tonne Dry Matter.

3 Biomass from animal product residues

3.1 Scope and size: production structure

In the Netherlands the livestock sector is an important sector. In 2021, there were about 23,530 cattle farmers, 3,410 pig farmers, and 1,720 poultry farmers who had about 4m cattle, 11 million pigs, and 50m broilers (Appendix 3). This resulted in 13.6 million tonnes of milk production, 0.4 million tonne of cattle meat, 1.7 million tonnes of pig meat, and 0.8 million tonne of poultry meat (Table 3-1). Next to meat and milk output (Table 3-2), the livestock also produces manure, including nutrients such as nitrogen (Figure 3-1) and phosphorous (Figure 3-3). The livestock sector was responsible for 73.4 billion kg manure resulting in 471 million kg nitrogen excretion and 148 million kg phosphorous excretion in 2021. In 2020, livestock was responsible for 19.1 million kg nitrous oxide emissions and 477 million methane emissions emitted in the Netherlands (Van Bruggen et al., 2022). Most of the manure is used again in the agricultural sector, but manure can also be processed, incinerated or exported.

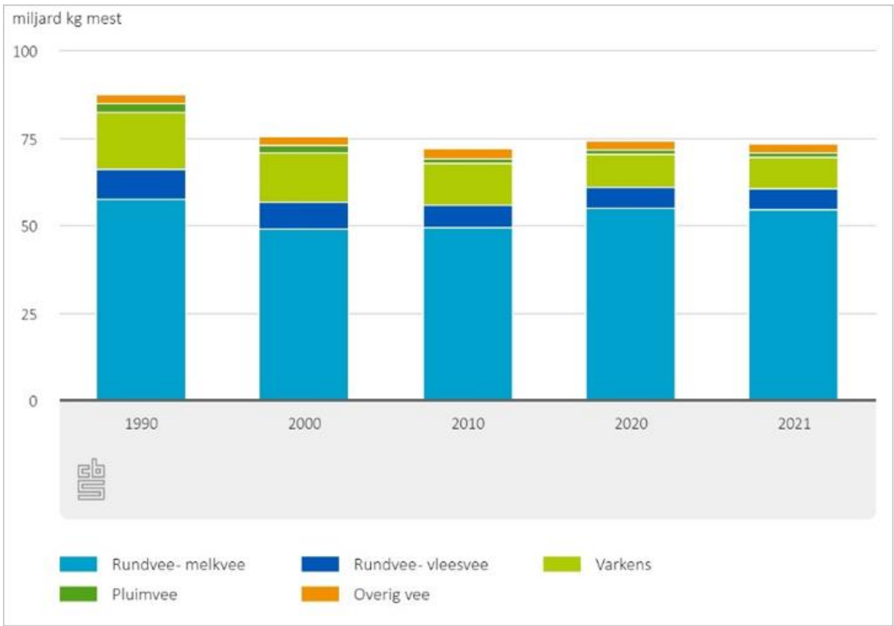

Figure 3-1 *Manure production of different livestock sectors in the Netherlands*
Source: CBS (2022a).

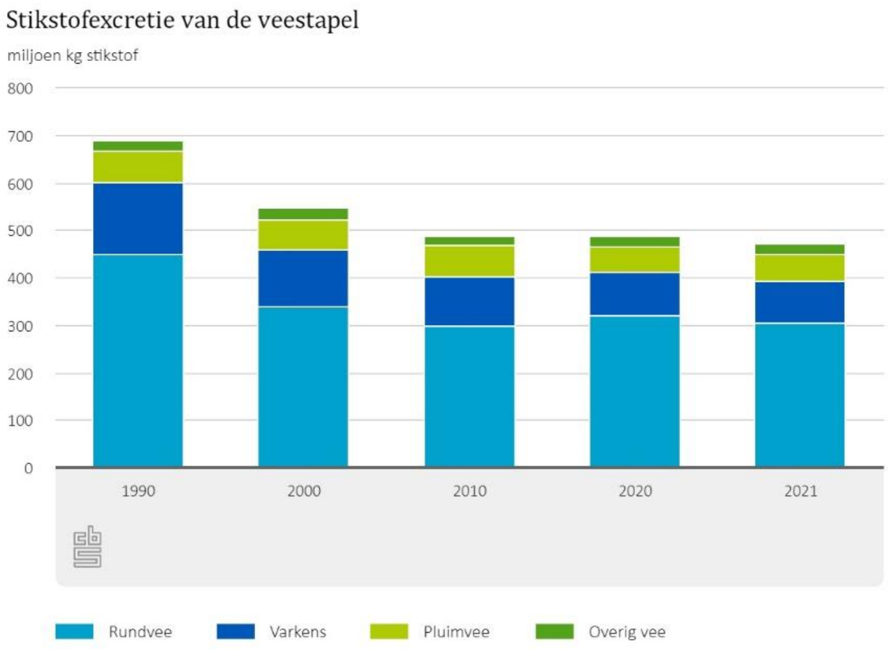

Figure 3-2 *Nitrogen excretion of different livestock sectors in the Netherlands*
Source: CBS (2022a).

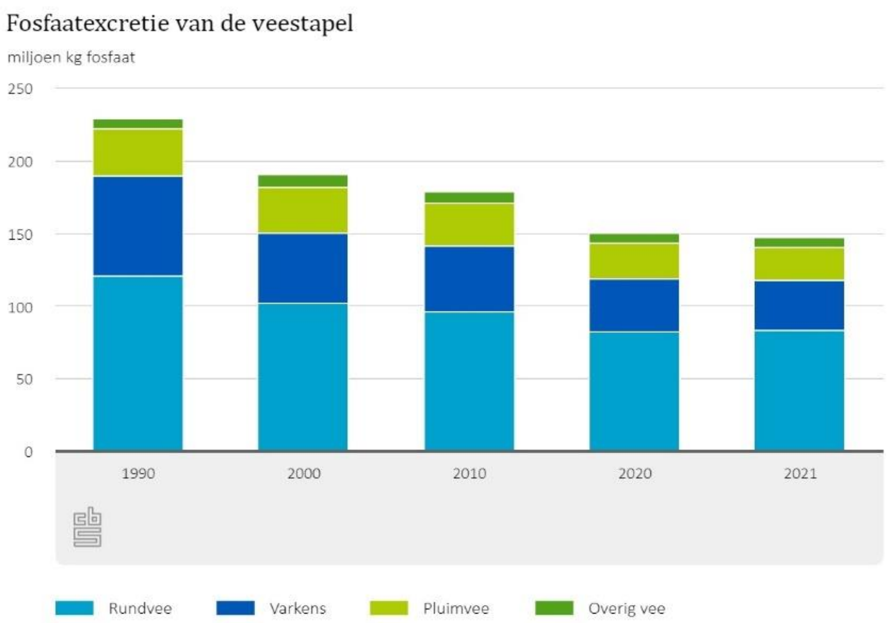

Figure 3-3 *Phosphorous excretion of different livestock sectors in the Netherlands*
Source: CBS (2022a).

Table 3-1 Total slaughter weight of livestock types, 2005-2021 (1,000 kg carcass weight)

	2005	2010	2015	2019	2020	2021
Cattle (total)	395,871	388,610	382,519	424,299	432,835	429,640
Total adult cattle	184,714	166,417	157,501	160,602	180,089	176,547
Dairy cows	153,999	140,546	129,281	134,418	150,530	147,589
Heifers	2,814	3,060	2,653	2,705	2,994	3,172
Bulls	27,902	22,810	25,567	23,479	26,565	25,785
Total calves	211,157	222,193	225,018	263,697	252,746	253,093
Calves younger than 9 months	.	175,919	189,687	231,314	221,776	222,635
Calves 9-12 months	.	46,274	35,331	32,384	30,969	30,458
Pigs (total)	1,298,367	1,288,274	1,456,215	1,628,293	1,661,645	1,719,419
Sheeps incl. lambs	13,462	13,165	12,981	13,272	15,929	15,618
Lambs	10,260	9,690	8,678	8,527	10,661	10,677
Goats (total)	320	1,363	1,466	2,256	2,612	2,844
Solipeds	497	553	751	432	358	414
Broiler	627,578	751,038	952,531	997,538	953,499	826,209
Other chicken	26,500	30,416	37,147	38,821	42,251	43,170
Other poultry	173	117	10	11	4	2

Source: CBS (2022b).

Table 3-2 Total milk and dairy products processed by dairy processors (1,000 kg)

	1995	2000	2005	2010	2019	2020	2021
Milk fat (%)	4.40	4.38	4.39	4.42	4.41	4.42	4.45
Milk protein (%)	3.48	3.47	3.49	3.52	3.58	3.58	3.59
Butter	132,300	126,200	118,800	133,419	136,524	133,605	137,503
Cheese	682,900	683,600	672,200	752,638	920,809	972,734	946,760
Milkpowder, total	154,000	166,000	160,400	199,087	243,958	248,115	209,138
Milkpowder, not skimmed	121,900	96,700	107,200	135,457	177,122	177,605	118,152
Milkpowder, skimmed	32,100	69,300	53,200	63,630	66,836	70,510	90,986
Condensed milk	353,100	273,500	291,800	347,285	390,833	393,852	391,644
Whey powder	126,700	129,700	68,316	.	.	.	.
Milk amount	10,811,000	10,733,600	10,478,900	11,626,123	13,802,159	13,986,695	13,603,304

Source: CBS (2022c).

3.2 Classification and quantification

In the Netherlands a lot of flows are already measured or calculated. The MFM is mainly focused on flows with an economic value, but for monitoring the livestock sector also flows without economic value should be included. This especially accounts for manure and by-products and waste from processing meat and milk. The focus is here on residues from primary production. However, residues from processing are excluded, as for example type of feed ingredients from feed companies are not publicly available. On the other hand, nitrogen and phosphorous values of compound feed are monitored and used to calculate nitrogen and phosphorous excretion. Wet by-products from processing that are fed to livestock are monitored by the OPNV and yearly reported (OPNV, 2022). Nitrogen and phosphorus flows of manure are yearly calculated and reported by CBS (CBS, 2021). By-products from slaughterhouses are reported in Chapter 10 from CPA. However, several livestock species are included in one category, for example edible offal of swine, beef, sheep etc. Based on standard conversion ratios, live weight of different type of livestock can be divided in different type of products (EC, 2018).

3.3 Coding Approach

The general coding approach is already discussed in Chapter 2 and livestock products follows the same principle as explained for crop products. Currently nitrogen, phosphorous and by-products from for example ‘Better life’ or organic livestock production are not yet reported separately. Because of the increasing attention for different type of production systems this differentiation has been made in our KB1-1B although dedicated data are not available. Only organic output (e.g. carcass weight, milk production) are currently reported by CBS. Agrimatie shows only more detailed information about dairy farms (Agrimatie, 2022). However, for a good estimation data are needed on feed intake, nutrient values and retention rates. These are currently not registered, and a high variation can be expected. Therefore this cannot yet be estimated but the option in the coding is there when data will become available in the future. Also type of breeds are not publicly registered, but type of breed is mainly included because this was important for the fishery section (Chapter 4). Therefore, breed is not yet specified but the option is available if data and importance increase in future.

Table 3-3 *Overview of digits of livestock and related input*

Digit	Aim	CBS Tabel Name	Source	Remark
7-8	Divide livestock in different ages	Omvang veestapel op agrarische bedrijven: peildatum 1 april en 1 december	StatLine - Omvang veestapel op agrarische bedrijven: peildatum 1 april en 1 december (cbs.nl)	
9-10	Divide livestock in different type of breeds	-	-	Mainly included because of importance for fishery
11-12	Divide livestock in different type of production systems	Activiteiten van biologische landbouwbedrijven	StatLine - Activiteiten van biologische landbouwbedrijven; regio (cbs.nl)	Only organic available
13-14	Different type of products	Vleesproductie; aantal slachtingen en geslacht gewicht per diersoort	StatLine - Vleesproductie; aantal slachtingen en geslacht gewicht per diersoort (cbs.nl)	
Attributes	Volume of manure. Composition and amount of minerals in manure		Dierlijke mest en mineralen 2021 (cbs.nl)	Only N, and P are monitored, other minerals can be estimated based on ratios in manure from KWIN

Source: Authors.

4 Biomass from aquatic product residues

4.1 Scope and size: production structure

To understand how to progress to a more circular bioeconomy the insight into biomass flows in the bioeconomy must be improved. An important aspect in this respect is the flow of biomass resources and the individual components they consist of in fisheries and aquaculture. The production and residues in these sectors are often either oversimplified or not included at all in bio-economy frameworks. While fish production values are often well-documented by statistical agencies, such as Eurostat, the Scientific Technical and Economic Committee for Fisheries (STECF), Rijksdienst voor Ondernemend Nederland (RVO) and Wageningen Marine Research (WMR), fish residues are often difficult to estimate and require more sophisticated methods to estimate values. In short, a strong quantification framework is lacking for flows early in the fish production chain. Setting up such a quantification approach will provide significant improvement of our understanding of biomass flows in the Dutch bioeconomy. This chapter presents a first approach to quantifying on a regular basis the type and amount of residues produced in the Dutch fisheries and aquaculture sector. The approach builds on existing work and uses existing statistical data sources to ensure regular updates in time which can be used in other monitoring activities for circularity.

4.2 Classification and quantification

4.2.1 Primary residue flows

Defining the residue flows in aquatic biomass production can be a difficult exercise as the sector is rather different from land-based production. For instance, marine production consists of marine aquaculture sector, the pelagic fisheries sector, demersal fisheries sector, crustacean fisheries and so on. These sectors are difficult to describe as a whole since the sectors differ significantly from each other, especially in the production of residues. Therefore, in an effort to describe the sector as a whole, it is important to define a clear and consistent definition of residue flows in marine production as well as a clear cut off point that defines when biomass flows transition from production industries to processing industries (see Figure 4-1). As a result, this section defines residue flows in production as follows for capture fisheries and aquaculture separately:

> ‘Residue flows in capture fisheries (wild caught production) are residues of the production industry if the residues are produced before landing the product. Therefore, any processing waste produced on-ship, before the product has been on land, is considered a residue of the production industry. On the other hand any processing waste occurring after a marine product has been on land, is considered a residue of the processing industry.’

Similarly, residue flows in aquaculture (reared fish) are residues of the production if the residues are produced before the marine product is landed. For any aquaculture on open sea, this means that residues occurring during transport from aquaculture culture plot to land are also considered production residues, rather than processing residues. For near-shore or on-land aquaculture this translates to: any waste produced before leaving an aquaculture pen or plot is considered production waste, any waste produced after is considered a residue of the processing industry.

This distinction, however, provides some border cases in that should be addressed and, in which case, an extension of the above stated definitions and distinctions is needed. The most pressing exception to address, is capture-based aquaculture. Capture-based aquaculture is a subsector of the aquaculture sector that rears wild caught eggs, juvenile or other immature forms of aquatic life to mature products. An example in the Netherlands is presented through the mussel culture sector. In the mussel sector, wild caught, immature, mussel spat is transported to culture plots, after which they are grown out to the point that the mussels are mature enough for the consumer market. To position capture-based aquaculture in the distinction between production and processing residues, capture-based aquaculture should be considered to produce production residues in two separate production sectors, before entering the processing industry: First, the wild capture of immature aquatic life generates production residues before the aquatic life is safely delivered to the aquaculture plot. Second, production residues are produced during the outgrow phase of production and the distinction defined for aquaculture in general applies. Figure 4-1 shows the biomass flows from fisheries, aquaculture and other aquatic production sectors. Black arrows represent produced biomass flows that are not residues, while orange arrows represent the residue flows occurring in the production sectors considered. The distinction before and after landing is made as hard border between the production and processing parts of the product chain. An extensive description of the classification is given in Section 4.4.

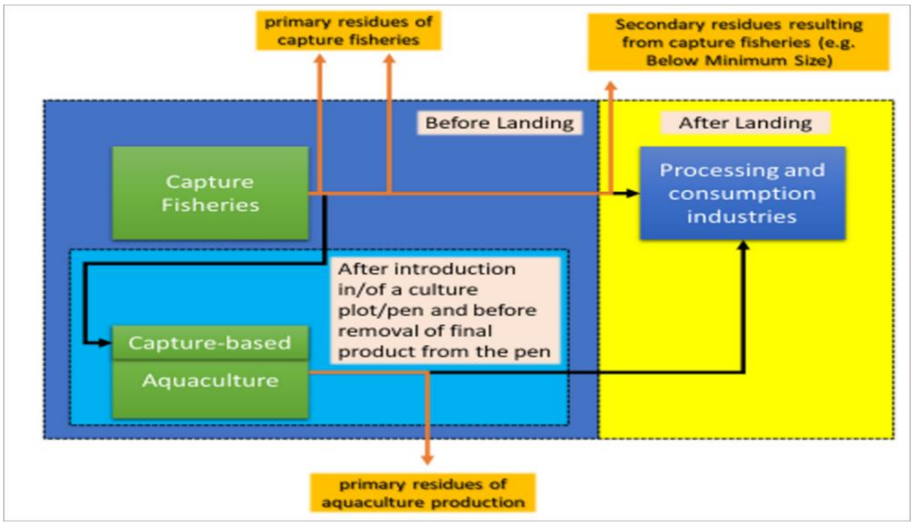

Figure 4-1 *Biomass flows from fisheries, aquaculture and other aquatic production sectors and the definition of sectors, primary and secondary residues*
Source: Authors.

4.2.2 Exports and imports in primary production flows

With a significant part of the production in the aquatic sector occurring in international waters the distinction between an import, export and regularly produced flow can be blurry. As a result a clear delineation and definition of what this factsheet regards as an import, export or neither needs to be given here. An visual representation of the classification of imports and export are given in Figure 4-2.

Following the logic of the above, imports or export at the production stage are also as belonging to either production imports, production exports, exports further in the chain and imports further in the chain. To delineate clear boundaries for export and import flows this factsheet considers the nationality of the marine production unit (e.g. country of registration of the fishing vessel) and the country of landing.

- If the nationality of the vessel and the country of landing are both the Netherlands, the flow is considered as neither import nor export.
- If the nationality of the vessel is Dutch but the product of landing is not landed in the Netherlands, the flow is considered as export. However, every residue created before landing is still considered as residue of the Dutch bioeconomy.
- If the nationality of the vessel is not Dutch but the product is landed in the Netherlands, the flow itself is considered as an import to the Dutch processing sector. Contrarily, since the flow is not produced by a Dutch vessel, neither are the residue flows before landing. Consequently, any residue flows that are produced by foreign vessels but never landed (in the Netherlands) are excluded from the analysis. However, if the produced residue are landed in the Netherlands, they are considered as imports of residue.
- If neither the nationality of the vessel nor the country of landing is the Netherlands, the biomass flows will never be part of the Dutch bioeconomy and excluded from the analysis.

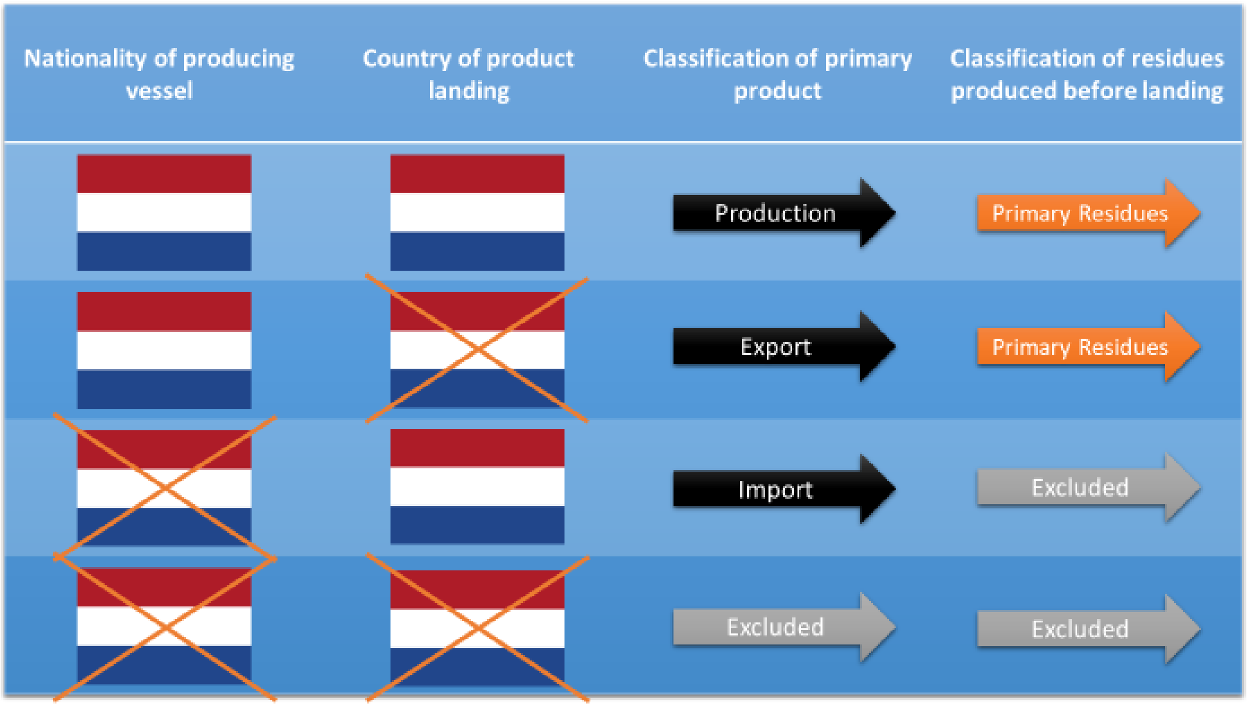

Figure 4-2 *Visual clarification of the classification, to export, import or primary product, of biomass flows, including residue flows, in the marine fisheries sector, as part of the fisheries, aquaculture and aquatic production sectors considered in this section*
Source: Authors.

4.3 Coding approach

As will be described in Section 4.4, the fishery data is available in presentation form and ASFIS/ISSCAAP. For consistency with other primary sectors (crop and livestock farming) and with coding system used by CBS in MFM, the product classification coding builds upon the CPA and NACE coding system (see Section 2.3 and Figure 2-6). Similar as for crops (Figure 2-6) and animal products (Table 3-3) also for aquatic products four aggregation levels are added after NACE coding level 4 for aquatic products, which eventually leads up to 14 alpha-numerical digits.

Below the four NACE levels the classification in the WUR MFM adds four deeper levels of disaggregation. The exact coding of these levels for fisheries is defined as either a numerical, alpha-numerical or alphabetical code depending on whether the source data makes use of an international and/ or widely used coding system:

1. *Digits 7-8 (level 5):* A(n) (alpha-)numerical or alphabetical code representing the product type and/or age. For instance wild caught fisheries discern 'Below Minimum Size' (BMS – below legal minimum length set for produced fish) and 'Above Minimum Size' (AMS – above the aforementioned minimal legal requirements) animal products and aquaculture can yield products as eggs, juveniles or adult animals. For an extensive overview of the (potential) groupings in this level, see Appendix 4.
2. *Digits 9-10 (level 7):* An (alpha-)numerical or alphabetical code representing the species, variety or race of the organism a product originates from. For instance aquatic production may yield products from characteristic species such as Blue Mussels, Herrings, Sardines or Flounders. In the current data sources a total of +- 330 species are identified. See Appendix 5 for a full list of the species present in the currently considered data sources.
3. *Digits 11-12 (level 6):* An (alpha-)numerical or alphabetical code representing the mode of production according to practice labels or good standards. For instance wild caught fisheries production can be awarded the Marine Stewardship Council (MSC) label for good fishery practices (or not), similarly aquaculture may be rewarded (or not) the Aquaculture Stewardship Council (ASC) label for good

production practices. Due to an expected lack of data, this level merely contains a single 'unclear' grouping. Future data availability may remedy the lack of groupings in this level, hence the inclusion.

4. *Digits 13-14 (level 8):* An (alpha-)numerical or alphabetical code representing the product form. for instance wild caught fish may be landed as whole fish, fish fillets and gutted fish. In the current data sources the product can be presented in different presentation forms (e.g. fillets, tails, gutted etc.) when landed. See Appendix 6 for a full list of the product forms that are in the currently considered data sources.

4.4 Data sources on aquatic biomass flows

Data on fisheries are often limited and scattered. While some data might be available from more reliable or detailed sources, the data used to estimate marine production residue flows are, when possible, collected from Eurostat for consistency and comparability reasons. However, not all data deemed necessary were available from the Eurostat databases. Consequently, this section first presents all used databases form Eurostat. The second part describes the other data sources used to acquire raw data from. Lastly, the third part describes several supplementary data sources that are not used to extract raw data, but to acquire conversion factors, alternative names, groupings or other supporting data to compile data on residue flows.

All Eurostat data were either extracted by hand from government websites or extracted and analysed using Python (v3.9.4) with package *eurostat* (v0.2.3). Other data were extracted and aggregated by employees of the *Centrum for Visserijonderzoek – CVO* (Center for Fisheries Research) from confidential data based on *Rijksdienst voor Ondernemend Nederland - RVO* (Netherlands Enterprising Agency) Official Logbook data. Also classification schemes from other statistical institutes, such as Eurostat and the statistical offices of the Food and Agricultural Organization (FAO) were used for compiling data and adding metadata on categories in the data.

4.4.1 Eurostat databases

This section serves to highlight the datasets from Eurostat are used to compile the current data to estimate main products and residue flows in the marine production sector. All Eurostat statistics employ the 'Aquatic Sciences and Fisheries Information System' (ASFIS) coding for species, and the 'International Standard Statistical Classification for Aquatic Animals and Plants' (ISSCAAP) statistical codes for the aggregation of these species to higher levels.

Eurostat landings of fishery products in <country of interest> (fish_ld_<insert country code>) represents the landings of all fishery products on the country of interest's shores. The database can split the landings to nationality of the vessel landing, making it possible to discern the capture fisheries landings of the Dutch fleet on these shores. The unit of the database is either Tonnes Product Weight (TPW) (e.g. tonnes of fillet, tonnes of gutted fish etc.), Euro per Tonne, or Euros. For the analysis of biomass flows this study employs the data presented in the unit of Tonnes Product Weight (TPW). Additionally, the data can be split out to presentation form (Fresh, fish, frozen fish, gutted fish etc.). Landings not originating from vessels registered under the Dutch flag are filtered as these are beyond the scope of the Material Flow Monitor. The landings by the Dutch fleet on non-Dutch shores are defined as exports in the Material Flow Monitor. The specific Eurostat databases employed in this study and implemented as described above are:

- Eurostat Landings of fishery products in Belgium (fish_ld_be)
- Eurostat Landings of fishery products in Bulgaria (fish_ld_bg)
- Eurostat Landings of fishery products in Denmark (fish_ld_dk)
- Eurostat Landings of fishery products in Germany (fish_ld_de)
- Eurostat Landings of fishery products in Estonia (fish_ld_ee)
- Eurostat Landings of fishery products in Ireland (fish_ld_ie)
- Eurostat Landings of fishery products in Greece (fish_ld_el)
- Eurostat Landings of fishery products in Spain (fish_ld_es)
- Eurostat Landings of fishery products in France (fish_ld_fr)
- Eurostat Landings of fishery products in Iceland (fish_ld_is)
- Eurostat Landings of fishery products in Italy (fish_ld_it)

- Eurostat Landings of fishery products in Cyprus (fish_ld_cy)
- Eurostat Landings of fishery products in Latvia (fish_ld_lv)
- Eurostat Landings of fishery products in Lithuania (fish_ld_lt)
- Eurostat Landings of fishery products in Malta (fish_ld_mt)
- Eurostat Landings of fishery products in Poland (fish_ld_pl)
- Eurostat Landings of fishery products in Portugal (fish_ld_pt)
- Eurostat Landings of fishery products in Romania (fish_ld_ro)
- Eurostat Landings of fishery products in Slovenia (fish_ld_si)
- Eurostat Landings of fishery products in Finland (fish_ld_fi)
- Eurostat Landings of fishery products in Sweden (fish_ld_se)
- Eurostat Landings of fishery products in the United Kingdom (fish_ld_uk)
- Eurostat Landings of fishery products in Norway (fish_ld_no)
- Eurostat Landings of fishery products in Croatia (fish_ld_hr)

Eurostat Landings of Fishery products in the Netherlands (fish_ld_nl) is also included. While the descriptions and characteristics of the databases mentioned above still holds, this database specifically is treated differently. In this database the landings by vessels registered under non-Dutch flags are not filtered out but kept separately as they are defined as imports in the Material Flow Monitor. Additionally the landings of Vessels registered under the Dutch Flag and landed on Dutch shores are defined as regular production, not representing export or import as the extracted values from the other Eurostat databases mentioned above do.

Eurostat Production from aquaculture excluding hatcheries and nurseries (from 2008 onwards) (fish_aq2a) represents the production of mature aquatic products from aquaculture in Europe. The database can split the production to the country level, making it possible to discern the aquaculture production in the Netherlands. The unit of the database is either Tonnes Live Weight (TLW), Euro per Tonne, or Euros. For the analysis of biomass flows this study employs the data presented in the unit of Tonnes Live Weight (TLW). Aquaculture production outside of the Netherlands is excluded from the analysis.

Eurostat Production of fish eggs for human consumption from aquaculture (from 2008 onwards) (fish_aq2b) represents the production of egg-stage aquatic products from aquaculture in Europe, specifically intended for consumptive use. The database can split the production to the country level, making it possible to discern the aquaculture production in the Netherlands. The unit of the database is either Tonnes Live Weight (TLW), Euro per Tonne, or Euros. For the analysis of biomass flows this study employs the data presented in the unit of Tonnes Live Weight (TLW). Aquaculture production outside of the Netherlands is filtered out for the analysis.

Eurostat Input to capture-based aquaculture (from 2008 onwards) (fish_aq3) represents the immature, wild caught, aquatic products that are placed in capture based aquaculture structures intended to be grown out to mature products in Europe. The database can split the inputs to the country level, making it possible to discern the capture-base aquaculture inputs in the Netherlands. The unit of the database is either Tonnes Live Weight (TLW), Number, Euro per Tonne, or Euros. For the analysis of biomass flows this study employs the data presented in the unit of Tonnes Live Weight (TLW). Inputs to capture-based aquaculture outside of the Netherlands is filtered out for the analysis.

Eurostat Production of hatcheries and nurseries at eggs stage in life cycle (from 2008 onwards) (fish_aq4a) represents the production of egg-stage aquatic products from aquaculture in Europe, specifically not intended for (direct) consumptive use. The database can split the production to the country level, making it possible to discern the production in the Netherlands. Intended uses defined in this database are ‘To be released in the wild’ (WLD), likely as part of conservation efforts, and ‘Transferred to a controlled environment (for on-growing)’ (ENVC), intended as immature input for aquaculture production, aquaculture hatcheries or nurseries. The unit of the database is Million Individuals (MIO). Production outside of the Netherlands is excluded from the analysis. Since production intended ‘to be released in the wild’ will neither result in a biomass flow intended for economical purposes nor can it be seen as a residual flow of production, it is filtered out for the analysis. However, since intended uses can also be defined as ‘Not Specified’, it is unavoidable some of the ‘to be released in the wild’ destined production may become part of the material flow monitor.

Eurostat Production of hatcheries and nurseries at juvenile stage in life cycle (from 2008 onwards)(fish_aq4b) represents the production of juvenile-stage aquatic products from aquaculture in Europe, specifically not intended for (direct) consumptive use. The database can split the production to the country level, making it possible to discern the production in the Netherlands. Intended uses defined in this database are 'To be released in the wild' (WLD), likely as part of conservation efforts, and 'Transferred to a controlled environment (for on-growing)' (ENVC), intended as immature input for aquaculture production, aquaculture hatcheries or nurseries. The unit of the database is Million Individuals (MIO). Production outside of the Netherlands is excluded from the analysis. Since production intended 'to be released in the wild' will neither result in a biomass flow intended for economical purposes nor can it be seen as a residual flow of production, it is filtered out for the analysis. However, since intended uses can also be defined as 'Not Specified', it is unavoidable some of the 'to be released in the wild' destined production may become part of the material flow monitor.

4.4.2 Other primary data sources

Some biomass flows in marine production could not be estimated based on Eurostat database and are therefore taken from other sources, specifically the following data source is used to estimate these flows.

Netherlands Enterprise Agency (RVO) Official Logbook data on fish landings in the Netherlands represents the data that is collected by the RVO to chart Dutch fishery markets statistics. Through a data request to researchers of Center for Fisheries Research (CVO) as part of Wageningen Marine Research (WMR). While the raw data contain information on disaggregation to for instance metièr and geographical area, the CVO researchers aggregated and selected the data to only include yearly values per species and per fishing area for the Above Minimum Size (AMS) and Below Minimum Size (BMS) landings of the Dutch fleet in the Netherlands, avoiding any confidentiality issues. Raw data and confidential access can be granted by CVO only. For the analysis the data were aggregated to yearly values per species.

4.4.3 Supplementary data used to compile or group data

To streamline and further aggregate or compile data several additional sources and classification schemes are used:

International Standard Statistical Classification for Aquatic Animals and Plants (ISSCAAP) provides a classification and grouping structure compiled by the Food and Agriculture Organization of the United Nations (FAO) to facilitate aggregation of aquatic animals and plants. The classifications include two levels of aggregation into 50 lower level groups and nine higher level divisions. ISSCAAP is a well-known and widely used structure, for instance in Eurostat databases, to aggregate data for aquatic life.

Aquatic Sciences and Fisheries Information System (ASFIS) list of species for fishery statistics purposes is a classification of species in fisheries widely used for statistical purposes, for instance in Eurostat databases, compiled by the FAO. The list assigns 13,060 species (so far on 2 February 2022), identified as relevant to fisheries, a stable and unique 3-alpha and 10-13 digit taxonomic code. Additionally, the list couples each ASFIS code to the higher level aggregation code from the ISSCAAP, making aggregation of species to ISSCAAP aggregations possible.

Commission Implementing Regulation (EU) no 404/2011 of 8 April 2011 laying down detailed rules for the implementation of Council Regulation (EC) No 1224/2009 establishing a Community control system for ensuring compliance with the rules of the Common Fisheries Policy (version 14 July 2020) outlines many of the definitions of codes on fishery statistics in the EU, including Eurostat. Additionally, the appendixes of the regulation outline many of the conversion factors to be used in European fishery statistics, such as the conversion factors from product weight to live weight for a number of species.

4.5 Estimating aquatic production biomass and residue flows

This section presents several ways to estimate residue flows from aquatic production. Due to relatively small contributions of aquaculture to the Dutch aquatic production volumes, it was chosen to focus on the capture fishery sectors, making aquaculture residues beyond the scope of this study. The focus is on three key residue flows form capture fishery production: primary residues as a result of at sea offcuts, primary residues as a result of at sea discards and secondary residues as a result of Below Minimum Size Landing Obligations. For both discards and Below Minimum Size Landings, data is severely limited or of questionable quality. The considerations will be outlined in this section.

4.5.1 Primary residues as a result of at sea offcuts

As many products are not landed as whole, fresh fish, but already pre-processed to derivative products, conversion factors are necessary to estimate the at sea residue flows in wet weight of marine life produced. As conversion factors for species in marine production are generally not (widely) available or not known, this analysis focuses in 12 species/groups of species as proof of concept. These 12 species were chosen specifically as they are either most likely to have conversion factors for at-sea processing (primary residues) available and/or cover a large section (of the total Dutch at sea residue volume) of the Dutch wild capture fisheries. The selection was made based on expertise of colleagues within Wageningen Marine Research.

The species considered in the analysis are European Plaice (PLE), Common Sole (SOL), Turbot (TUR), Common Dab (DAB), Brill (BLL), Atlantic Cod (COD), Whiting (WHG), European Flounder (FLE), Rays, Stingrays and Mantas nei (SRX), Norway Lobster (NEP), Grey Gurnard (GUG) and Tub Gurnard (GUU). The full list of identified conversion factors for each of these species are mentioned in Table 4-1 as well.

Additionally, based on the in-house expertise at Wageningen Marine Research, pelagic fish species, when not specifically mentioned in the list above, are only landed marginally in processed forms, resulting in our assumption these products have not produced any primary residues before landing.

Table 4-1 *Twelve selected species with promising conversion factors and/or significant contribution to residues produced by the Dutch fishery sector (for fresh presentation forms to fresh, whole catch)*

ASFIS 3A_CODE	English name	Gutted	Gutted & Headed	Headed	Filleted	Filleted and Skinned	Fresh Tail	Fresh Wings
BLL	Brill	1.09 a)						NA
COD	Atlantic Cod	1.17 a)	1.70 a)	1.38 a)	2.60 a)	2.60 a)		NA
DAB	Common Dab	1.11 a)	1.39 a)					NA
FLE	European Flounder	1.08 a)	1.39 a)					NA
GUG	Grey Gurnard							NA
GUU	Tub Gurnard							NA
NEP	Norway Lobsters						3.00 a)	NA
PLE	European Plaice	1.07 a)	1.39 a)		2.40 a)			NA
SOL	Common Sole	1.04 a)						NA
SRX	Rays, Skates & Mante nei	1.13 a)						2.09[1]
TUR	Turbot	1.09 a)						NA
WHG	Whiting	1.18 a)						NA

a) Conversion factors taken from 'Commission implementing regulation (EU) no. 404/2011 (8 April 2011).'

Table 4-2 gives a justification for the twelve species chosen as contribution total landed volume in the Netherlands. The number here are presented as the % of total volume landed in the Netherlands (Weight landed in as % of total weight landed for a given species for fresh presentation forms). It is constructed based on the database Eurostat Landings of Fishery products in the Netherlands (fish_ld_nl), values for 2020, accessed on 17-08-2022.

Table 4-2 *The 12 selected species contributing to the total landed volume (%), the Netherlands*

ASFIS 3A_CODE	English name	Whole	Gutted	Gutted & Headed	Headed	Filleted	Filleted and Skinned	Fresh Tail	Fresh Wings	TOTAL coverage
BLL	Brill	1.6	98.25	0	NE	0	NE	0	NE	99.85
COD	Atlantic Cod	0.12	99.82	0	NE	0	NE	0	NE	99.95
DAB	Common Dab	6.97	92.94	0.01	NE	NC	NE	0	NE	99.91
FLE	European Flounder	96.73	0.33	<0.005	NE	NC	NE	0	NE	97.06
GUG	Grey Gurnard	99.63	NC	0	NE	0	NE	0	NE	99.63
GUU	Tub Gurnard	99.88	NC	0	NE	0	NE	0	NE	99.88
NEP	Norway Lobsters	94.38	0	NC	NE	0	NE		NE	99.30
PLE	European Plaice	0.66	99.25	<0.005	NE	0	NE	0	NE	99.91
SOL	Common Sole	2.09	97.91	0	NE	NC	NE	0	NE	100
SRX^{SR}	Rays, Skates & Manta nei	55.32	44.50	0	NE	0	NE	0	NE	99.82
TUR	Turbot	0.12	99.84	0	NE	NC	NE	0	NE	99.96
WHG	Whiting	35.25	52.73	NC	NE	NC	NE	0	NE	87.98

^{NC} While volumes >0 are reported in Eurostat, no conversion factors could be obtained for this species and presentation form combination; ^{NE} Eurostat does not report on this presentation form, this is likely contained in either Eurostat's category 'Fresh, not specified' or 'Fresh, other'; ^{FI} Eurostat does not distinguish between fillets and skinned fillets in presentation forms; ^{SR} To make up this category the sum of all species with an ASFIS code starting with RJ* was taken.

In addition to these selected species, for pelagic species processing waste can often be neglected due to most catches not being process (Table 4-3), but only frozen, producing neglectable residues.

Table 4-3 *Justification for regarding all pelagic fish species as producing no primary residue flows (TPW), showing nearly all products are landed as whole, frozen fish*

ISSCAAP code (Eurostat)	English name	Whole frozen landings (in TPW)	Total landings (in TPW)	Estimated residue flows as % of landings
F35	Herrings, Sardines, Anchovies	139,884.569	139.921,578	99,97%
F36	Tunas, Bonitos, Billfishes	80.05	80.05	100,00%
F37	Miscellaneous Pelagic Fish	86,513.159	88,274.903	98,00%

Taking into account the twelve species mentioned above and the pelagic species, our analysis can identify the associated primary residue flows for roughly 65% of all fishery products landed by the Dutch Fleet in the Netherlands, including all other fisheries besides pelagic fisheries (Table 4-4).

Table 4-4 *Calculated at-sea produced primary residues (TPW) for the 12 selected (groups of) species*

		Gutted associated	Gutted & Headed associated	Filleted associated	Fresh Tail associated	TOTAL primary residues
ASFIS 3A_CODE	**English name**	**Guts**	**Guts & Heads**	**Fillet offcuts**	**Not Tails**	**Total at sea offcuts (in TPW)**
BLL	Brill	68,706.630	0	0	0	68,269.770
COD	Atlantic Cod	88,815.820	0	0	0	88,332.400
DAB	Common Dab	202,630.010	53.430	NC	0	201,400.510
FLE	European Flounder	2,921.200	2.340	NC	0	2,923.540
GUG	Grey Gurnard	NC	0	0	0	0
GUU	Tub Gurnard	NC	0	0	0	0
NEP	Norway Lobsters	0	NC	0	77,828	77,828.000
PLE	European Plaice	1,266,919.430	0	0	0	1,266,919.430
SOL	Common Sole	254,391.600	0	NC	0	254,391.600
SRX	Rays, Skates & Manta nei	24,629.930	0	0	0	24,629.930
TUR	Turbot	176,711.850	0	NC	0	176,711.850
WHG	Whiting	107,879.760	NC	NC	0	107,879.760

NC While volumes >0 are reported in Eurostat, no conversion factors could be obtained for this species and presentation form combination, making estimation of these offcuts impossible.

4.5.2 Primary residues as a result of at-sea discards

As the selectivity of fishing nets is rarely perfect, almost always fishing catches non target species or fish of insufficient marketable (or legally allowed) sizes. Much of this so-called ‘bycatch’ is bound by a myriad of legal constraints, such as the Landing Obligation for Below Minimum Size (BMS) fish. However, much of this bycatch is also subject to legal exceptions, for instance if the species has a high chance of survival when thrown back into the sea, it gains a legal exception from the landing obligation. Another consideration for at sea discards, is whether or not they are an actual flow within the Dutch bioeconomy: discards are produced on board, but immediately returned to the sea, remaining in the natural system (although in many cases as deceased biomass). The fact that these flows are generated at sea, data collection is difficult and compliance with legal constraints is difficult. Given these constraints, data collection is still in its infancy and reliable yearly estimates of (conversion factors for) the amount of discards were not found. However, discards are an important residue flow in the fishing industry, form both an economic and environmental perspective and should therefore be included in the structure of the Material Flow Monitor and included quantitatively when estimates become available.

4.5.3 Secondary residues from landed Below Minimum Size (BMS) catches

Landed Below Minimum Size (BMS) fish are fish of sizes below legally accepted minimum sizes of fish. Law requires these fish to be landed and the amounts registered. However, based on expert knowledge at Wageningen Marine Research on the selectivity of fishing gear, we expect the landed values to be an underestimation of the actual BMS fish and a significant portion of the BMS fish that should be landed to make up part of the discard residue flow (section 4.5.2). Accurate values of the actual BMS fish landed as reported by RVO and aggregated by the Center for Fisheries Research (CVO). RVO’s full list of 51 species is available in Appendix 7, while Table 4-5 contains the 21 species with a reported BMS larger than zero.

Table 4-5 *Below Minimum Size fish landed in tonnes live weight (TLW) as catches by the Dutch fishing fleet landed in the Netherlands*

ASFIS 3A_CODE	English name	Above Minimum Size landings (in TLW)	Below Minimum Size landings (in TLW)	Total landings (in TLW)	BMS as % of total landings
BLL	Brill	840.216	0.599	840.815	0.0711
COD	Atlantic cod	610.723	0.090	610.813	0.015
DAB	Common dab	2,172.144	1.373	2,173.517	0.063
FLE	European flounder	1,287.007	0.003	1,287.010	0.000
GHL	Greenland halibut	0.677	3.493	4.170	83.765
GUG	Grey gurnard	460.236	0.040	460.276	0.009
GUR[1]	Red gurnard a)	234.502	0.020	234.522	0.009
HAD	Haddock	215.561	69.089	284.650	24.272
HAL	Atlantic halibut	7.893	4.313	12.206	35.335
HER	Atlantic herring	79,223.904	89.027	79,312.931	0.112
HKE	European hake	310.722	0.086	310.808	0.028
HOM	Atlantic horse mackerel	18,782.627	0.025	18,782.652	0.000
LEM	Lemon sole	437.613	0.036	427.649	0.008
MAC	Atlantic mackerel	29,736.173	233.518	29,969.691	0.779
MON	Angler	355.131	0.005	355.136	0.001
NEP	Norway Lobster	930.636	0.026	930.662	0.003
PLE	European plaice	19,004.780	157.221	19,162.001	0.820
SOL	Common sole	6,719.101	32.635	6,751.736	0.483
TUR	Turbot	2,145.206	0.284	2,145.490	0.013
WHB	Blue whiting	62,066.000	0.325	62,066.325	0.001
WHG	Whiting	1,182.745	71.274	1,254.019	5.684

a) The scientific name of the Red Gurnard (Chelidon**i**chthys cuculus) was spelled different as Chelidon**y**chthys cuculus in the ASFIS species code list. Based on the same English name and the minimal changes (a single letter) in the name in both datasets it was assumed this species are one and the same.
Source: CVO (2020) as aggregation of RVO data.

After landing, the continued fate of bellow minimum size fish is difficult and rarely looked into, making the quantification of the continued fate of this flow in the Dutch Bioeconomy impossible. Qualitatively, expert opinions from Wageningen Economic Research employees state that most of the fish is used for generating electricity in biomass plants. Quantitative inclusion of the residual flow in the future is therefore dependent on further research into the fate of the this flow.

5 Biomass in secondary and tertiary residues

5.1 Scope and size: production structure

Primary residues originate from the field (e.g. straw). Secondary residues originate from processing in industry (e.g. saw dust), tertiary residues originate after consumption of the product (e.g. food leftovers, discarded furniture). Secondary residues are often used as cattle feed or fertiliser (e.g. foam earth). A small fraction of the secondary residues is processed as waste. Tertiary residues are usually collected as waste and processed in the waste processing sector.

Waste streams flow from the economy into the waste processing sector (Figure 5-1). Waste processing includes:
- Anaerobic digestion
- Composting
- Separation into fractions that can be reused (reuse includes use as fuel in the energy sector)
- Waste incineration (usually with energy recovery)
- Waste dump.

Sometimes treated waste is delivered to another waste treatment sector for further treatment (e.g. sewage sludge from sewage treatment to waste incinerators).

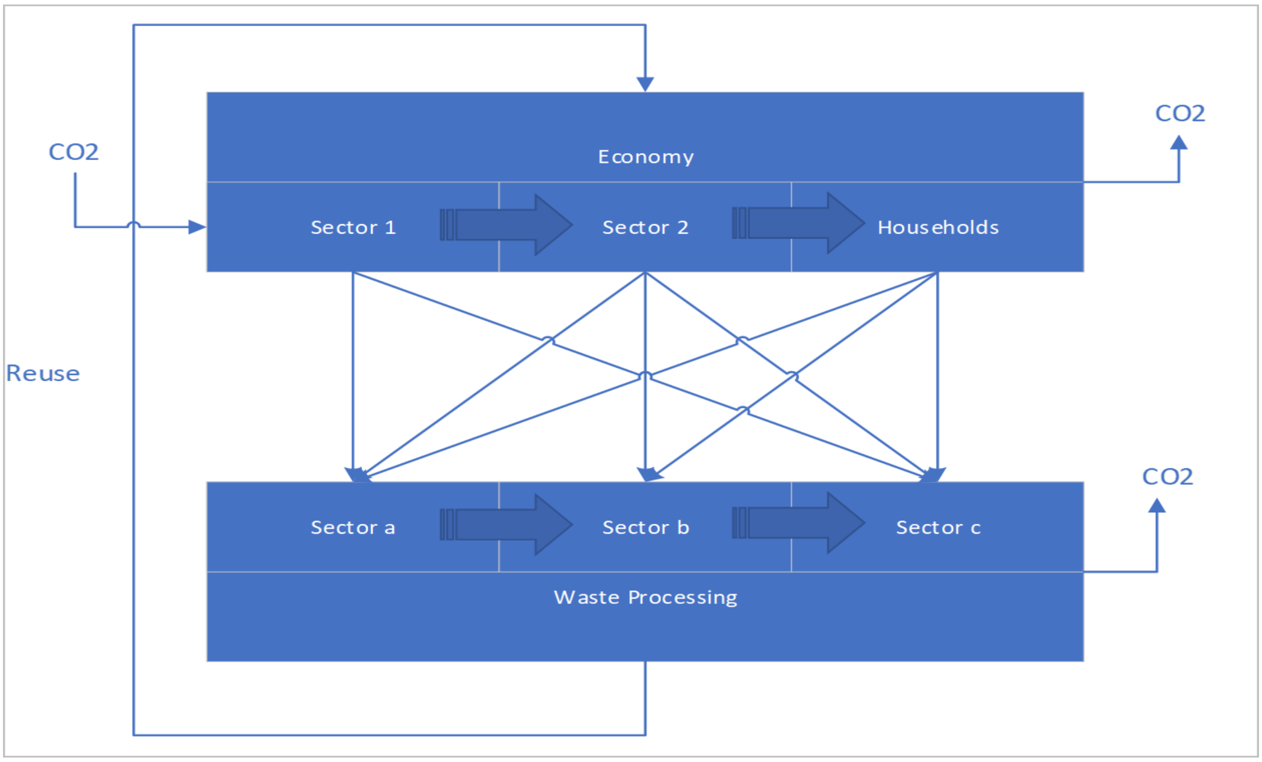

Figure 5-1 *Schematic overview of waste flows*
Source: Authors. For definitions and abbreviations, please see Table 5-18.

Following tables contain information on bio-based secondary and tertiary residue streams that have been derived from readily available CBS statistics. Section 5.2 provides the relevant data sources.

Table 5-1 *Estimate for bio-based materials in collected waste streams from households, in 2016*

	Total collected material (KT TM)	Fraction of organic material in total (share)	Sum of bio-based material (KT DM)
AfgedankteElektrOnIscheApparaten_19	86		0
AsbesthoudendAfval_31	11		0
Autobanden_33	4	0.20	1
BitumenhoudendeDakbedekking_29	11		0
BruikbaarHuisraad_20	49	0.30	15
Drankenkartons_11	0	0.55	0
FrituurvetEnOlie_16	2	0.80	2
GasflessenEnBrandblussers_35	0		0
GFTAfval_6	1548	0.35	542
Gips_30	25	0.05	1
GrofHuishoudelijkRestafval_4	515	0.21	108
GrofTuinafval_18	485	0.42	204
HardePlastics_21	28		0
HoutafvalAEnBHout_25	450	0.78	349
HoutafvalCHout_26	48	0.75	36
HuishoudelijkRestafval_3	2829	0.35	990
Kadavers_36	0	0.54	0
KleinChemischAfvalKCA_14	23		0
KunststofVerpakkingen_10	7		0
Luiers_15	12		0
Matrassen_23	13	0.18	2
Mengfracties_17	1		0
Metalen_27	80		0
MetalenVerpakkingenBlik_12	1		0
OudPapierEnKarton_7	837	0.60	498
OverigHuishoudelijkAfval_37	2		0
Piepschuim_34	1		0
PMDFractie_13	334	0.48	160
SchoneGrond_32	98		0
SchoonPuin_24	455	0.00	0
Textiel_8	86	0.27	23
Verbouwingsrestafval_5	79	0.18	14
Verpakkingsglas_9	357		0
Vlakglas_28	13		0
Vloerbedekking_22	10	0.18	2
Total	8500	0.35	2947

Source: Total collected material from 83558NED, fraction of bio-based material in total from own estimate as given in Table 5-9; sum of bio-based material calculated by multiplication.

Table 5-2 *Quantity of bio-based material in GFT waste taking into account local differences, in 2016*

	Fraction of bio-based material in the total stream (-)	Total volume (KT TM)	Total bio-based volume (KT DM)
Matig stedelijk	0.34	278	97
Niet stedelijk	0.32	191	67
Sterk stedelijk	0.36	451	158
Weinig stedelijk	0.32	504	176
Zeer sterk stedelijk	0.36	125	44
Total	0.35	1549	542

Source: Authors, see Table 5-20.

The fraction of bio-based material is an estimate for the share of bio-based material in the total stream volume. This yields an average bio-based fraction of 0.35. Following tables show information on secondary residue types.

Table 5-3 *Quantity of industrial wastes (KT TM) (sector level 6, category level 3), in 2016*

	Dierlijk, plantaardig afval	Gemengd afval	Glasafval	Houtafval	Kunststof-, rubberafval	Metaalafval	Mineralen, steenachtig afval	Overig niet-chemisch afval	Papier-, kartonafval	Slib	Textiel-, lederafval	Grand Total
10 Voedingsmiddelenindustrie	5,861	302	3	8	22	19	711	0	94	656	0	7,676
11 Drankenindustrie	605	6	23	0	6	3	0	0	9	23	0	675
12 Tabaksindustrie	1	1	0	0	0	0	1	0	1	0	0	4
13-15 Textiel-, kleding-, lederindustrie	0	18	0	2	2	1	2	0	7	3	11	46
16 Houtindustrie	1	20	0	111	2	1	6	0	3	0	0	144
17 Papierindustrie	0	143	0	6	17	5	8	0	223	34	0	436
18 Grafische industrie	1	12	0	1	3	4	0	0	125	0	0	146
19 Aardolie-industrie	7	4	0	0	5	3	75	0	0	0	0	94
20 Chemische industrie	45	114	0	6	19	17	117	0	15	22	0	355
21 Farmaceutische industrie	39	9	0	1	1	0	8	0	4	0	0	62
22 Rubber- en kunststofproductindustrie	0	49	1	7	60	3	2	0	15	0	0	137
23 Bouwmaterialenindustrie	0	40	10	13	1	7	484	0	4	0	0	559
24 Basismetaalindustrie	0	58	0	5	1	89	1,422	0	3	0	0	1,578
25 Metaalproductenindustrie	1	77	2	12	3	158	31	0	22	2	0	308
26 Elektrotechnische industrie	1	5	0	1	0	2	1	0	4	0	0	14
27 Elektrische apparatenindustrie	0	8	0	2	3	18	18	0	5	0	0	54
28 Machine-industrie	2	35	0	11	2	75	5	0	22	1	0	153
29-30 Transportmiddelenindustrie	3	23	0	11	7	52	6	1	12	0	0	115
31 Meubelindustrie	0	16	0	113	1	2	6	0	5	0	1	144
32 Overige industrie	16	25	0	2	1	2	2	0	18	2	1	69
33 Reparatie en installatie van machines	0	24	0	4	1	15	2	0	10	0	0	56
360 Waterleidingbedrijven	1	21	0	0	2	3	114	0	0	113	0	254
370 Afvalwaterinzameling en -behandeling	36	26	0	0	0	0	11	0	0	1,482	0	1,555
381 Inzameling van afval	0	2	0	0	0	0	0	0	0	0	0	2
382 Behandeling van afval	0	1,089	4	327	121	417	3,264	0	10	0	7	5,239
383 Voorbereiding tot recycling	29	276	14	18	57	56	483	1	3	0	1	938
390 Sanering en overig afvalbeheer	9	3	0	7	0	28	13	0	0	1	0	61
Total	6,658	2,406	57	668	337	980	6,792	2	614	2,339	21	20,874

Source: CBS (84970NED).

Table 5-4 *Estimated quantity of bio-based material in industrial waste (sector level 6, category level 3) (KT DM), based on estimates for bio-based fraction, in 2016*

	Dierlijk, plantaardig afval	**Gemengd afval**	**Glasafval**	**Houtafval**	**Kunststof-, rubberafval**	**Papier-, kartonafval**	**Slib**	**Textiel-, lederafval**	**(blank)**	**Grand Total**
10 Voedingsmiddelenindustrie	2,784	91	0	6	4	51	157	0	0	3,093
11 Drankenindustrie	287	2	1	0	1	5	6	0	0	302
12 Tabaksindustrie	0	0	0	0	0	1	0	0	0	1
13-15 Textiel-, kleding-, lederindustrie	0	5	0	2	0	4	1	3	0	15
16 Houtindustrie	0	6	0	90	0	2	0	0	0	98
17 Papierindustrie	0	43	0	5	3	121	8	0	0	180
18 Grafische industrie	0	4	0	1	1	68	0	0	0	73
19 Aardolie-industrie	3	1	0	0	1	0	0	0	0	5
20 Chemische industrie	21	34	0	5	3	8	5	0	0	77
21 Farmaceutische industrie	19	3	0	1	0	2	0	0	0	24
22 Rubber- en kunststofproductindustrie	0	15	0	6	10	8	0	0	0	39
23 Bouwmaterialenindustrie	0	12	0	10	0	2	0	0	0	25
24 Basismetaalindustrie	0	17	0	4	0	2	0	0	0	23
25 Metaalproductenindustrie	0	23	0	10	1	12	0	0	0	46
26 Elektrotechnische industrie	0	2	0	1	0	2	0	0	0	5
27 Elektrische apparatenindustrie	0	2	0	2	1	3	0	0	0	7
28 Machine-industrie	1	11	0	9	0	12	0	0	0	33
29-30 Transportmiddelenindustrie	1	7	0	9	1	7	0	0	0	25
31 Meubelindustrie	0	5	0	91	0	3	0	0	0	99
32 Overige industrie	8	8	0	2	0	10	0	0	0	27
33 Reparatie en installatie van machines	0	7	0	3	0	5	0	0	0	16
360 Waterleidingbedrijven	0	6	0	0	0	0	27	0	0	34
370 Afvalwaterinzameling en -behandeling	17	8	0	0	0	0	356	0	0	381
381 Inzameling van afval	0	1	0	0	0	0	0	0	0	1
382 Behandeling van afval	0	327	0	264	21	5	0	2	0	619
383 Voorbereiding tot recycling	14	83	1	15	10	2	0	0	0	123
390 Sanering en overig afvalbeheer	4	1	0	6	0	0	0	0	0	11
Total	3,163	722	3	539	57	334	561	5	0	5,384

Source: Data from CBS (84970NED) multiplied by own estimates for bio-based fraction.

The data in the Dutch national accounts also provide information on residues from services (sectors D-U) (Table 5-5), of which the flow of bio-based dry matter in these streams has been estimated (Table 5-6). Additionally, the Dutch national account holds data on imports and exports (Table 5-7) and waste treatment methods (Table 5-8).

Table 5-5 *Quantities of waste reported in Dutch national accounts (KT/year) (sector level 5, category level 3), in 2016*

	Afgedankt materiaal	Ander metaalafval	Chemisch afval	Dierlijk en plantaardig afval	Gemengd afval	Gemengd metaalafval	Glasafval	Houtafval	IJzerafval	Mineraal afval	Overig recyclebaar afval	Papierafval	Plasticafval	Rubberafval	Slib	Textielafval
B Delfstoffenwinning	0	0	28	0	4	1	0	1	0	21	0	1	1	0	0	0
C Industrie	5	44	1,431	6,583	994	299	39	325	132	2,787	0	592	155	2	188	12
D Energievoorziening	1	2	7	2	6	8	0	1	5	1,933	0	2	1	0	1	
E Waterbedrijven en afvalbeheer	17	43	287	60	355	7	14	22	150	406	0	4	59	0	356	1
F Bouwnijverheid	1	117	16	488	369	144	59	1453	704	19,917	0	6	27	0	31	0
G-I Handel, vervoer en horeca	137	8	273	204	724	21	79	114	21	2	0	223	50	44	0	2
J Informatie en communicatie	0	0	0	1	121	0	6	7	0	0	0	40	3	0	0	0
K Financiële dienstverlening	0	0	2	4	86	0	3	2	0	0	0	18	2	0	0	0
L Verhuur en handel van onroerend goed	1	2	1	1	34	1	2	2	4	0	0	10	1	0	0	0
M-N Zakelijke dienstverlening	1	0	50	262	575	13	28	14	14	0	0	182	12	0	0	0
O-Q Overheid en zorg	31	0	58	641	1,006	0	27	0	0	1	0	213	34	0	82	0
R-U Cultuur, recreatie, overige diensten	1	0	2	431	98	2	7	1	0	0	0	35	3	0	0	0
Total	195	216	2,155	8,677	4,372	496	264	1,942	1,030	25,067	0	1,326	348	46	658	15

Source: CBS (83554NED).

Table 5-6 *Estimated quantity of materials of bio-based origin in residues (KT DM) from Dutch national accounts (sector level 5, category level 3) using estimated bio-based fractions, in 2016*

	Chemisch afval	Dierlijk en plantaardig afval	Gemengd afval	Glasafval	Houtafval	Papierafval	Plasticafval	Rubberafval	Slib	Textielafval
B Delfstoffenwinning	7		1		1	1	0			
C Industrie	343	3,127	298	2	262	322	26	0	150	3
D Energievoorziening	2	1	2		1	1	0		1	
E Waterbedrijven en afvalbeheer	69	29	107	1	18	2	10		285	0
F Bouwnijverheid	4	232	111	3	1,173	3	5		25	
G-I Handel, vervoer en horeca	66	97	217	4	92	121	9	7		0
J Informatie en communicatie		0	36	0	6	22	1			
K Financiële dienstverlening	0	2	26	0	2	10	0			
L Verhuur en handel van onroerend goed	0	0	10	0	2	5	0			
M-N Zakelijke dienstverlening	12	124	173	1	11	99	2			
O-Q Overheid en zorg	14	304	302	1		116	6		66	
R-U Cultuur, recreatie, overige diensten	0	205	29	0	1	19	1			
Total	517	4,122	1,312	12	1,568	721	59	8	526	4

Source: Data from CBS (83554NED) multiplied by own estimates for bio-based fraction.

Table 5-7 *Quantity of import and export volumes (KT TM) (sector level 2, category level 3), in 2016*

	Bestemming: buitenland	Bestemming: verwerking producenten	Herkomst: buitenland	Herkomst: Nederlandse economie
Afgedankt materiaal	127	524	109	541
Ander metaalafval	536	65	384	217
Chemisch afval	376	1,925	127	2,174
Dierlijk en plantaardig afval	7,748	17,483	10,417	14,814
Gemengd afval	838	9,830	2,153	8,516
Gemengd metaalafval	1	557	0	558
Glasafval	306	804	492	617
Houtafval	663	2,057	419	2,301
IJzerafval	3,355	1,495	3,818	1,032
Mineraal afval	1,650	26,736	2,719	25,667
Overig recyclebaar afval	0	1	0	0
Papierafval	3,096	1,972	2,874	2,193
Plasticafval	459	683	708	434
Rubberafval	100	99	96	103
Slib	32	633	2	662
Textielafval	252	52	203	101
Total	19,539	64,916	24,521	59,930

Source: CBS (83554NED).

Table 5-8 *Quantity of waste reused, dumped and incinerated (KT TM) (sector level 3, category level 3), in 2016*

	Verwerking producenten: hergebruik	Verwerking producenten: storten en lozen	Verwerking producenten: verbranding
Afgedankt materiaal	475	7	42
Ander metaalafval	64	1	0
Chemisch afval	918	228	779
Dierlijk en plantaardig afval	16,266	40	1,178
Gemengd afval	1,326	512	7,992
Gemengd metaalafval	551	5	1
Glasafval	793	11	0
Houtafval	621	29	1,407
IJzerafval	1,491	2	1
Mineraal afval	26,042	615	79
Overig recyclebaar afval	1	0	0
Papierafval	1,963	0	9
Plasticafval	672	11	0
Rubberafval	96	0	3
Slib	240	22	371
Textielafval	37	3	12
Total	51,556	1,486	11,874

Source: CBS (83554NED): Gemeentelijke afvalstoffen; hoeveelheden (cbs.nl).

5.2 Classification and quantification

The Dutch statistics (CBS Statline) contains three databases that are relevant for monitoring biomass flows from tertiary waste on:

- Municipal waste (83558NED)
- Industrial waste (84970NED)
- One that includes - besides industry - government and services (83554NED).

All these data sources monitor the *demand* for waste streams as received by the waste sector. The waste sector reports these quantities to CBS. The origin of the waste streams is administrated by the collection services, and therefore these numbers also monitor the supply of waste streams per sector.

5.2.1 Municipal waste (83558NED)

Most of the municipal waste is collected by waste collection services. A smaller part is brought to waste collection points of waste treatment services or municipalities. Municipalities also collect waste originating from maintenance of municipal parks.

Wastewater that flows to wastewater treatment plants via the sewerage system may also be seen as municipal waste. Wastewater is not included in Table 83558NED. The sludge produced in wastewater treatments however, is collected by the waste sector (and reported as such in the tables on industrial waste). Municipal wastewater is of major importance in the phosphorous cycle as a large part of phosphorous present in agricultural crops ends up in municipal wastewater. Most of the phosphorous ends in the sludge. So, even though wastewater is not included, it will still be possible to monitor most of the phosphorous.

Municipal waste streams are monitored and reported by CBS (83558NED). Waste streams may have a varying water content, ash content and bio-based content. Selected waste streams with considerable amounts of bio-based materials are listed in Table 5-9.

Table 5-9 *Municipal waste reported by CBS where bio-based content is expected in 2019 (KT TM)*

Type of waste	Bio-based origin	KT TM
Huishoudelijk restafval	Content bio-based heavily dependent on local collection policy	2,829.0
Grof huishoudelijk restafval	Part of this will be wood	499
Verbouwingsrestafval	Part of this will be wood	79.0
GFT	Almost 100%, but high in ash	1,548.0
Paper and cardboard	Around 60%	837.0
Textiel	Contains cotton, wool linen, etc.	86.0
Drankenkartons	Largely cardboard	0.4
PMD	Less than 60%	334.0
Frituurvet	Almost 100%, water may be present	1.7
Grof tuinafval	Almost 100%, but high in ash	485.0
Bruikbaar huisraad	Will contain wood	49.0
Vloerbedekking	Contains wool and linoleum	10.0
Matrassen	Latex	12.9
Houtafval (A en B)	Close to 100%	455.0
Houtafval (C)	Close to 100%	48.0
Gips	Plaster is often held together by layers of paper	25.0
Autobanden	Contains natural rubber	4.4
Kadavers	Almost 100%	0.2

Source: bio-based origin from author; KT TM from data reported in 83558NED.

5.2.2 Industrial waste (84970NED)

Industrial waste is reported per sector in 84970NED (bedrijfsafval; afvalsoort, bedrijfstak (SBI 2008) (cbs.nl)in Table 5-10. This list contains several subsets and therefore a sector level has been added to zoom into multiple levels of detail where the sum of all sub- sectors equals the sum of all sectors. If level 3 is chosen, the numbers for B, C, D and E sectors will be selected. If level 4 is chosen, the numbers 10-12, 13-15, 16+23, 17-18 etc. industries are selected. Level 6 is a further disaggregation of level 5.

Table 5-10 *Industrial sectors for which waste streams are reported by CBS in Table 84970NED*

Sector	Sector Level	Sector	Sector Level
B-E Nijverheid (geen bouw) en energie	2	24 Basismetaalindustrie	6
B Delfstoffenwinning	3	25 Metaalproductenindustrie	6
C Industrie	3	26-27 Elektrische en elektron. Industrie	5
10-12 Voedings-, genotmiddelenindustrie	4	26-28 Elektrotechnische en machine-industrie	5
10 Voedingsmiddelenindustrie	6	26 Elektrotechnische industrie	6
11 Drankenindustrie	6	27 Elektrische apparatenindustrie	6
12 Tabaksindustrie	6	28 Machine-industrie	6
13-15 Textiel-, kleding-, lederindustrie	6*	29-30 Transportmiddelenindustrie	6
16+23 Hout- en bouwmaterialenindustrie	4	31-33 Overige industrie en reparatie	4
16 Houtindustrie	6	31-32 Meubel- en overige industrie	5
17-18 Papier- en grafische industrie	4	31 Meubelindustrie	6
17 Papierindustrie	6	32 Overige industrie	6
18 Grafische industrie	6	33 Reparatie en installatie van machines	6
19-22 Raffinaderijen en chemie	4	D Energievoorziening	3
19 Aardolie-industrie	6	E Waterbedrijven en afvalbeheer	3
20-21 Chemie en farmaceutische industrie	4	360 Waterleidingbedrijven	6
20 Chemische industrie	6	370 Afvalwaterinzameling en -behandeling	6
21 Farmaceutische industrie	6	381 Inzameling van afval	6
22 Rubber- en kunststofproductindustrie	6	382 Behandeling van afval	6
23 Bouwmaterialenindustrie	6	383 Voorbereiding tot recycling	6
24-30, 33 Metalektro	4	390 Sanering en overig afvalbeheer	6
24-25 Basismetaal, metaalprod.-industrie	5		

Should also be level 4.

Source: 84970NED (bedrijfsafval; afvalsoort, bedrijfstak (SBI 2008).

The quantity of industrial waste is reported for several categories of waste. Table 5-11 shows a list of waste categories with considerable bio-based content. A category level has been introduced to zoom into multiple levels of category detail. Note that the sum of all-sub categories equals the sum of the overall category.

Table 5-11 *Waste categories of industrial waste*

Industrial waste category	Category Level	Bio-based part
Totaal naar verwerking	1	Sum of all
Niet-chemisch afval	2	Sum of all – chemical waste
Metaalafval	3	- (negligible)
Glasafval	3	- (negligible)
Papier-, kartonafval	3	++ (usually high in ash)
Kunststof-, rubberafval	3	+ (bioplastics and natural rubber)
Houtafval	3	+++
Textiel-, lederafval	3	+ (cotton, leather, wool, linen, bioPET)
Dierlijk, plantaardig afval	3	+++ Residues from animal breeding (incl. manure), plant breeding, the agro and food industry. These streams are largely covered in Chapter 2 and Chapter 3. Most of these are not tertiary residues
Gemengd afval	3	+
Slib	3	+
Mineralen, steenachtig afval	3	- (negligible)
Overig niet-chemisch afval	3	- (mostly discarded devices)
Chemisch afval	2	Almost fully fossil, but this might contain more bio-based in the future

-: bio-based contents low; + bio-based components present; ++ considerable bio-based content (>50% bio-based); +++ >95% bio-based.
Source: CBS.

5.2.3 Waste balance (83554NED)

This balance contains data on the waste of Government and services (83554NED) as well as industrial waste (that is already included in 84970NED). It also has data on import and export of tertiary wastes.

5.3 Coding approach

The CBS waste categories are not always easily convertible into CPA codes. It should be taken into consideration that the properties of waste streams can depend heavily on local circumstances; e.g. if no source separation is implemented, the organic content of 'Huishoudelijk restafval' is much higher due to presence of GFT, cardboard and beverage carton. The quality of organic waste may be quite different in urban and rural areas, therefore it is suggested to introduce two different codes, one for urban and one for rural areas.

Differences may also be found regarding the waste that originates from different industries. For example, glass from 'glaszetters' is in general very clean and pollution mainly regards aluminium, while glass collected from 'horeca' is highly contaminated with food residues. Therefore, it is proposed to give all these streams an own specific product code. The code system for waste streams is built up from a disposer code and a material code.

5.3.1 Disposer codes

For the municipal waste, the existing CPA code is used (Table 5-12), while existing SBI codes are used for the industrial sectors (Table 5-13) as well as for government, services and household sectors (Table 5-14).

Table 5-12 Disposer code of municipal sectors

	CPA2008
Households	98

Table 5-13 Disposer codes of industrial sectors

CBS	CPA 2008	
B-E Nijverheid (geen bouw) en energie	B-E	05-390
B Delfstoffenwinning	B	05, 06, 07, 08, 09
C Industrie	C	10-33
10-12 Voedings-, genotmiddelenindustrie	C	10, 11, 12
10 Voedingsmiddelenindustrie	C	10
11 Drankenindustrie	C	11
12 Tabaksindustrie	C	12
13-15 Textiel-, kleding-, lederindustrie	C	13, 14, 15
16+23 Hout- en bouwmaterialenindustrie	C	16, 23
16 Houtindustrie	C	16
17-18 Papier- en grafische industrie	C	17, 18
17 Papierindustrie	C	17
18 Grafische industrie	C	18
19-22 Raffinaderijen en chemie	C	19, 20, 21, 22
19 Aardolie-industrie	C	19
20-21 Chemie en farmaceutische industrie	C	20, 21
20 Chemische industrie	C	20
21 Farmaceutische industrie	C	21
22 Rubber- en kunststofproductindustrie	C	22
23 Bouwmaterialenindustrie	C	23
24-30, 33 Metaal en elektro	C	24, 25, 26, 27, 28, 29, 30, 33
24-25 Basismetaal, metaalproduktie industrie	C	24, 25
24 Basismetaalindustrie	C	24
25 Metaalproductenindustrie	C	25
26-27 Elektrische en elektronische industrie	C	26, 27
26-28 Elektrotechnische en machine industrie	C	26, 27, 28
26 Elektrotechnische industrie	C	26
27 Elektrische apparatenindustrie	C	27
28 Machine-industrie	C	28
29-30 Transportmiddelenindustrie	C	29, 30
31-33 Overige industrie en reparatie	C	31, 32, 33
31-32 Meubel- en overige industrie	C	31, 32
31 Meubelindustrie	C	31
32 Overige industrie	C	32
33 Reparatie en installatie van machines	C	33
D Energievoorziening	D	35
E Waterbedrijven en afvalbeheer	E	36, 37, 38, 39
360 Waterleidingbedrijven	E	360
370 Afvalwaterinzameling en -behandeling	E	370
381 Inzameling van afval	E	381
382 Behandeling van afval	E	382
383 Voorbereiding tot recycling	E	383
390 Sanering en overig afvalbeheer	E	390

Table 5-14 *Disposer codes for government, services and household sectors in Table 83554NED*

CBS	**CPA 2008**	
'F Bouwnijverheid'	F	41, 42, 43, 44
'G-I Handel, vervoer en horeca'	G-I	45, 46, 47, 48, 49, 50, 51, 52, 53, 55, 56,
'J Informatie en communicatie'	J	58, 59, 60, 61, 62, 63,
'K Financiële dienstverlening'	K	64, 65, 66,
'L Verhuur en handel van onroerend goed'	L	68
'M-N Zakelijke dienstverlening'	M-N	69, 70, 71, 72, 73, 74,75, 77, 78, 79 80, 81, 82
'O-Q Overheid en zorg'	O-Q	84, 85, 86, 87, 88
'R-U Cultuur, recreatie, overige diensten'	R-U	90, 91, 92, 93 94, 95, 96
'Particulier huishouden'	T	97, 98

Source: 83554NED: afvalbalans, afvalsoort naar sector, nationale rekeningen (cbs.nl).

5.3.2 Material codes

The streams listed in Table 5-15 already have a CPA2008 code:
- First 4 digits indicate the sector where the material is collected (38.11: Collection service of non-hazardous waste).
- Last 2 digits indicate the character of the material (52: paper and paperboard waste; 53: used pneumatic tyres of rubber, etc).

Table 5-15 *CPA codes for relevant materials gathered by Collection service of non-hazardous waste*

CPA2008 codes	**Category**
38.11.52	Paper and paperboard waste
38.11.53	Used pneumatic tyres of rubber
38.11.54	Other rubber waste
38.11.55	Plastic waste
38.11.56	Textile waste
38.11.57	Leather waste

Source: CPA 2008 structure (europa.eu).

When these materials are ready for reuse, a new number has been given in CPA 2008 (Table 5-16). Unfortunately these numbers have little relation with the numbers in Table 5-15, while also the categories are slightly different.

Table 5-16 *CPA 2008 numbers for relevant materials ready for reuse*

CPA2008 codes	**Category**
38.32.31	Secondary raw material of glass
38.32.32	Secondary raw material of paper and paperboard
38.32.33	Secondary raw material of plastic
38.32.34	Secondary raw material of rubber
38.32.35	Secondary raw material of textile

Source: CPA 2008 structure (europa.eu).

For materials that are not present in above list, CPA2008-like codes have been proposed (Table 5-17). Sub-numbers above 100 have been chosen to avoid collision with existing categories or future additions to CPA 2008.

Table 5-17 *Proposal for CPA2008-like codes for materials without CPA2008 code*

CPA2008-like code	Category	Origin
38.11.101	Huishoudelijk restafval	Municipal waste
38.11.102	Grof huishoudelijk restafval	Municipal waste
38.11.103	Verbouwingsrestafval	Municipal waste
38.11.104	GFT	Municipal waste
38.11.105	Drankenkartons	Municipal waste
38.11.106	PMD	Municipal waste
38.11.107	Frituurvet	Municipal waste
38.11.108	Grof tuinafval	Municipal waste
38.11.109	Bruikbaar huisraad	Municipal waste
38.11.110	Vloerbedekking	Municipal waste
38.11.111	Matrassen	Municipal waste
38.11.112	Houtafval (A en B)	Municipal waste
38.11.113	Houtafval (C)	Municipal waste
38.11.114	Gips	Municipal waste
38.11.115	Kadavers	Municipal waste
38.11.116	Afvalwater	Municipal waste
38.11.201	Gemengd afval	Industrial waste
38.11.202	Slib	Industrial waste
38.11.203	Kunststof-, rubberafval	Industrial waste
38.11.204	Textiel-, lederafval	Industrial waste
38.11.205	Wastewater	Industrial waste

Source: Authors.

5.4 Data sources on material streams (attributes)

Composition estimates enable the conversion of data retrieved from the CBS tables into dry matter, ashes, bio-based dry matter, fossil based dry matter or metals respectively. Used abbreviations for the selected attributes are explained in Table 5-18.

Table 5-18 *Abbreviations (explanation of) attributes*

Item	Refers to	Unit	Remark
DM	Dry Matter content	kgDM/kgTM	
DM	Dry Matter	KT DM	
TM	Total Matter	KT TM	
Ash	Minerals in Dry Matter	kgAsh/kgDM	Metals in oxidation state 0 excluded, bioaccumulated ashes excluded
BB	Bio-based content	kgBB/kgDM	Bioaccumulated ashes included
FBB	Bio-based content	kgBB/kgTM	Bioaccumulated ashes included
Fossil	Fossil-based content	kgFossil/kgDM	Excluding fossil minerals and metals
Metals	Metal parts in waste streams (i.e. screws)	kgMetal/kgDM	Metal oxides excluded

The composition estimates are not readily available. Therefore, all numbers in Table 5-19 are guestimates and indicative only (Meesters, 2022); it is recommended to check with literature. The total of ash, bio-based, fossil and metal should equal 1.

Table 5-19 *Estimate for composition of waste streams from households and municipalities*

	Dry MaTTEr	Ash	Bio-based	Fossil	Metal	Total
Autobanden_33	1	0.1	0.2	0.6	0.1	1
BruikbaarHuisraad_20	1	0.1	0.3	0.3	0.3	1
Drankenkartons_11	0.8	0.3	0.7			1
FrituurvetEnOlie_16	0.8		1			1
GFTAfval_6	0.5 a)	0.3 a)	0.7 a)			1
Gips_30	0.95	0.95	0.05			1
GrofHuishoudelijkRestafval_4	0.7	0.3	0.3	0.2	0.2	1
GrofTuinafval_18	0.6	0.3	0.7			1
HoutafvalAEnBHout_25	0.8	0.02	0.97		0.01	1
HoutafvalCHout_26	0.8	0.03	0.94	0.02	0.01	1
HuishoudelijkRestafval_3	0.7	0.3	0.5	0.1	0.1	1
Kadavers_36	0.6	0.1	0.9			1
Matrassen_23	0.9		0.2	0.7	0.1	1
OudPapierEnKarton_7	0.85	0.3	0.7			1
PMDFractie_13	0.8	0.2	0.6	0.1	0.1	1
SchoonPuin_24	0.9	0.9			0.1	1
Textiel_8	0.9		0.3	0.69	0.01	1
TotaalGemeentelijkAfval_1						0
TotaalHuishoudelijkAfval_2						0
Verbouwingsrestafval_5	0.9	0.6	0.2	0.1	0.1	1
Vloerbedekking_22	0.9	0.2	0.2	0.6		1

a) It is assumed that GFT composition is dependent on collection area characteristics. The fraction bio-based is calculated according to: FBB = DM*BB (kg BB/kg TM).

Source: Authors.

Table 5-20 *GFT composition as function of collection area characteristics*

	DM	Ash	Bio-based	Fossil	Metal	Total	FBB
Stedelijk	0.45	0.30	0.70	0.00	0.00	1.00	0.32
Landelijk	0.55	0.35	0.65	0.00	0.00	1.00	0.36

Source: Authors.

With the guestimates presented in Table 5-20 the fraction bio-based is almost independent on collection area characteristics (mainly because the differences cancel out).

5.5 Embedding residues in MFM

Transparency and consistency in collecting and managing data are essential conditions for safeguarding the maintenance and replication of the WUR-MFM that under development. Data – raw and derived – required for quantification of the attributes/indicators to be monitored in the MFM are available in Excel files and Power-BI files. In the Power-BI files, the data are sorted, selected and connected.

Mapping is needed to fit the tertiary residues data into the MFM. Currently, the waste sector is a column in the MFM. But to produce proper sector balances, the waste data should be made available as rows in the MFM. The data are there, but it is expected that the sector-specific data are less reliable than the more aggregated data as the sector-specific data are derived from waste collection administrations that also have non-specific wastes as an entry. It might be very worthwhile to aggregate sectors that are not really important for the circular bio-based economy, and to disaggregate sectors that are highly relevant (agriculture, husbandry, food processing).

In the national accounts no ‘extraction’ is foreseen for households. To produce mass balances, this extraction should be added to the national accounts. Garden waste is extracted from the garden, such as the farmer extracts crops from his cropland).

6 Illustration of MFM application: cereal straw flows

6.1 Introduction

This chapter illustrates how to include the supply and use of straw in the MFM and how it gives insight into the circular use of biomass. The departure point is the total above-ground residual biomass production assessed in Chapter 2 and quantified in Table 2-6. Before integrating straw flows in the MFM there is a need to further review i) the amount of residual biomass (straw and chaff) that is actually removed from the field, ii) other sources of straw brought to the Netherlands through trade and iii) straw that is exported by the Netherlands, and iv) the main uses and related end-of-life uses.

6.2 Defining and quantifying cereal residue removal rates in fields

Only for cereals, especially wheat and barley, it is common practice to (partly) remove it from the field. For all other primary residues, it is most common to leave it on the field where it will (partly) contribute the carbon capture in the soil. Information from the Bedrijveninformatienet database[5] is used to estimate the amount of primary residues that are currently harvested, such as the number of farmers that sell straw from their own fields (see Table 6-1 for barley and Table 6-2 for wheat).

Table 6-1 *Total primary residue production and removal from the field for barley in the Netherlands*

	Unit	2015	2016	2017	2018	2019	2020	Average 6 years
Area with barley	*ha*	32,810	34,798	30,205	36,153	33,703	38,694	*34,394*
1) Above-ground biomass a)	*Tonne DM*	347,490	358,433	311,299	383,661	372,151	385,835	*359,811*
2) Main product (grains) a)	*Tonne DM*	192,548	198,165	171,746	213,165	208,132	211,076	*199,139*
3) Residue 1) minus 2) Main product	*Tonne DM*	154,941	160,268	139,552	170,496	164,019	174,759	*160,673*
4) Residue - chaff (20% of residue) b)	*Tonne DM*	30,988	32,054	27,910	34,099	32,804	34,952	*32,135*
5) Residue - straw on field (80% of residue) b)	*Tonne DM*	123,953	128,215	111,642	136,397	131,215	139,807	*128,538*
% of barley farmers harvesting straw to sell c)	%	42	41	40	49	50	41	*44*
6) Straw removed from field c)	*Tonne DM*	48,022	50,264	42,122	62,351	59,476	55,911	*53,024*
7) Straw left on field	*Tonne DM*	75,931	77,951	69,520	74,046	71,739	83,896	*75,514*

a) Own assessment based on Appendix 1 calculation rules explained in former sections and CBS statistical agricultural data on land use and production of main agricultural product; b) Literature review; Suardi, A., Saia, S., Stefanonni, W., Gunnarsson, C., Sundberg, M., Pari, L. (2020). Admixing Chaff with Straw Increased the Residues Collected without Compromising Machinery Efficiencies. Energies 2020, 13, 1766; doi:10.3390/en13071766;
c) Bedrijveninformatienet. It is assumed here that the amount of straw that is sold, is also the amount of straw removed from the field. It is however possible that more straw is removed for own use.

[5] Bedrijveninformatienet. This is the Dutch version of FADN (Farm Accountancy Data Network). In the Netherlands it contains the farm accountancy data of around 1,500 agricultural and horticultural farms which in principle are a representative sample of all farms in the Netherlands. For more information see: https://www.wur.nl/nl/Onderzoek-Resultaten/Onderzoeks-instituten/Economic-Research/Over-ons/Data-modellen-en-tools/Bedrijveninformatienet.htm

Table 6-2 *Total primary residue production and removal from the field for wheat in the Netherlands*

	Unit	2015	2016	2017	2018	2019	2020	*Average 6 years*
Area with wheat	*ha*	142,469	128,065	116,430	112,042	121,064	109,630	*121,617*
1) Aboveground biomass a)	*Tonne DM*	2,129,733	1,733,289	1,727,493	1,627,942	1,865,660	1,579,726	*1,777,307*
2) Main product (grains) a)	*Tonne DM*	1,093,678	854,255	885,988	827,081	972,106	800,803	*905,652*
3) Residue 1) minus 2)	*Tonne DM*	1,036,054	879,034	841,504	800,861	893,554	778,923	*871,655*
4) Residue – chaff (20% of residue) b)	*Tonne DM*	207,211	175,807	168,301	160,172	178,711	155,785	*174,331*
5) Residue – straw on field (80% of residue) b)	*Tonne DM*	828,843	703,227	673,203	640,689	714,843	623,138	*697,324*
% of wheat farmers harvesting straw to sell c)	*%*	63	58	59	70	63	66	*63*
6) Straw removed from field c)	*Tonne DM*	402,429	331,640	308,987	352,132	344,941	324,879	*344,168*
7) Straw left on field	*Tonne DM*	426,415	371,587	364,216	288,557	369,902	298,259	*353,156*

a) Own assessment based on Appendix 1 calculation rules explained in former sections and CBS statistical agricultural data on land use and production of main agricultural product; b) Literature review: Suardi, A., Saia, S., Stefanonni, W., Gunnarsson, C., Sundberg, M., Pari, L. (2020). Admixing Chaff with Straw Increased the Residues Collected without Compromising Machinery Efficiencies. Energies 2020, 13, 1766; doi:10.3390/en13071766;
c) Bedrijveninformatienet. It is assumed here that the amount of straw that is sold, is also the amount of straw removed from the field. It is however possible that more straw is removed for own use.

As for the straw removal rates, it is assumed that this equals to all straw that is reported to be sold as recorded in the Bedrijveninformatienet (see Tables 6-1 and 6-2). This implies that we assume that no straw is harvested for own use. This may be a simple assumption, but in the Netherlands it is likely to be common practice, given that there are hardly any mixed farms (crops and livestock combined) left.

The tables show that on average around 400 KT DM straw per year is derived from barley and wheat production together in the Netherlands between 2015-2020. On the other hand, more than 400 KT DM straw (including stubble) is left in the field. The chaff (about 200 KT) that falls off during the harvesting of the grain will mostly go to feed or stay in the field. However, it is assumed here that everything is for feed because data on the exact use of this residue could not be found.

6.3 Defining and quantifying straw uses

There are five main uses for straw in the Netherlands which are in:
- Horticultural production, especially flower bulbs and strawberry production
- Livestock production
- Mushroom production
- Bio-based application
- Exports and imports.

Some uses are connected, especially the straw use by horses and in mushroom production, where there is some form of cascading use. Furthermore, since straw can be an important source of carbon in the soil, it makes sense to include the soil within the boundaries of the analysis.

6.3.1 Straw use in horticultural production

Strawberry production in the Netherlands is important and straw is used to protect the developing fruits from wet soils, prevent the strawberries to become sandy and it also helps to suppress weeds. To identify the quantity of straw used in horticulture different data sources are consulted (Table 6-3).

In *flowerbulb* production the use of straw is very common. The study by PPO (Schreuder and Wekken, 2005) provides detailed data on the average amount of straw used in every type of flowerbulb production (Table 6-3).

The two sources reviewed to estimate the straw use in strawberry production provide very different amounts, while they show quite similar estimates for flower bulbs. It is likely that Hisfa (2021) strongly overestimates the straw use in strawberries, and therefore an average figure from the two data sources is assumed. In total 157.5 KT DM straw is estimated to be used in horticulture, i.e. for the production of strawberries and flower bulbs.

Table 6-3 *Straw use in horticulture, data sources consulted and estimated amounts*

Use	Data source 1	Data source 2	Final amount used (KT DM/ DM=90%)
Straw for strawberry production	Hisfa (2021): a) approximately 10% of traded straw went to strawberries. In 2021 669 KT DM was traded, 10%=67 KT DM/year	Nieuwe Oogst (2021): b) 1500 ha strawberries (1,000 ha in field/500 ha in green houses). DLV (2011): c) 10 tonnes/ha straw in open field and 5 tonnes/ha for green houses. Total use= (1,000*0.010+500*0.005)*0.9 = 11.3 KT DM	Average = (67 + 11.3)/2 = 39 KT DM/year
Straw for flower bulb production	Hisfa (2021): a) approximately 15% of traded straw went to flower bulb production. In 2021 669 KT DM was traded, 15%= 100.3 KT DM/year	CBS (2021): d) Production area 2020: 15,010 ha tulip; 5,340 ha lily; 1,540 ha daffodil; 1,440 ha hyacinth; 100 ha iris. PPO (2005): e) Use: 5.5 tonnes straw/ha tulip (p.164/166); 4 tonne/ha lily (p.144); 14 tonnes/ha daffodil; 18 tonnes/ha hyacinth (p.134); 5 tonnes/ha Iris (p.136). Total estimated straw use= 137 KT DM	Average = (100.3 + 137)/2 = 118.5 KT DM/year

a) Hisfa, data provided through telephone interview in September 2021;

b) https://www.nieuweoogst.nl/nieuws/2021/06/15/nederlanders-eten-steeds-meer-aardbeien;

c) https://edepot.wur.nl/170085; d) https://longreads.cbs.nl/nederland-in-cijfers-2020/welke-bloembollen-telen-we-het-meest/#:~:text=Het%20bloembollenareaal%20groeide%20van%2022,keer%20zoveel%20als%20in%202000; e) Schreuder and van der Wekken (2005). Kwantitatieve informatie bloembollen en bolbloemen (KWIN 2005). https://library.wur.nl/WebQuery/groenekennis/1795524

6.3.2 Straw use in livestock production

The use of straw in livestock production is assessed according to different data sources as presented in Table 6-4.

Table 6-4 *Straw and chaff use is livestock production in the Netherlands*

Use	Data source 1	Data source 2	Final use (KT DM)
Straw as feed	In 2021 669 KT DM was traded straw. Hisfa (2021): a) about 20% of traded straw went to livestock feed (133.7 KT DM/year)		133.7 KT DM
Chaff as feed	Chaff is removed from the field with the grains and in the processing the chaff is removed. We assume that all (own assumption) chaff is used in animal feed		206.5 KT DM
Total straw use in livestock production	Hisfa (2021): a) about 50-55% of traded straw went to livestock bedding. In 2021 669 KT DM was traded, 52.5%= 351 KT DM/year	SecureFeed (2021): b) estimates straw amount used for bedding in 2021 at 405 KT/year which is 364.5	Secure feed: b) 358 KT DM
Of which: Bedding in horse stables	CBS c) and KNHS d) estimate a total of 450,000 horses & ponies (2021). Scarlat et al. (2010) indicates 1,5 kg straw used per horse/per day. Total straw use = 450,000*0.0015*365 days*0.9 = 221.7 KT DM straw		221.7 KT DM
Of which: Bedding for sheep & goats	CBS (2021) estimates 890,000 sheep and 633,000 goats in 2020. Scarlat (2010): e) 0.1 kg straw/sheep (and goat)/day. Total straw use: (890,471+632,616)*0.001*365*0.9 = 50 KT DM/year		50 KT DM
Of which: Bedding for bovine	No data were found specifying straw use for bedding for bovine animals. The amount was therefore estimated as a 'rest' category. Total straw use for bedding for horses, sheep and goats was subtracted from total bedding straw use = 358,000 – (221,738+50,033) = 86 KT DM/year		86 KT DM

a) Hisfa, data provided through telephone interview in September 2021; b)SecureFeed: data provided through telephone interview in September 2021; c) CBS: https://opendata.cbs.nl/statline/#/CBS/nl/dataset/80780NED/table?dl=6082C; d) KNHS: https://www.knhs.nl/media/11389/nederland-paardenland_web-v2.pdf; e) Scarlat et al. (2010). Assessment of the availability of agricultural crop residues in the European Union: Potential and limitations for bioenergy use. Waste Management Volume 30, Issue 10, October 2010, Pages 1889-1897. https://doi.org/10.1016/j.wasman.2010.04.016

6.3.3 Straw use in mushroom production

The largescale *mushroom cultivation* in the Netherlands uses large quantities of straw mixed with horse manure, which together form compost. To calculate the total straw demand in mushroom production, the following data were collected:

- Total straw demand for mushroom production in the Netherlands is estimated to be on average at 222 KT DM straw/year. This average is based on three sources:
  - Total Dutch mushroom production according to RTL (2020)[6] amounts to 240 KT/year. According to PPO (2003) there is a need of 1.19 tonne straw (82% DM) for one tonne of mushrooms. This implies that total straw demand for mushroom production amounts to 233 KT DM straw/year.
  - CNC Grondstoffen (2022) specifies that in the Netherlands there is on average per week 30 KT horse manure with straw needed for the production of mushrooms. It mentions a 40% share of straw in the substrate on the basis of dry matter. Under the assumption that horse manure has 71% moisture[7] (so 29% DM) and straw has 12% moisture (so 88% DM), a total of 0.16 tonne DM straw is required for 1 tonne of compost (wet/as is). This implies that a weekly production of 30 KT compost needs 4,800 tonnes DM straw. On a yearly basis 52*4,800 tonnes DM straw = 250 KT DM straw is required for compost production.

6 https://www.rtlnieuws.nl/economie/bedrijven/artikel/5191178/sun-ziet-champignons-als-groeimarkt
7 https://www.eurolab.nl/meststof-organisch-v.htm

- After consultation with a specialist[8] the total amount of straw needed for mushroom production in the Netherlands is estimated at 180 KT DM straw per year.

Next question is which share of the Dutch compost demand in mushroom production is produced domestically and how much straw (as part of compost) is imported:

- After consultation with a specialist[9] it was assumed that 50% of horse manure/straw is from domestic origin, the other part is imported, i.e. 111 KT DM is imported.

The final factor to be known in the straw-mushroom chain is what happens to the straw in the compost after production of the mushrooms. This remaining residue is called 'champost'. The following information is reviewed to understand the end-of-life of straw (Table 6-5):

- BTC (2022)[10] estimates a total release of champost in the Netherlands of around 850 KT/year which equals to 138 KT DM straw/year if the ratio horse manure/straw does not change during mushroom production. Considering 83 KT DM straw export (next bullet) implies 55 KT DM straw/year for champost use in the Netherlands.
- The export of champost is estimated at 513 KT, which contains 83 KT DM straw. This estimate is based on the calculated phosphate that is exported via champost (2,000 tonnes of phosphates) (BMA, 2017)[11] and the amount of phosphate per tonne of champost (3.9 kg P/tonne champost).[12]
- At last, 84 KT DM straw/year part of the compost is 'eaten' in the mushrooms production process. This is calculated by taking the total compost used in mushroom production (with 222 KT straw content) and subtracting the champost released to Dutch soil and export markets (with 138 KT straw content).

Table 6-5 *Summary of straw uses and releases in mushroom production in the Netherlands (KT DM straw/year)*

	Straw used in mushroom production (KT DM straw/year)		**Champost residue remaining after mushroom production (KT straw equivalent/year)**
Total compost used	222	Champost exported	83
-of which domestic	*111*	Champost used domestically	55
-of which imported	*111*	Champost consumed in mushroom production (38%)	84

Source: See accompanying text above this table.

6.3.4 Straw use in bio-based applications

Straw is used for the generation of bio-based products such as building materials and second generation /advanced production of biofuels using the sugars in the lignocellulosic material. Figures about the amount of straw use in these applications is hard to find. Based on personal communication with Hisfa it could be indicated that 5% of the traded straw (669 KT)[13] is used in bio-based applications, thus amounting to 17 KT DM straw.

6.3.5 Straw exports and imports

Finally, numbers on straw imports and exports are from the CBS database on trade,[14] specified either in the form of straw or other forms (e.g. densified, pelletised, ground or minced). Most recent data are for 2021 (Table 6-6). As the amounts of straw and chaff imported and exported can range strongly over the years, for the purpose of this assessment a 5 years average is calculated and applied for the total straw production and removal levels. On average, 352 KT DM of straw and chaff are imported and 76 KT DM are exported.

8 P. Vervoort, email exchange May 2022.
9 P. Vervoort, email exchange May 2022.
10 https://biotreatcenter.nl/over-btc/aanjager-hofmanshorst/
11 https://www.mestverwaarding.nl/storage/article/files/2018/11/5c019af01db6e.pdf
12 CZAV (2018): Flat rate content of phosphate is 3,9 kg/ton champost.
13 Hisfa, data provided through telephone interview in September 2021.
14 StatLine - Goederensoorten naar EU, niet-EU; natuur, voeding en tabak (cbs.nl)

Table 6-6 Straw and chaff imports and exports tonne and 1,000 euros

		Imports		Exports	
	Year	**1,000 Euros**	**Tonne**	**1,000 Euros**	**Tonne**
Straw and chaff of cereals	2017	31,997	246,096	12,701	43,398
	2018	44,784	273,660	17,071	63,385
	2019	55,253	339,668	17,665	71,448
	2020	77,945	466,045	13,948	49,585
	2021	102,101	628,616	22,374	196,971
Average (10% DM)		62,416	390,817	16,752	84,957
Average DM			351,735		76,461

Source: CBS handelsstatistiek.[15]

6.4 Integration of total supply and use of straw

The former sections described the supply and uses of straw in terms of assessment and data use. This section presents the integration of the supply and uses to provide a final understanding of the flows of both the biomass itself and the carbon in the straw system. Table 6-7 shows a balance sheet of all straw supply and uses in the Netherlands, which must be considered as a sub-balance within the total MFM of the Netherlands. Same table makes clear that a total of 1.4m DM straw and chaff is supplied in the Netherlands either from domestic cereal production or from imports. Around one third of this remains in the field where it is produced and thus remains on the soil. Another one third (463 KT) is imported either in the form of straw, pellets or as compost (so mixed with horse manure) to be used for mushroom production. The last one third is from domestic origin and consists of straw and chaff and is then used for different applications. It is assumed that all chaff goes to feed, though real hard data confirming this couldn't be found.

Table 6-7 Straw supply and primary, secondary and tertiary uses of straw, including for use in soil

Supply	Tonne DM	Primary use	Tonne DM	Secondary use	Tonne DM	Tertiary use	Tonne DM
Straw NOT removed from field	428,670	Straw not removed returned to soil	428,670	Compost (straw & horse manure) domestic used for mushrooms	110,998	Champost exported	83,115
Straw removed from field	397,192	Chaff to feed	185,819	Compost (straw& horse manure) from imports used for mushrooms	110,998	Champost domestically used in soil	54,648
Straw & chaff imported	351,735	Straw & chaff exported	76,461	Used straw in horticulture to soil	157,548	Straw used for mushroom growth (to food) (converted)	84,233
Chaff removed from field (with grains)	206,466	Straw use horticulture (strawberries & flower bulbs)	157,548	Used straw in stables to soil	245,402		
		Straw use stables horses	221,737	Straw & chaff in feed to manure to soil	319,533		
		Straw use other animals (bedding)	134,663				
		Straw to feed	133,714				
		Straw for bio-based uses	16,714				
		Balance	*-28,737*				
Total	1,384,064		1,384,064		944,479		221,996

15 StatLine - Goederensoorten naar EU, niet-EU; natuur, voeding en tabak (cbs.nl)

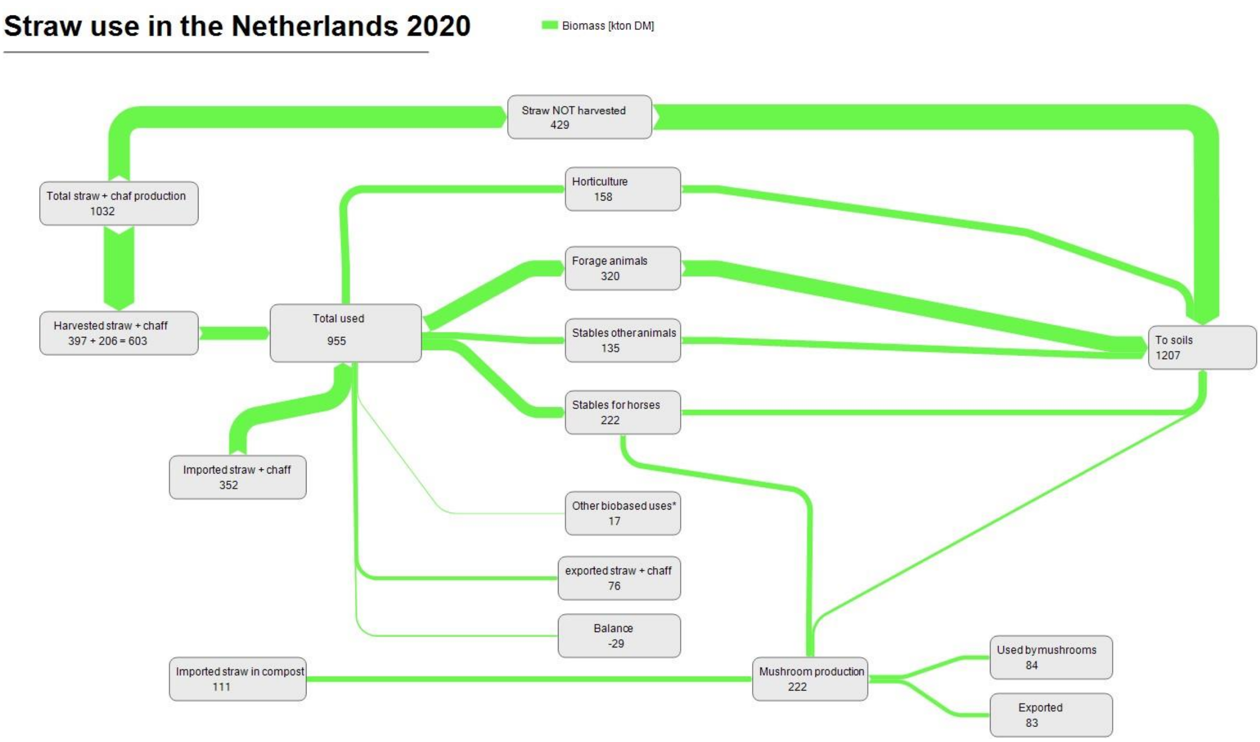

Figure 6-1 *Sankey diagram showing the biomass flow of straw in the Dutch economy (KT DM)*

Table 6-7 includes, in yellow, a figure for the balance indicating that the difference between supply and demand amounts to 16 KT of straw. In principle the sum of all supplies should equalise the sum of all uses, but due to uncertainties in uses, assumptions and estimations made, and the use of data from different years there is a disbalance of 2%.

Overall, it is clear that there is more straw used in the Netherlands than produced. In fact, the country could just be self-sufficient in straw if all straw would be collected from the fields. This however would not be a good option as this is likely to lead to a reduction in soil carbon in cereal fields which will be challenging to compensate. This said, it should be realised that more information needs to be gathered and research done to understand better how much of the straw left in the field will contribute to the long term stable carbon capture in the soil.

The analysis also makes obvious that the yearly amount of straw directly or via secondary uses returning to the soil is larger than the straw removed from the soil. This is due to the types of uses in horticulture, feed, bedding and compost for mushrooms which eventually end up in the soil again. Another reason is that the Netherlands import more straw than they export (see Sankey diagram in Figure 6-1), and also this straw mostly ends up in Dutch agricultural soils after primary uses as mentioned in the former.

Figure 6-1 shows the flows of straw through the Dutch economy in tonnes of DM biomass. These flows can also be translated in flows of carbon (tons carbon) or nutrients such as nitrogen (N) and phosphate (P) or potassium (K). This however requires more data and information gathering which is recommended to do in a follow up of this project. For example, what needs further information gathering is the compositions of the straw in terms of C, N and P when it comes from the field and also after different uses. As to the different uses, it is also possible that part of the C and other nutrients are lost to water, air (e.g. CO_2, CH_4, NH_3) and soil. Also products produced with straw as input, such as mushrooms, flower bulbs and strawberries, take up part of the nutrients. Another aspect that requires additional understanding regards the fate of carbon, and N and P when the straw is eaten by animals or when it is used in stables and then mixed with the manure of animals. There is much research done currently on the fate of carbon in crop residues (e.g. straw) when left on the land as this practice is expected to be effective in improving the carbon sink in soils and is of interest for so-called 'carbon farming'[16].

[16] See e.g. research programme Slim Landgebruik: https://www.slimlandgebruik.nl/ and also https://edepot.wur.nl/564620

6.5 Findings

The MFM needs to be enriched particularly for bioeconomy subsectors in the Dutch economy to monitor how transition to a more bio-based and circular economy can take place. The balance of all straw supply and use constructed for the Netherlands is an example how to enrich the MFMD with an important biomass type.

The detailed analysis has shown that the Netherlands has a positive soil straw balance of 173 KT DM straw. There is more straw and chaff ending up in Dutch soils then domestically produced due to a significant import of straw and chaff, and most of it ends up in the soil again after one or two intermediate uses. More than half (429 KT DM) of total straw production in the Netherlands (826 KT DM) is not removed from the land and goes straight to the soil. The removed part (397 KT DM) together with an imported straw amount (352 KT DM) goes to different uses, while the amount of Dutch exported straw is limited (160 KT DM). The most important first uses of straw and chaff in the Netherlands are for bedding, feed and horticulture. The main secondary uses are for mushroom production in the form of compost, a mix of straw with horse manure, and as compost or soil improver after it is used in bedding. Also, the straw used in horticulture ends up in the soil after production of the flower bulbs and strawberries. In mushroom production straw also has a tertiary use when residues end in champost (138 KT DM straw equivalent) which is used as soil improver either in the Netherlands (55 KT DM straw) or abroad (83 KT DM).

The analysis illustrates that this straw balance could not have been compiled when it had to rely only on data for traded products that is registered in existing statistical data bases (e.g. Trade statistics, ProdCom or structural business statistics. Instead many alternative data sources have been consulted combined with information derived from several experts involved in science and in business organisations active in some part of the whole straw supply and use chain. It shows that there are many data limitations which need to be addressed for extending the current MFM to cover more sections of the bioeconomy and understand more in detail the circular use of our biomass resources. The straw case also shows that for an MFM covering the bioeconomy it is recommendable to not limit the system boundaries to the monetary economic flows, but also include traded non-monetary flows as well as biomass that flows to soil, air and water ecosystems. This will enable a better understanding of how circular important components of the biomass are treated such as carbon, nitrogen and phosphates and that losses to the environment are avoided.

A final challenge that will need to be addressed carefully when integrating the straw biomass flow in the MFM is their secondary and tertiary use. Integration of these uses will provide risks for double counting as supply and uses need to be in balance. Note that this also holds in any other circular and cascading use of a material or biomass.

7 Enhanced Material Flow Monitor

7.1 Introduction

7.1.1 CBS version of MFM as starting point

The MFM, developed by CBS, describes the physical material flows, measured in million kilos, to, from and within the Dutch economy. It is a macro-economic database of all material flows within the economy, imports and exports and flows between the economy and the environment. The basis for these figures are the monetary supply and use tables (MSUT) compiled by the national accounts department of statistical offices and unit prices per product. These SUTs accounts for flows from and to different sectors, for example, grain that is produced by the agricultural sector is reported in the supply table, while the grain used as input for the food processing industry for bread production pops up in the use table.

A full list of the sectors and products reported in the MFM of CBS can be found in Van Berkel en Delahaye (2019). Both the supply table and the use table have the same format: products are in the rows and sectors in columns (Table 7-1).

Table 7-1 *Common format of the supply and use table of the MFM*

	Industries	Households	Accumulation	Rest of the world	Environment	Total
Supply table						
Natural inputs					Flows from the environment	Total supply of natural inputs
Products	Output			Imports		Total supply of products
Residuals	Residuals generated by industry	Residuals generated by final household consumption	Residuals from scrapping and demolition of produced assets			Total supply of residuals
Use table						
Natural inputs	Extraction of natural inputs					Total use of natural inputs
Products	Intermediate consumption	Household final consumption	Gross capital formation	Exports		Total use of products
Residuals	Collection & treatment of waste and other residuals		Accumulation of waste in controlled landfill sites		Residual flows direct to environment	Total use of residuals

Source: SEEA-CF System of Environmental-Economic Accounting Central framework.

The row with products is calculated using the method of MSUT and unit values as described in this chapter. The rows with natural inputs and residuals are additional information obtained from e.g. waste or extraction statistics. The column Environment is added to include the resources that the environment supplies to the economy and the residuals it uses. Details on these MSUT can differ per country and are compiled by national statistical institutions (NSI's).

As physical SUTs (PSUT) are compiled according to concepts and definitions of the monetary SUTs in the national accounts and through its connections with economic statistics (GDP, employment) and environmental statistics (emissions) a broad range of socio-economic and, environment indicators can be quantified.

The BioMonitor project (H2020; 2018-2022) has enhanced the MFM of CBS with biomass flows that are connected to non-food and non-feed products (Figure 1-1). In principle any single product in the MFM is for its full 100% assigned to one of the four main material categories: biomass, metals, non-metal minerals and fossil energy carriers. Further, *composite* goods that consist of more than one material, e.g. biomass and fossil energy carriers, are allocated to the material that makes up the largest part (in physical terms). So called *ambiguous* goods, which are manufactured from either biomass or another material (e.g. plastics), are allocated to the material type of the most common production method (e.g. plastics are assigned to products made of fossil energy carriers). Based on expert knowledge, composite and ambiguous products have been split over different material categories according to their intrinsic biomass contents and bio-based shares (van Berkel en Delahaye, 2019; Piotrowski and Carus, 2017).

7.1.2 Identified gaps

The KB1-1B study has also adopted the MFM of CBS as starting point for monitoring flows of biomass and its residues. It wants to enhance it with detailed data on agricultural residues along different stages of the production and consumption process (primary, secondary and tertiary residues) to improve insights into the circularity of biomass. The MFM is a macro-economic picture with focus on relation between materials and sectors, but the integration of micro data, for example on agricultural and forestry residues, could obviously enrich it (Delahaye, 2022; other references). The MFM of CBS already contains supply and use accounts for waste and recycled materials (Berkel et al., 2019; Berkel and Delahaye (2019)), but lacks a good level of detail on:
- Biomass residues for non-traded products, e.g. production of grass and corn.
- Underlying types of biomass, as waste and recycled materials are reported as aggregates.
- Dry matter, water, proteins, minerals, carbon and hazardous substances of biomass (residues).

To understand how to progress to a more circular bioeconomy more knowledge is needed on detailed flows of biomass resources and the individual components they consist of as crop, livestock and fish sectors produce large amounts of primary, secondary and tertiary residues. Thus, unravelling the content of any biomass (residue) resource in components (water, carbon, nitrogen, phosphorus, hazardous substances) will improve insights in sort of leakages to the environments and search for potential circular business cases to close the leakages. As addressed in the previous section, the MFM is reported in physical terms and derived from monetary supply and use tables, and therefore includes only traded goods with a price. Apart from this, there are also biomass flows outside the economy, such as grass production and farm consumption, that substitute with other biomass flows in the system and might give alternative (circular) use options (e.g. berm grass used for packaging) and could bring positive environmental impacts.

7.1.3 WUR version of MFM

The WUR version of MFM aims to monitor relevant biomass (residue) flows between industries, production processes of industries, and to identify leverage points for creating new business cases in the circular bioeconomy. Also, it should be able to quantify indicators related to dependency on non-renewable resources (e.g. biomaterial replacing non-renewable resources) and the economic competitiveness of bio-based products. The approach developed to enrich the MFM with detailed biomass (residue) information builds upon WUR expertise about agricultural and marine sectors (e.g. economic, biophysical, policies and strategies) and data handling (e.g. collecting and estimating, harmonising and coding, integrating and visualising of data).

In principle there are two ways to include more detail in the CBS version of the MFM at:
- *Product level:* a) splitting an aggregate group of products into sub-products (e.g. 'manure' into products 'animal waste' and 'plant waste'), or b) adding new products (e.g. 'straw').
- *Sector level:* a) splitting an aggregate group of sectors, or b) adding new sectors. For example, originally the sector 'horticulture' is an aggregate of 'horticulture in open air', 'horticulture in glasshouses' and 'other horticulture'. As the three types each have specific supply and use structures, it makes sense to split the aggregated horticulture sector into three industry types. Especially energy use, for example, significantly differs between open air horticulture and glasshouse horticulture.

Reasons to include more biomass detail in the supply and use tables of the MFM could for example be the importance of a specific biomass product or sector size for the economy, specific policy and research questions to be addressed, and availability of data. In general any preferred product/sector extension requires the gathering of additional data and knowledge on supply and use sides of the respective product/sector. The KB1-1B study has extended the MFM as follows:

- *Implementation of supply and uses of new biomass products, including residues.* One part of *grass, forage maize* (fodder crops) and *animal manure* is not financially traded because produced and used within the same farm. Another part is traded as it belongs to a broad product group in CBS's version of the MFM. The last related products have been split-off and then added to their respective product.
- *Addition of new biomass residue products.* Chapter 6 illustrates the supply and use of *straw* and how it gives insight into the circular biomass use. Departure is the total above-ground residual biomass production assessed in Chapter 2 and detailed review of i) the amount of residual biomass (straw and chaff) that is really removed from the field, ii) other sources of straw brought to the Netherlands through trade, iii) straw that is exported by the Netherlands, and iv) the main uses and related end-off life uses.
- *Disaggregation of hybrid biomass product groups into dedicated biomass products*. The CBS version of the MFM captures a mixed product 'total plant and animal residues', which is broken down in our KB-1B study into sub-groups *plant residues* and *animal residues*. Next, the group 'plant residues' is split into dedicated products *brewers' dregs* and *sugar beet pulp,* and a *rest plant residue* group. This enables a more accurate tracking of product flows through the system in terms of dry matter, carbon and nutrients contents.
- *Dry matter contents of biomass products*. CBS's version of the MFM (reported in kg product weight) includes different biomass product categories, e.g. potatoes or fodder crops, which differ in their product composition, such as content of water or nutrients. Consequently, an aggregation of different (bio-based) products will not represent the usable amount of available biomass (in dry matter, thus excluding water), and/or the fact that production processes can change the biomass weight by adding water or by valorisation of water. Based on the procedure applied by Gurría et al. (2017) this gap was closed by transferring all material flows from product weight in dry matter based on applied conversion factors of CBS and Remmelink (ed., 2009).
- *Decomposing contents of biomass (residue) products (in kg dry matter) in attributes (carbon, nitrogen, oxides* and *ammonia)* to get insight into mineral balances (e.g. nitrogen, phosphorus and potassium) and leakages to the environment. Especially losses on nitrogen and phosphorus can cause environmental damage in case of excesses, e.g. nitrogen can leach to (ground) water and air, and phosphorus can lead to eutrophication. Flows of organic N, P and K are highly related to the flows of animal manure and other organic fertilisers. On the supply side N, P and K can be determined by using the mineral content of manure and other organic fertilisers. On the use side new balance items are required to be able to capture the losses by emissions and leaching. As an illustration, supply and use flows of *straw* to, within and out of the economy are reported in both dry matter and carbon in Chapter 6.

7.2 Approach to enhance CBS version of MFM

This section describes the generic approach assessed in the KB1-1B study for enhancing the MFM of CBS. It builds upon three data management related activities (Figure 7-1):

1. Collecting, harmonising, coding and storing data in a datawarehouse[17].
2. Visualising data.
3. Implementing data in the MFM.

[17] A datawarehouse can be seen as a house with boxes that contain data. Boxes can be opened using specific tools.

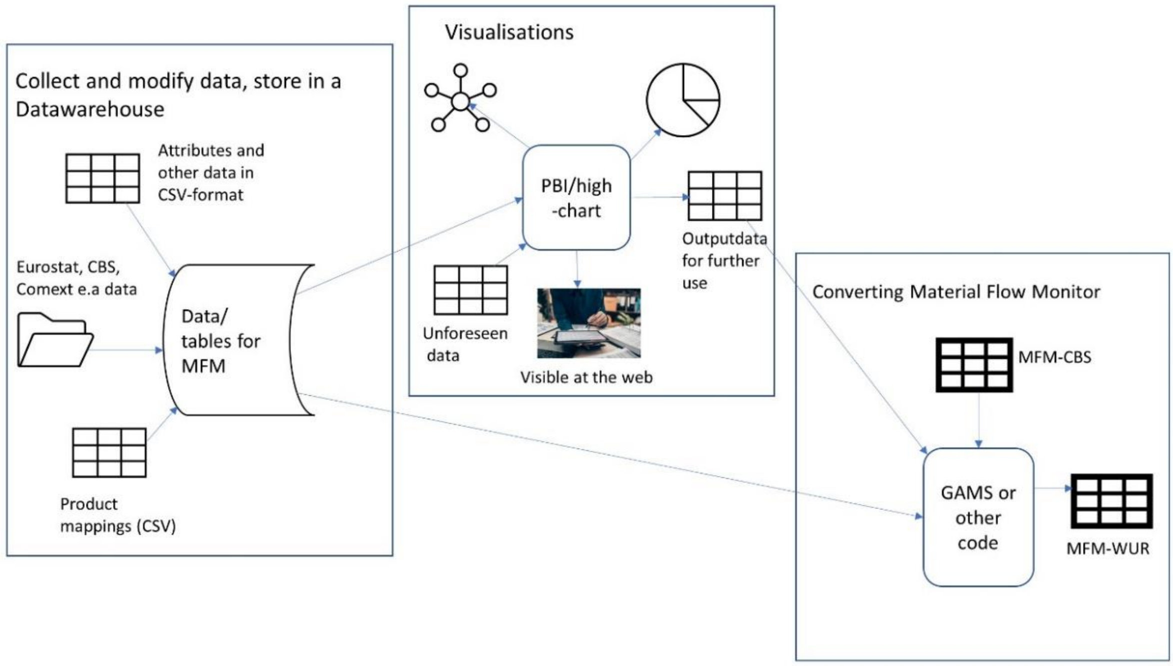

Figure 7-1 *Activities assessed to construct WUR's Material Flow Monitor*
Source: Authors.

First, Section 7.2.1 highlights the key steps of the data management procedure from collecting to storing. Second, Section 7.2.2 shows the benefits of a data warehouse system when it is connected with presentation and visualisation tools. Third, the implementation of supply and use data in the MFM is illustrated for a main biomass residue product, i.e. straw, in Section 7.2.3.

7.2.1 Collecting, harmonising, coding and storing data

The data management process starts with collecting supply and use related data for a comprehensive set of primary agricultural products and their associated residues. This has been accurately described in Chapters 2 to 5. Data are preferably obtained from existing data sources, for example at EUROSTAT and CBS, but estimated based on sector expert knowledge and literature in case of data gaps. Previous chapters also explain the coding procedure of any new biomass (residue) product of interest, which are not in statistics yet but follows existing harmonised product coding systems. This is essential as to avoid double counting and to guarantee the uniqueness of each product, which are relevant when it comes to the quantification of attributes (or indicators) for any product.

As important next activity of our approach is the storage of the huge amount of collected data in an overarching database. This will facilitate the selection of specific data necessary for integration in the MFM, which most probably is at a higher aggregation level than the detail collected in Chapters 2 to 5. This requires the creation of a systematic and hierarchic database which facilitates that all gathered data get a similar format, can be processed into material flow indicators or other circularity indicators and controls the maintenance and update of the data in a formal way. For this KB1-1B study, data are stored and managed in the Datawarehouse (DWH) of Wageningen Economic Research (Figure 7-2).

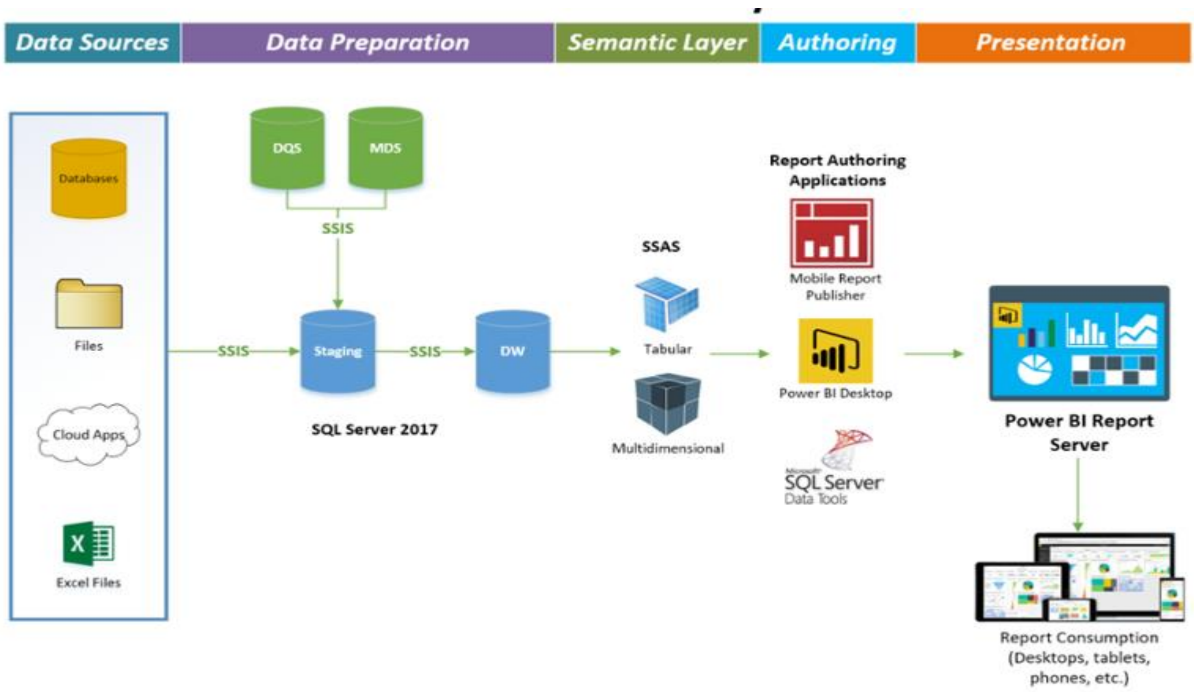

Figure 7-2 *Datawarehouse system of Wageningen Economic Research*

This filling of the DWH is ongoing work but already includes lots of data that are useful for extending CBS's version of the MFM with data on specific biomass (residue) products. Moreover, it enables the addition of more data in the system, which is illustrated for the comprehensive set of straw related data quantified (Chapter 6) and serves as example how these could be implemented in the MFM (Section 7.3). Specific indicators, such as biomass supply and use biomass residues or the carbon content of biomass products, can be calculated within the DWH via connecting existing data sources with calculation rules based on literature or expert knowledge. Advantage of the DWH is that it guarantees sort of automatic maintenance and version control in case of data updates in any next point in time (see Appendix 8).

7.2.2 Visualising data

Data stored in the DWH can be linked with different packages such as Python, Excel and Power-BI. It has as advantage that tailor-made dashboards with visualisations and tables can be created. As an illustration, Sankey diagrams offer a relevant way to follow the amount of biomass that flow to, within and out of the economy (see example Figure 7-3). Dashboards can be published on the web and used for web-presentations (see Appendix 8 for more details).

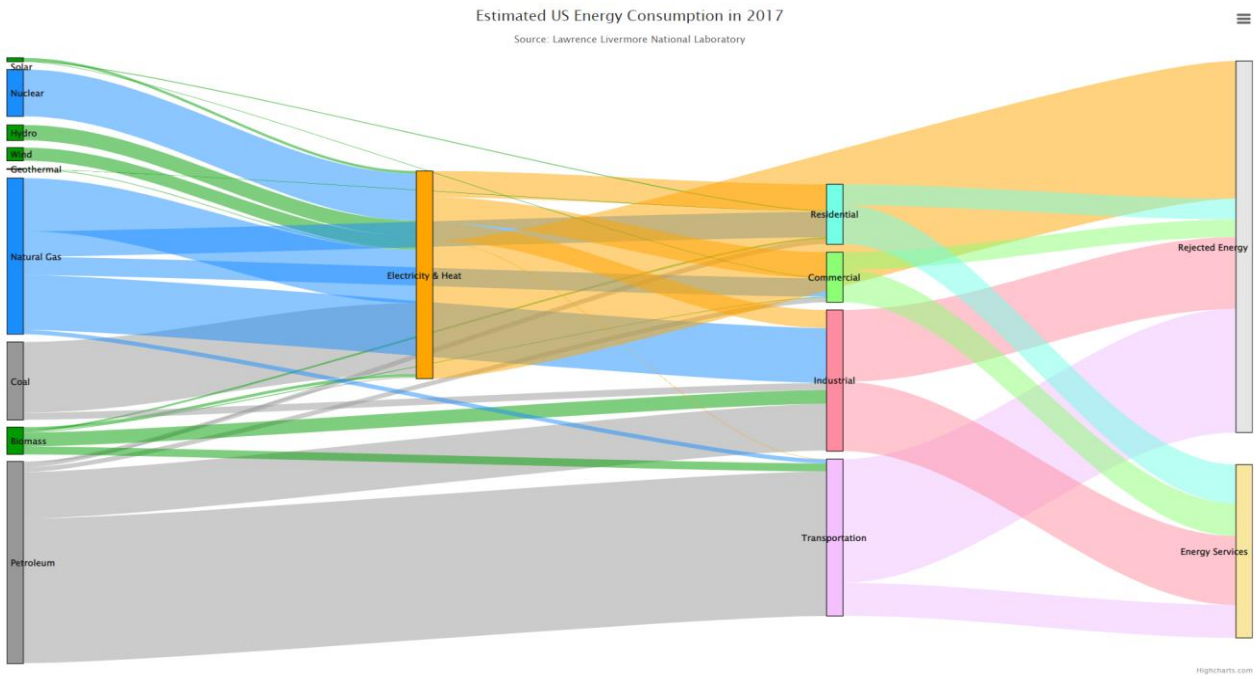

Figure 7-3 *Example of a Sankey diagram created by Highcharts*[18]

7.2.3 Implementing data in the MFM

As explained before, the preferred level of detail with regard to biomass products and sectors reported in the MFM depends on multiple factors, such as importance for the bioeconomy or policy and research question addressed. In general, any product or any sector added to the MFM requires the gathering of additional data and knowledge on the supply and use sides of the respective product or sector. When constructing or adapting a MFM, independently from the number of sectors and products involved, the following accounting rules must be regarded:

- Total supply per sector is equal to total use of sector.
- Total supply of a product is equal to total use of a product.

The technical process of extracting supply and use data from the DWH, which organises the data in the sense that they fit within the MFM framework, is illustrated in Section 7.3 for the product *straw*. The procedure is automated via a GAMS software program, which enables the application of similar data procedures for any other biomass residue (see Appendix 10).

7.3 Example: including straw data in the MFM

7.3.1 Calculating flows of straw fitting to MFM categories

Focus in this section is on the steps taken to get straw flows well-covered in the MFM. The DWH serves as stepping stone for selecting and quantifying data and transferring these into the MFM. The calculation of supply and use of straw and how straw flows from users to end-users is organised in the DWH, based on calculation rules explained in Chapter 6. Table 7-2 highlights the situation of straw flows in 2020. The first column shows the producers of straw, the second column shows the users of straw, and the third column contains the volume of the flow.

[18] https://www.highcharts.com/blog/chartchooser/sankey-categorical-flow/

Table 7-2 *Flows of straw in the Netherlands in 2020*

From producers	To users	Volume (tonne DM)
Straw production in the Netherlands	To the soil	428,670
Straw & chaff production in the Netherlands	Harvested	397,192
Harvested	Total used	397,192
Imported	Total used	351,735
Total use	Flower bulbs	118,496
Total use	Forage for animals (feed)	133,714
Total use	Forage for animals (chaff)	185,819
Total use	Mushroom production	222,000
Total use	Other bio-based use	16,714
Total use	Straw for stables of horses	221,737
Total use	Straw for stables of other animals	134,663
Total use	Strawberries	39,054
Harvested	Exported	76,461
Mushroom production	Exported	83,115
Straw for stables of horses	Mushroom production	110,998
Mushroom production	Used by mushrooms	84,223
Other bio-based use	Used by bio-based products	16,714
Used by mushrooms	To food	84,233
Used by bio-based products	To material and/or air	16,714
Mushroom production	To the soil	54,648
Strawberries	To the soil	39,054
Flower bulbs	To the soil	118,495
Forage for animals (feed)	To the soil	133,714
Straw for stables of horses	To the soil	110,998
Straw for stables of other animals	To the soil	134,663

Source: Authors.

7.3.2 Adding new products to MFM list

Based on the detailed information regarding the biomass residue product *straw* in Chapter 6, three new products must be added to the current product list of CBS's version of MFM, namely *straw*, *waste straw* and *recycle straw*.

First, *straw* is added. On the supply side, straw is linked to the sector 'Arable farming' as it is mainly derived from crops. The associated data are introduced in the supply table. On the use side, straw is input for producers of flower bulbs, strawberries, mushrooms, horsing, other animals, and users of feed, and the 'other bio-based use' sector. These specific uses must be assigned now either to sectors already defined in the MFM or must create new sectors, e.g. by splitting a current hybrid MFM sector. In the MFM version of CBS the production of *flower bulbs, strawberries* and *mushrooms* belong to the sector 'Horticulture', while *horsing*, *other animals* and *feed use* are mainly included in the sector 'Livestock'. As 80% of the horses belong to the sector Sports and Leisure,[19] only 20% of horse production is assigned to Livestock. With regard to the 'other bio-based use', these could take place in several bioeconomy sectors such as other agriculture, electricity and/or heat production, construction, or chemistry. It is assumed that this 'other bio-based use' is linked to the sector 'Other Livestock'. Finally, Table 7-3 reflects how straw flows from the producers' side to the use side.

[19] There are about 90,000 horses in agriculture (CBS) and 450,000 in total (Koninklijke Nederlandse Hypische Sportfederatie). It is assumed that horses outside agriculture are kept at riding schools and firms for competition horses. More information on modelling and code can be found in Appendix 10.

Table 7-3 Aggregated flows of straw in the Netherlands in 2020 suitable for the MFM

From producers	To users	Volume (tonne DM)
Straw production in the Netherlands	To the soil	428,670
Straw production in the Netherlands	Harvested	397,192
Harvested	Total used	397,192
Imported	Total used	351,735
Total use	Horticulture	379,536
Total use	Other agriculture	16,714
Total use	Livestock farming	476,396
Total use	Sport and leisure	177,389
Harvested	Exported	76,461
Livestock farming	Horticulture	22,200
Sports and leisure	Horticulture	88,789
Horticulture	Used by Horticulture (mushrooms)	84,223
Other agriculture	Used by Other sector	16,714
Horticulture	To the soil	212,197
Livestock farming	To the soil	454,196
Sport and leisure	To the soil	88,798
Horticulture	Exported	83,115

Source: Authors.

Second, *waste straw (AfvalStro – RAS)*[20] is added. Production of waste straw is representing the flow from sectors to the soil and air. User of the waste straw is linked to the sector 'Environment'.

Third, *recycle straw (recycle stro – RCS)*[21] is added. Production of recycle straw is representing the flow of own use (used by mushroom production), export and straw from horse stables to mushrooms. The user of the recycle straw is linked to the sector 'Environment', sector 'Export' and sector 'Horticulture'.

7.3.3 Transferring straw data in the MFM

The data transformation process consists of five steps (more details in Chapter 6 and Appendix 10):

- Step 0 allocates 80% of the horses, being now in agriculture, to the leisure sector based on the ratio between horses in agriculture and total number of horses (including ponies).
- Step 1 calculates on the supply side the gross straw production as the sum of straw production harvested and straw production left on the soil. These data are assigned to the sector Arable farming.
- Step 2 calculates the secondary supply, i.e. the supply of rest straw to the soil, which are linked to the product *Waste straw*. On top of this, the supply of *recycle straw* is calculated.
- Step 3 defines and calculates the use of gross straw production by horticulture, livestock, sports and leisure, export, environment and other agriculture sectors.
- Step 4 calculates uses of recycle straw and waste straw.
- Step 5 balances the straw production and the extraction of material from the environment. Straw production needs materials from soil, water and air (sector 'Environment'). It delivers material to the product 'Extraction Primary Crops', which is used by Arable farming to produce the straw.

7.3.4 Coding and computer program

In the original MFM of CBS, straw is partly included in the product 'forage for animals' as it only contains the trade part. Due to the interest in total straw flows, thus both the traded and untraded parts, straw is added as a separate product to the MFM and connected to its supplying and using sectors. Note that the traded straw has been extracted from the product 'forage for animals' to avoid double counting. Straw is mainly produced at arable farms and therefore linked to the sector Arable farming (code C1109), i.e. 'Arable farming' is the straw supplier. The new created product *straw* is assigned to a new unique product code

[20] 'Afvalstro' is the product name in the adapted MFM and 'RAS' is the accompanying code in the MFM.
[21] 'Recycle stro' is the product name in the adapted MFM and 'RCS' is the accompanying code in the MFM.

R119300. This code is in line with CBS product coding, however not with the 14-digits scheme as presented in Chapter 2 (Section 2.3). This is because straw is produced by several crops (cereals) which would lead to several ‘straw’ product varieties. The only known factor is how much straw a specific sector use, but the type of straw used is unknown. Table 7-4 shows the mapping of straw users to sectors in the MFM and associated sector codes.

Table 7-4 *Mapping of straw to using sectors in the MFM*

Products for which straw is used	Sector in MFM to which the product belon	Sector code in MFM
Straw for flower bulbs	Horticulture	C1209
Straw for strawberries	Horticulture	C1209
Straw for mushroom	Horticulture	C1209
Straw for forage for animals (feed)	Livestock	C1400
Straw for stable horses	Livestock	C1400
Straw for stable horses	Sport and Leisure	C93000
Straw for stable other animals	Livestock	C1400
Straw for other bio-based uses	Other agriculture	C1500
Straw to soil	Environment	C999999
Straw to air	Environment	C999999

Source: Authors.

Straw is used by sectors Horticulture (C1209), Livestock (C1400), Other Agriculture (C1500) and Sport and Leisure (C93000). About 80% of the horses are kept outside agriculture (CBS and Koninklijke Nederlandse Hypische Sportfederatie), i.e. at riding schools and firms for competition horses. As these subsectors are covered in the sector ‘Sports and leisure’ (C93000), part of the straw consumption is assigned to Livestock and part to Sports and leisure.

The product ‘Other bio-based uses’ is hard to link to a sector as it may be used for energy production, construction and other purposes. Moreover, the size of the product is rather small compared to other straw uses (Table B5.1). Therefore it is assumed to be linked to ‘Other agriculture’ as statistics don’t report on the use of other straw.

Next, it can be concluded from Table 7-4 that there are more users of straw, namely soil and air, which are both represented in the MFM by the sector ‘Environment’ (C999999).

To visualise all flows in the MFM, two other sectors are added: *waste straw* and *recycle straw*. Production of waste straw represents the flow from sectors to use category ‘Environment’ (representing soil and air). Production of recycle straw represents flows to internal use and exports, including straw from horse stables to mushrooms. Users of recycle straw are sectors ‘Environment’, ‘Export’ and ‘Horticulture’.

Finally, the developed GAMS program in this KB-1B study organises the automated data implementation in the MFM. Full coding of the five steps approach is presented in Appendix 10.

7.3.5 Visualising straw flows

The detailed data set for supply and use of straw as quantified in Chapter 6 has been implemented in the DWH. Figure 7-4 shows the flows of straw and straw products in a Sankey diagram derived from calculations in the DWH.

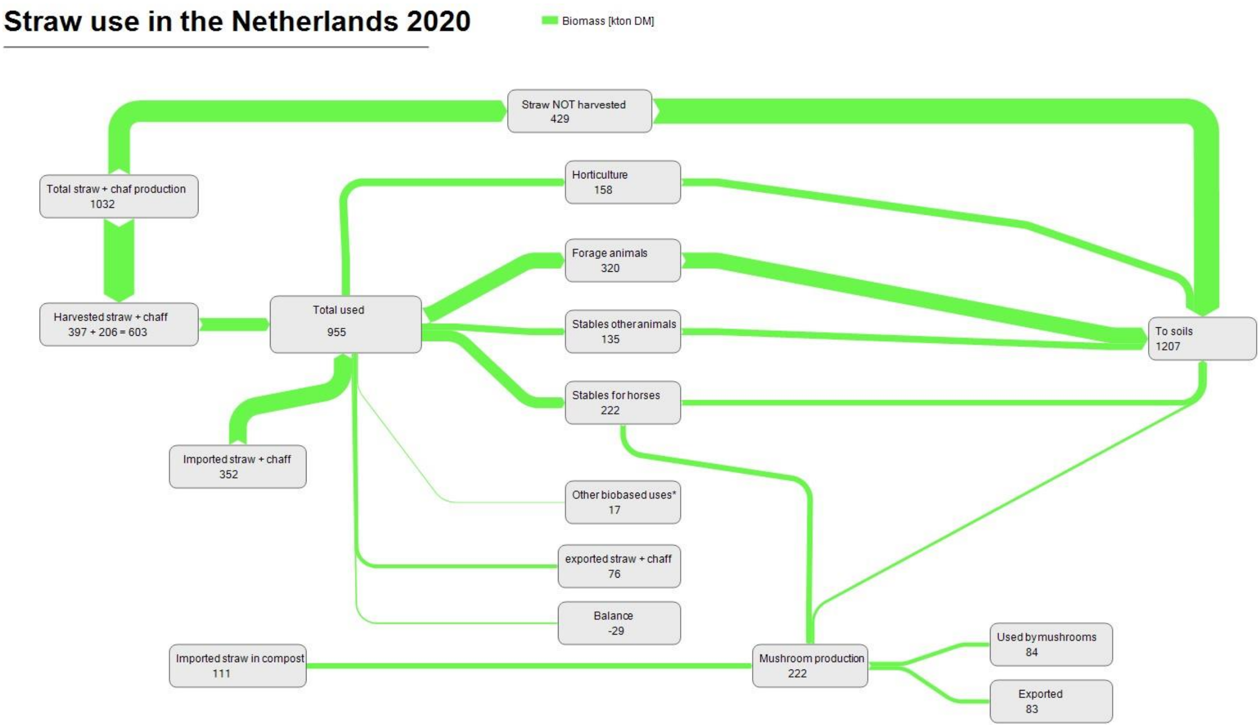

Figure 7-4 *Supply and use of straw and straw products in the Netherlands in 2020, created in DWH*

Alternatively, Figure 7-5 is an aggregated version of the Sankey diagram based on information in the extended MFM according to the five steps approach explained before.

There is a flow from straw used in stables of horses to mushroom production. Here is also an internal use of straw, likewise it is with bio-based products use. In the Sankey version created based on the enhanced MFM, this internal use is assumed to flow to the air and therefore linked to ‘environment’ to balance supply and use (Figure 7-5). Furthermore the figures show that the amount of straw left on the field has about same size as the imported straw.

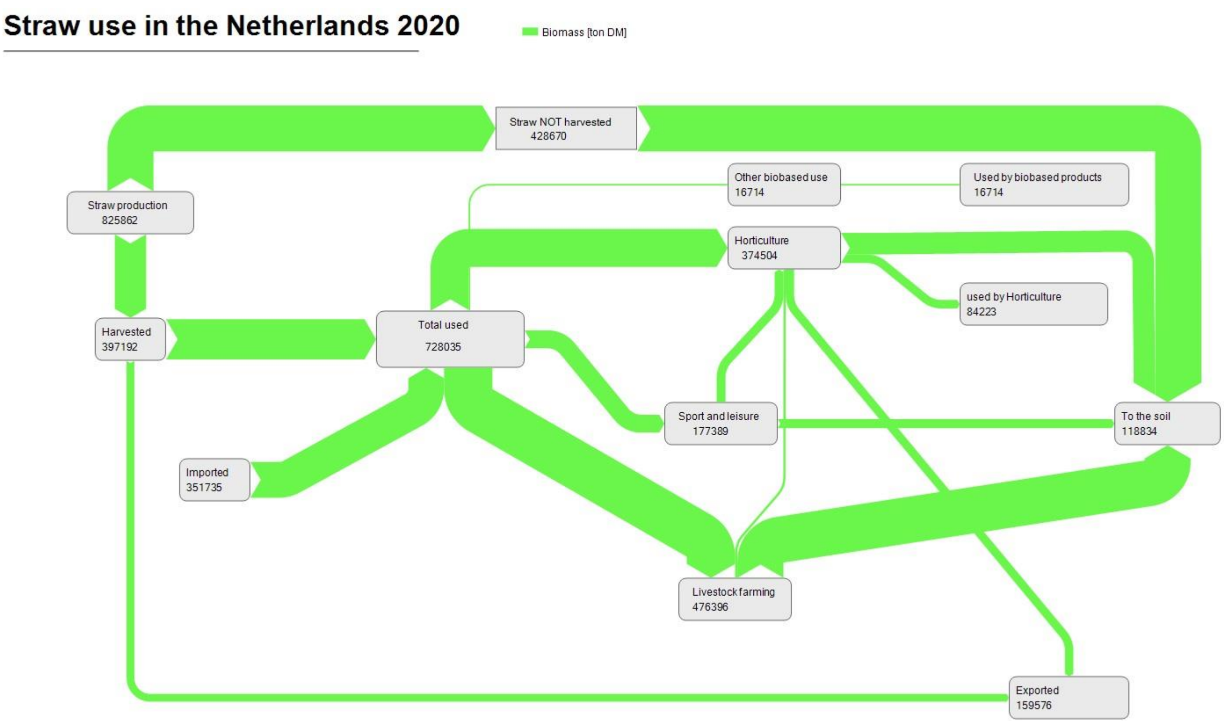

Figure 7-5 *Supply and use of straw and straw products in the Netherlands; an aggregated version derived from MFM*

It is obvious that the more detailed data are available the more detailed flow information the Sankey can provide. If a research question has a micro or product focus, e.g. identifying the supply and use of straw, then it is recommended to take the disaggregated supply and use information from the DWH. If a research question has a macro or sector focus, e.g. identifying the total supply of biomass residues in the Dutch economy and their distribution over industries, it is recommended to take the more aggregated supply and use information from the MFM.

8 Conclusions and Recommendations

8.1 Conclusions

To understand opportunities how to transit to a circular bioeconomy, it is important to have insight into the flows of biomass resources to, within and out of the economy, and the individual components these resources consist of. The crop, livestock and fish sectors produce large amounts of primary products and primary residues. Supply and uses of the primary products are well known through existing statistics and other regularly collected information systems. However, data for primary residues (e.g. field residues in case of crops, manure in case of livestock) are not systematically collected and a good quantification system is absent, which hinders the discovery of policy and business opportunities to boost the development of the circular bioeconomy. Moving along the food and feed value chains, there are also secondary residues (e.g. potatoes steam peels, beer brush in case of processed crops, animal fats in case of processed livestock products, or fish meal in case of processed fish), and tertiary residues at the end-of-life stage (e.g. municipal waste, household food waste). As in the case with primary residues, the systematic collection of data on generation and use of secondary and tertiary residues is incomplete and not systematically collected.

The objective of this KB1B study was to develop a system that can monitor different components in the produced, collected, processed and consumed biological resources and can detect options for reusing, recycling and reducing residual flows in particular. Following are the conclusions that can be drawn from the study.

Framework for the monitoring system
This KB1B study has developed an approach that improves the insight into the flows of biomass types and the components they consist of (e.g. nutrients, carbon) through the bioeconomy. It generates new information, e.g. on suppliers of biomass residues, demanders of biomass residues, and wanted or wanted leakages to the environment, that is systematically connected in a monitoring framework. It was decided not to develop a new monitoring system from scratch, but to build upon an existing system, i.e. the Material Flow Monitor (MFM), that is regularly developed by Statistics Netherlands (Delahaye et al., 2023). It contains physical flow accounts for supply and use of goods, published for 95 commodities and in a way mirrors the monetary flows of the National Accounts that accompanies these commodities. PBL, Statistics Netherlands and RIVM use it as tool for monitoring the development towards the *circular economy* in the Netherlands (Potting et al., 2018). In its original form the tool is however insufficient valuable for monitoring the development of the *circular bioeconomy* because flows of biomass residues are hardly captured. On the other hand, the MFM is a comprehensive system that is compiled from a variety of underlying source datasets and classifications, and can be enhanced or extended with new data if applicable. For that reason, this KB-1B study has identified, quantified, coded collected the supply and use data for a wide pallet of biomass resources and associated residues. First, both existing biomass data (e.g. on raw primary products obtained from underlying statistics) and newly generated data (e.g. product residues and how to calculated as there are no underlying statistics) are stored in the datawarehouse (DWH) developed by Wageningen Economic Research. The advantage of this DWH is that data sources of raw primary products are regularly updated, and at the same time the numbers for residues are updated via the inserted calculation rules. Second, biomass-related data are transferred from the DWH into the MFM of Statistics Netherlands depending on the topic of interest or policy question. The enriched MFM can provide better insight into waned or unwanted leakages to the environment (soil, air, water) due to the supply and use processes of biomass resources, and can identify potential new circular business cases using biomass residues more efficiently and reducing waste to a minimum.

Apart from including more commodity detail in the MFM, it is also possible to split off subsectors from the main sectors that are covered in the MFM of Statistics Netherlands. Depending on the policy or research question the same approach could be followed as for bringing in more detail at the commodity level. It all goes together with identifying the preferred sector disaggregation and how to get data – either collected or estimated – about these sectors.

Monitoring crop products and residues
Regarding the crop sector, data on varieties, production, yields and acreage, is well registered in statistics. The potential residues of the crop biomass is not reported in statistics, which means that its potential must be estimated. The approach assessed in this project is to use functions that express the relationship between economic yield and the amount of biomass. Residual above-ground and below-ground biomass have been considered, as well as the distinction between harvestable biomass versus the biomass that remain in the field. The new biomass residue categories identified are coded via a hierarchical system that aligns with existing product coding standards. The coding system is built up of 14 digits for crop and animal products and builds on the NACE coding system for plant and animal products which makes up the first 4 digits of the total 14-digit coding for plant and animal products and the related primary residues. It ensures that the additional product detail can be smoothly and gradually transferred into the MFM.

Monitoring animal products and residues
Regarding the livestock sector, data on type, number, and age of livestock is well registered in statistics. Moreover nitrogen and phosphorous flows are also calculated and published. Data are limited available for different types of production systems such as Better Life or organic. Considering the increased interest of these production systems, including these may improve monitoring changes in livestock production systems. Residue types are harmonised according to the developed generic coding system.

Monitoring aquatic products and residues
Incorporating aquatic production into monitoring schemes for the entire bioeconomy is still in its infancy. Issues with discerning the exact processes and volumes of biomass flows are highly opaque. In this study we have attempted to provide initial key steps to, to our knowledge for the first time ever, include aquatic production to much greater levels of detail. It was found that the new structure defined in this MFM could house aquatic production data very well, despite the noticeable differences between the aquatic production industries and other sectors of biomass production.

As the marine capture fisheries generally represent the largest volumes of the aquatic production industry, this initial attempt of monitoring has mostly focused on the marine capture fisheries sectors. Using key commercial species (groups) some primary residue flows could be estimated for well over 90% of the volumes produced. However, it must be noted that for other biomass flows the data needed to do so was only very sparsely available.

Consequently, future efforts should focus on 1) the generation of (reliable) estimates for the flows described and 2) completing future mass balances using the lower volumes represented by the aquatic production sectors outside of the marine capture industries, such as the, in the Netherlands relatively small, aquaculture sector.

Monitoring secondary and tertiary residues
An overview of bio-based residues was prepared. Bio-based materials are present in many residue streams (Fruit and garden waste, household waste, mattresses, tyres, demolition wood). Sometimes the fraction in these streams is high, sometimes negligible. Almost every sector produces residual streams. Largest contributors to bio-based residues are food processing industry, beverage industry, wood and paper industry, services (wastewater treatment), building industry, public services (waste processing) and households.

Data on total residue streams are more accurate than data on sector specific residue streams due to missing data. Balancing of residues with input and output per sector may prove difficult, especially for sectors where these residues are negligible in volume. Best would be to start with the main contributors. Other sectors could be aggregated to complete the overview.

An example: Monitoring straw in the Material Flow Monitor
The straw balance has been compiled based on using data from multiple public data sources, which are combined with information obtained from several experts involved in science and in business organisations

active in some part of the whole straw supply and use chain. It shows that there are many data limitations which need to be addressed for extending the CBS version of the MFM to cover more sections of the bioeconomy and understand more in detail the circular use of our biomass resources. The straw case also shows that for a better representation of the bioeconomy, the MFM should not limit the system boundaries to the monetary economic flows, but should also include traded non-monetary flows as well as biomass that flows to soil, air and water ecosystems. This will enable a better understanding of how circular important components of the biomass, such as carbon, nitrogen and phosphates, are treated and gives insight into how to avoid losses to the environment.

8.2 Recommendations

In 2020, the EC adopted the EU Circular Strategy, which is considered as a key building block of the EC Green Deal. The objective of the strategy is to make the EU climate neutral in 2050, which requires a transition to a circular economy with less pressure on natural resources, climate and biodiversity, and ensuring food and nutrition security and sustainable jobs and growth. The EU has also set several circular economy objectives in its Circular Economy Action Plan (EC, 2020) plan that seeks to transform the EU’s production and consumption system through a sustainably responsible model of ‘reduce, reuse, refurbish, repair and recycling’. It should result into a doubled portion of materials used in relation to overall material use and a halving of EU’s residual waste.

In turn, the EU bioeconomy is one of the central pillars of the EU’s Circular Economy Action Plan. A circular bioeconomy seeks to foster a societal shift away from fossil-based technologies. It must decarbonise energy and material activity, which takes places in the context of reducing EU’s dependence on third countries’ fossil resources, meeting its ambitious emissions reductions targets, and revitalising rural areas (Bioeconomy Strategy, 2018; Green Deal, 2019; Bioeconomy Progress report, 2022).

The transition towards a greener model of bio-based growth is also, however, fraught with potential trade-offs regarding the achievements of the interlinked (and sometimes conflicting) societal challenges. To understand better the current state of the circular bioeconomy as well as policy outcomes of potential transition pathways on the societal objectives the use of monitoring and simulation tools are needed. Biomass is a raw material that originates from plants and animals, and from residuals thereof in the chain of harvesting, consumption and final processing. The MFM developed in this KB-1B study can help public and private policymakers to monitor circularity in the Dutch economy and to identify the opportunities and barriers to closing biomass (residue) flows. Compared to the CBS version of the MFM, the study has integrated flows of biomass residues and therefore is better capable to monitor the development towards a circular bioeconomy. It provides insights into wanted or (unwanted leakages to the environment (soil, air, water) due to the production, processing and consumption of biomass, and it can better identify potential circular business cases that use biomass residues more efficiently. This is useful information for decision makers to respond with tailored measures that could boost the development of feasible circular business cases.

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Appendix 1 Overview of crops in the Netherlands and sources used

This appendix gives an overview of crops in the Netherlands and sources used to derive the information and factors from to assess the harvested primary product, the aboveground and belowground biomass potential, the harvested primary residue level and the unharvested primary residue level left in the soil.

	2020*	2020*	2020*						
	Area	Yield per ha (field fresh)	Total production (fresh)	Method used		DM content (based on Monfreda)			Practice
	ha	1 000 kg	1 000 kg	Above-ground biomass	Below-ground biomass		Type of field residue	Type of field residue	Residue harvested, partly left in field
Wheat (total)	108908	8.8	953863	Garcia C. eq 6	Monfreda	0.89	Straw	Chaff	harvested
Wheat, winter	92462	9.2	848718	Garcia C. eq 6	Monfreda	0.89	Straw	Chaff	harvested
Wheat, summer	16447	6.4	105146	Garcia C. eq 6	Monfreda	0.89	Straw	Chaff	harvested
Barley, winter	9618	7.6	73176	Garcia C. eq 6	Monfreda	0.89	Straw	Chaff	harvested
Barley, summer	28763	6.2	178836	Garcia C. eq 6	Monfreda	0.89	Straw	Chaff	harvested
Rye	1781	4.4	7782	Garcia C. eq 6**	Monfreda	0.88	Straw	Chaff	harvested
Oats	1566	5	7804	Garcia C. eq 6**	Monfreda	0.89	Straw	Chaff	harvested
Triticale	1165	4.8	5579	Garcia C. eq 6**	Monfreda	0.89	Straw	Chaff	harvested
Grain Maize	12732	11.6	147208	Garcia C. eq 6	Monfreda	0.89	Stover		harvested
Forage maize	194654	44.9	8747475	Garcia C. eq 6	Monfreda	0.35	n.a.	n.a.	n.a.
Maize, grain cob	6690	10.7	71764	Garcia C. eq 6	Monfreda	0.89	Stover		harvested
Brown beans	2127	2.4	5105	Monfreda	Monfreda	0.9	Stuble		Field -soil
Rapeseed	1675	3.6	5946	Garcia C. eq 7	Monfreda	0.73	Stuble		Field -soil
Flax	1925	3.8	7353	Monfreda	Monfreda	0.8	n.a.	n.a.	n.a.
Linseed	1925	0.7	1434	Monfreda	Monfreda	0.73	Stuble		Field -soil
Chicory roots	3778	38.2	144434	Monfreda	Monfreda	0.8	Stuble		Field -soil
Hemp	1827	7	12786	Monfreda	Monfreda	0.8	n.a.	n.a.	n.a.
Potato	164504	42.7	7020062	Garcia C. eq 6	Monfreda	0.28	Stuble		Field -soil
Potato	75771	48.6	3681626	Garcia C. eq 6	Monfreda	0.28	Stuble		Field -soil
Potato	43629	34.5	1507199	Garcia C. eq 6	Monfreda	0.28	Stuble		Field -soil
Starch potatoes	45104	40.6	1831237	Garcia C. eq 6	Monfreda	0.28	Stuble		Field -soil
Sgar beet	81459	82.1	6691364	Garcia C. eq 7	Monfreda	0.12	Leaves		Field -soil
Seed onions	26844	49	1314081	Monfreda	Monfreda	0.13	Stuble		Field -soil
Seed onions (2nd year)	6343	44.5	282560	Monfreda	Monfreda	0.09	n.a.	n.a.	n.a.

Appendix 2 Harvest index (HI), dry fraction (DMF) and above ground fraction

This section provides the harvest index, dry fraction and above-ground fraction factors identified by Monfreda et al. (2008) that must be used to calculate above-ground and below-ground biomass per plant for crops not covered by Garcia-Condado et al. (2019).

Crop	Harvest index (HI)	Dry matter fraction	Above-ground fraction	Source of harvest index	Source of dry fraction	Source of above-ground fraction
Abaca (Manila Hemp)	0.28	0.8	0.5	Smil, 1999 (misc. crops)	Smil, 1999 (misc. crops)	Squire, 1990 (misc. perennial)
Agave Fibers, other	0.28	0.8	0.5	Smil, 1999 (misc. crops)	Smil, 1999 (misc. crops)	Squire, 1990 (misc. perennial)
Alfalfa	1	0.2	0.53	na	FAOSTAT	Hicke and Lobell, 2004
Almonds	0.28	0.9	0.75	Smil, 1999 (misc. crops)	National Research Council, 2003	Goudriaan and van Laar, 1994 (fruit)
Anise, Badian and Fennel	0.28	0.8	0.5	Smil, 1999 (misc. crops)	Smil, 1999 (misc. crops)	Squire, 1990 (misc. perennial)
Apples	0.3	0.16	0.75	Goudriaan and van Laar, 1994	National Research Council, 2003	Goudriaan and van Laar, 1994
Apricots	0.3	0.14	0.75	Goudriaan and van Laar, 1994	National Research Council, 2003	Goudriaan and van Laar, 1994
Areca Nuts (Betel)	0.28	0.8	0.5	Smil, 1999 (misc. crops)	Smil, 1999 (misc. crops)	Squire, 1990 (misc. perennial)
Artichokes	0.45	0.13	0.85	Goudriaan and van Laar, 1994	Goudriaan and van Laar, 1994	Goudriaan and van Laar, 1994
Asparagus	0.45	0.08	0.85	Goudriaan and van Laar, 1994	National Research Council, 2003	Goudriaan and van Laar, 1994
Avocados	0.3	0.26	0.75	Goudriaan and van Laar, 1994	National Research Council, 2003	Goudriaan and van Laar, 1994
Bambara Beans	0.49	0.9	0.85	Smil, 1999 (pulses)	Goudriaan and van Laar, 1994	Goudriaan and van Laar, 1994
Bananas	0.3	0.2	0.75	Goudriaan and van Laar, 1994	National Research Council, 2003	Goudriaan and van Laar, 1994
Barley	0.49	0.89	0.5	Bradford et al., 2005	National Research Council, 2003	Bradford et al., 2005
Beans, Dry	0.55	0.9	0.74	Bradford et al., 2005	Goudriaan and van Laar, 1994	Bradford et al., 2005
Beans, Green	0.45	0.1	0.85	Goudriaan and van Laar, 1994	National Research Council, 2003	Goudriaan and van Laar, 1994
Beets for Fodder	1	0.13	0.85	na	National Research Council, 2003	Goudriaan and van Laar, 1994
Berries, other	0.3	0.19	0.75	Goudriaan and van Laar, 1994	Goudriaan and van Laar, 1994	Goudriaan and van Laar, 1994
Blueberries	0.3	0.15	0.75	Goudriaan and van Laar, 1994	National Research Council, 2003	Goudriaan and van Laar, 1994
Brazil Nuts	0.28	0.8	0.75	Smil, 1999 (misc. crops)	Smil, 1999 (misc. crops)	Goudriaan and van Laar, 1994 (fruit)
Broad Beans, Dry	0.49	0.9	0.85	Smil, 1999 (pulses)	Goudriaan and van Laar, 1994	Goudriaan and van Laar, 1994
Broad Beans, Green	0.45	0.13	0.85	Goudriaan and van Laar, 1994	Goudriaan and van Laar, 1994	Goudriaan and van Laar, 1994
Buckwheat	0.4	0.88	0.8	Smil, 1999 (misc. crops)	National Research Council, 2003	Squire, 1990 (misc. annual)
Cabbage for Fodder	1	0.08	0.85	na	National Research Council, 2003	Goudriaan and van Laar, 1994

Crop	Harvest index (HI)	Dry matter fraction	Above-ground fraction	Source of harvest index	Source of dry fraction	Source of above-ground fraction
Cabbages	0.45	0.08	0.85	Goudriaan and van Laar, 1994	National Research Council, 2003	Goudriaan and van Laar, 1994
Canary Seed	0.4	0.88	0.8	Smil, 1999 (cereals)	Smil, 1999 (cereals)	Squire, 1990 (misc. annual)
Cantaloupes & other Melons	0.45	0.1	0.85	Goudriaan and van Laar, 1994	National Research Council, 2003	Goudriaan and van Laar, 1994
Carobs	0.3	0.19	0.75	Goudriaan and van Laar, 1994	Goudriaan and van Laar, 1994	Goudriaan and van Laar, 1994
Carrots	0.45	0.12	0.85	Goudriaan and van Laar, 1994	National Research Council, 2003	Goudriaan and van Laar, 1994
Carrots for Fodder	1	0.12	0.85	na	National Research Council, 2003	Goudriaan and van Laar, 1994
Cashew Nuts	0.28	0.8	0.75	Smil, 1999 (misc. crops)	Smil, 1999 (misc. crops)	Goudriaan and van Laar, 1994 (fruit)
Cashewapple	0.3	0.19	0.75	Goudriaan and van Laar, 1994	Goudriaan and van Laar, 1994	Goudriaan and van Laar, 1994
Cassava	0.48	0.32	0.85	Hay, 1995	National Research Council, 2003	Goudriaan and van Laar, 1994
Castor Beans	0.52	0.73	0.8	Smil, 1999 (oilcrops)	Smil, 1999 (oilcrops)	Squire, 1990 (misc. annual)
Cauliflower	0.45	0.08	0.85	Goudriaan and van Laar, 1994	National Research Council, 2003	Goudriaan and van Laar, 1994
Cereals, other	0.4	0.88	0.8	Smil, 1999 (cereals)	Smil, 1999 (cereals)	Squire, 1990 (misc. annual)
Cherries	0.3	0.14	0.75	Goudriaan and van Laar, 1994	National Research Council, 2003	Goudriaan and van Laar, 1994
Chestnuts	0.28	0.8	0.75	Smil, 1999 (misc. crops)	Smil, 1999 (misc. crops)	Goudriaan and van Laar, 1994 (fruit)
Chick-Peas	0.44	0.9	0.85	Ayaz et al., 2004	Goudriaan and van Laar, 1994	Goudriaan and van Laar, 1994
Chicory Roots	0.28	0.8	0.8	Smil, 1999 (misc. crops)	Smil, 1999 (misc. crops)	Squire, 1990 (misc. annual)
Chillies & Peppers, Green	0.45	0.08	0.85	Goudriaan and van Laar, 1994	National Research Council, 2003	Goudriaan and van Laar, 1994
Cinnamon (Canella)	0.28	0.8	0.5	Smil, 1999 (misc. crops)	Smil, 1999 (misc. crops)	Squire, 1990 (misc. perennial)
Citrus Fruit, other	0.3	0.13	0.75	Goudriaan and van Laar, 1994	Goudriaan and van Laar, 1994	Goudriaan and van Laar, 1994
Clover	1	0.2	0.5	na	see alfalfa	Squire, 1990 (misc. perennial)
Cloves	0.28	0.8	0.5	Smil, 1999 (misc. crops)	Smil, 1999 (misc. crops)	Squire, 1990 (misc. perennial)
Cocoa Beans	0.28	0.8	0.5	Smil, 1999 (misc. crops)	Smil, 1999 (misc. crops)	Squire, 1990 (misc. perennial)
Coconuts	0.28	0.8	0.5	Smil, 1999 (oilcrops)	Smil, 1999 (oilcrops)	Squire, 1990 (misc. perennial)
Coffee, Green	0.28	0.8	0.5	Smil, 1999 (misc. crops)	Smil, 1999 (misc. crops)	Squire, 1990 (misc. perennial)
Coir	0.28	0.8	0.8	Smil, 1999 (misc. crops)	Smil, 1999 (misc. crops)	Squire, 1990 (misc. annual)
Cow Peas, Dry	0.55	0.9	0.85	Hay, 1995	Goudriaan and van Laar, 1994	Goudriaan and van Laar, 1994
Cranberries	0.3	0.19	0.75	Goudriaan and van Laar, 1994	Goudriaan and van Laar, 1994	Goudriaan and van Laar, 1994
Cucumbers and Gherkins	0.45	0.04	0.85	Goudriaan and van Laar, 1994	National Research Council, 2003	Goudriaan and van Laar, 1994
Currants	0.3	0.19	0.75	Goudriaan and van Laar, 1994	Goudriaan and van Laar, 1994	Goudriaan and van Laar, 1994
Dates	0.3	0.19	0.75	Goudriaan and van Laar, 1994	Goudriaan and van Laar, 1994	Goudriaan and van Laar, 1994
Eggplants	0.45	0.08	0.85	Goudriaan and van Laar, 1994	National Research Council, 2003	Goudriaan and van Laar, 1994

Crop	Harvest index (HI)	Dry matter fraction	Above-ground fraction	Source of harvest index	Source of dry fraction	Source of above-ground fraction
Fibre Crops, other	0.28	0.8	0.8	Smil, 1999 (misc. crops)	Smil, 1999 (misc. crops)	Squire, 1990 (misc. annual)
Figs	0.3	0.21	0.75	Goudriaan and van Laar, 1994	National Research Council, 2003	Goudriaan and van Laar, 1994
Flax Fibre and Tow	0.28	0.8	0.8	Smil, 1999 (misc. crops)	Smil, 1999 (misc. crops)	Squire, 1990 (misc. annual)
Fonio	0.4	0.88	0.8	Smil, 1999 (cereals)	Smil, 1999 (cereals)	Squire, 1990 (misc. annual)
Forage Products, other	1	0.2	0.65	na	see alfalfa	Squire, 1990 (mean misc.annual/perennial)
Fruit Fresh, other	0.3	0.19	0.75	Goudriaan and van Laar, 1994	Goudriaan and van Laar, 1994	Goudriaan and van Laar, 1994
Fruit Tropical Fresh, other	0.3	0.19	0.75	Goudriaan and van Laar, 1994	Goudriaan and van Laar, 1994	Goudriaan and van Laar, 1994
Garlic	0.45	0.13	0.85	Goudriaan and van Laar, 1994	Goudriaan and van Laar, 1994	Goudriaan and van Laar, 1994
Ginger	0.28	0.8	0.5	Smil, 1999 (misc. crops)	Smil, 1999 (misc. crops)	Squire, 1990 (misc. perennial)
Gooseberries	0.3	0.19	0.75	Goudriaan and van Laar, 1994	Goudriaan and van Laar, 1994	Goudriaan and van Laar, 1994
Grapefruit and Pomelos	0.3	0.09	0.75	Goudriaan and van Laar, 1994	National Research Council, 2003	Goudriaan and van Laar, 1994
Grapes	0.3	0.19	0.75	Goudriaan and van Laar, 1994	National Research Council, 2003	Goudriaan and van Laar, 1994
Grasses, other	1	0.2	0.65	na	see alfalfa	Squire, 1990 (mean misc.annual/perennial)
Green Corn (Maize)	0.45	0.13	0.85	Goudriaan and van Laar, 1994	Goudriaan and van Laar, 1994	Goudriaan and van Laar, 1994
Green Oilseeds for Fodder	1	0.35	0.8	na	see maize for silage	Squire, 1990 (misc. annual)
Groundnuts in Shell	0.4	0.92	0.8	Hicke and Lobell, 2004	National Research Council, 2003	Hicke and Lobell, 2004
Hazelnuts (Filberts)	0.28	0.8	0.75	Smil, 1999 (misc. crops)	Smil, 1999 (misc. crops)	Goudriaan and van Laar, 1994(fruit)
Hemp Fiber and Tow	0.28	0.8	0.8	Smil, 1999 (misc. crops)	Smil, 1999 (misc. crops)	Squire, 1990 (misc. annual)
Hempseed	0.52	0.73	0.8	Smil, 1999 (oilcrops)	Smil, 1999 (oilcrops)	Squire, 1990 (misc. annual)
Hops	0.28	0.8	0.5	Smil, 1999 (misc. crops)	Smil, 1999 (misc. crops)	Squire, 1990 (misc. perennial)
Jute	0.28	0.8	0.8	Smil, 1999 (misc. crops)	Smil, 1999 (misc. crops)	Squire, 1990 (misc. annual)
Jute-Like Fibers	0.28	0.8	0.8	Smil, 1999 (misc. crops)	Smil, 1999 (misc. crops)	Squire, 1990 (misc. annual)
Kapok Fiber	0.28	0.8	0.5	Smil, 1999 (misc. crops)	Smil, 1999 (misc. crops)	Squire, 1990 (misc. perennial)
Kapokseed in Shell	0.28	0.8	0.5	Smil, 1999 (misc. crops)	Smil, 1999 (misc. crops)	Squire, 1990 (misc. perennial)
Karite Nuts (Sheanuts)	0.28	0.8	0.5	Smil, 1999 (oilcrops)	Smil, 1999 (oilcrops)	Squire, 1990 (misc. perennial)
Kiwi Fruit	0.3	0.13	0.75	Goudriaan and van Laar, 1994	Goudriaan and van Laar, 1994	Goudriaan and van Laar, 1994
Kolanuts	0.28	0.8	0.5	Smil, 1999 (misc. crops)	Smil, 1999 (misc. crops)	Squire, 1990 (misc. perennial)
Legumes, other	1	0.2	0.65	na	see alfalfa	Squire, 1990 (mean misc.annual/perennial)
Lemons and Limes	0.3	0.13	0.75	Goudriaan and van Laar, 1994	Goudriaan and van Laar, 1994	Goudriaan and van Laar, 1994
Lentils	0.46	0.89	0.85	Ayaz et al., 2004	National Research Council, 2003	Goudriaan and van Laar, 1994
Lettuce	0.45	0.05	0.85	Goudriaan and van Laar, 1994	National Research Council, 2003	Goudriaan and van Laar, 1994

Crop	Harvest index (HI)	Dry matter fraction	Above-ground fraction	Source of harvest index	Source of dry fraction	Source of above-ground fraction
Linseed	0.52	0.73	0.8	Smil, 1999 (oilcrops)	Smil, 1999 (oilcrops)	Squire, 1990 (misc. annual)
Lupins	0.41	0.89	0.85	Ayaz et al., 2004	National Research Council, 2003	Goudriaan and van Laar, 1994
Maize	0.45	0.89	0.85	Hicke and Lobell, 2004	National Research Council, 2003	Hicke and Lobell, 2004
Maize for Forage and Silage	1	0.35	0.85	na	Hicke and Lobell, 2004	Hicke and Lobell, 2004
Mangoes	0.3	0.18	0.75	Goudriaan and van Laar, 1994	National Research Council, 2003	Goudriaan and van Laar, 1994
Mate	0.28	0.8	0.5	Smil, 1999 (misc. crops)	Smil, 1999 (misc. crops)	Squire, 1990 (misc. perennial)
Melonseed	0.52	0.73	0.8	Smil, 1999 (oilcrops)	Smil, 1999 (oilcrops)	Squire, 1990 (misc. annual)
Millet	0.4	0.9	0.88	Larcher, 1995	National Research Council, 2003	Larcher, 1995
Mixed Grain	0.4	0.88	0.8	Smil, 1999 (cereals)	Smil, 1999 (cereals)	Squire, 1990 (misc. annual)
Mixed Grasses & Legumes	1	0.2	0.65	na	see alfalfa	Squire, 1990 (mean misc. annual/perennial)
Mushrooms	0.45	0.13	0.85	Goudriaan and van Laar, 1994	Goudriaan and van Laar, 1994	Goudriaan and van Laar, 1994
Mustard Seed	0.52	0.73	0.8	Smil, 1999 (oilcrops)	Smil, 1999 (oilcrops)	Squire, 1990 (misc. annual)
Natural Gums	0.28	0.8	0.5	Smil, 1999 (misc. crops)	Smil, 1999 (misc. crops)	Squire, 1990 (misc. perennial)
Natural Rubber	0.28	0.8	0.5	Smil, 1999 (misc. crops)	Smil, 1999 (misc. crops)	Squire, 1990 (misc. perennial)
Nutmeg, Mace and Cardamons	0.28	0.8	0.5	Smil, 1999 (misc. crops)	Smil, 1999 (misc. crops)	Squire, 1990 (misc. perennial)
Nuts, other	0.28	0.8	0.75	Smil, 1999 (misc. crops)	Smil, 1999 (misc. crops)	Goudriaan and van Laar, 1994(fruit)
Oats	0.4	0.89	0.71	Hicke and Lobell, 2004	National Research Council, 2003	Hicke and Lobell, 2004
Oil Palm Fruit	0.28	0.8	0.5	Smil, 1999 (oilcrops)	Smil, 1999 (oilcrops)	Squire, 1990 (misc. perennial)
Oilseeds, other	0.52	0.73	0.8	Smil, 1999 (oilcrops)	Smil, 1999 (oilcrops)	Squire, 1990 (misc. annual)
Okra	0.45	0.1	0.85	Goudriaan and van Laar, 1994	National Research Council, 2003	Goudriaan and van Laar, 1994
Olives	0.28	0.8	0.5	Smil, 1999 (oilcrops)	Smil, 1999 (oilcrops)	Squire, 1990 (misc. perennial)
Onions, Dry	0.45	0.13	0.85	Goudriaan and van Laar, 1994	Goudriaan and van Laar, 1994	Goudriaan and van Laar, 1994
Onions & Shallots, Green	0.45	0.09	0.85	Goudriaan and van Laar, 1994	National Research Council, 2003	Goudriaan and van Laar, 1994
Oranges	0.3	0.13	0.5	Goudriaan and van Laar, 1994	National Research Council, 2003	Goudriaan and van Laar, 1994
Papayas	0.3	0.11	0.75	Goudriaan and van Laar, 1994	National Research Council, 2003	Goudriaan and van Laar, 1994
Peaches and Nectarines	0.3	0.14	0.75	Goudriaan and van Laar, 1994	National Research Council, 2003	Goudriaan and van Laar, 1994
Pears	0.3	0.16	0.75	Goudriaan and van Laar, 1994	National Research Council, 2003	Goudriaan and
Peas, Dry	0.45	0.89	0.85	Ayaz et al., 2004	National Research Council, 2003	Goudriaan and van Laar, 1994
Peas, Green	0.45	0.13	0.85	Goudriaan and van Laar, 1994	Goudriaan and van Laar, 1994	Goudriaan and van Laar, 1994
Pepper	0.28	0.8	0.5	Smil, 1999 (misc. crops)	Smil, 1999 (misc. crops)	Squire, 1990 (misc. perennial)
Peppermint	0.28	0.8	0.5	Smil, 1999 (misc. crops)	Smil, 1999 (misc. crops)	Squire, 1990 (misc. perennial)

Crop	Harvest index (HI)	Dry matter fraction	Above-ground fraction	Source of harvest index	Source of dry fraction	Source of above-ground fraction
Persimmons	0.3	0.36	0.75	Goudriaan and van Laar, 1994	National Research Council, 2003	Goudriaan and van Laar, 1994
Pigeon Peas	0.23	0.9	0.85	Hay, 1995	Goudriaan and van Laar, 1994	Goudriaan and van Laar, 1994
Pimento	0.28	0.8	0.8	Smil, 1999 (misc. crops)	Smil, 1999 (misc. crops)	Squire, 1990 (misc. annual)
Pineapples	0.3	0.14	0.75	Goudriaan and van Laar, 1994	National Research Council, 2003	Goudriaan and van Laar, 1994
Pistachios	0.28	0.8	0.75	Smil, 1999 (misc. crops)	Smil, 1999 (misc. crops)	Goudriaan and van Laar, 1994(fruit)
Plantains	0.3	0.2	0.75	Goudriaan and van Laar, 1994	see banana	Goudriaan and van Laar, 1994
Plums	0.3	0.15	0.75	Goudriaan and van Laar, 1994	National Research Council, 2003	Goudriaan and van Laar, 1994
Pop Corn	0.45	0.89	0.85	see maize	see maize	see maize
Poppy Seed	0.52	0.73	0.8	Smil, 1999 (oilcrops)	Smil, 1999 (oilcrops)	Squire, 1990 (misc. annual)
Potato	0.5	0.28	0.8	Hicke and Lobell, 2004	National Research Council, 2003	Hicke and Lobell, 2004
Pulses, other	0.49	0.9	0.85	Smil, 1999 (pulses)	Goudriaan and van Laar, 1994	Goudriaan and van Laar, 1994
Pumpkins, Squash, Gourds	0.45	0.2	0.85	Goudriaan and van Laar, 1994	National Research Council, 2003	Goudriaan and van Laar, 1994
Pyrethrum, Dried Flowers	0.28	0.8	0.5	Smil, 1999 (misc. crops)	Smil, 1999 (misc. crops)	Squire, 1990 (misc. perennial)
Quinces	0.3	0.16	0.75	Goudriaan and van Laar, 1994	National Research Council, 2003	Goudriaan and van Laar, 1994
Quinoa	0.4	0.88	0.8	Smil, 1999 (cereals)	Smil, 1999 (cereals)	Squire, 1990 (misc. annual)
Ramie	0.28	0.8	0.5	Smil, 1999 (misc. crops)	Smil, 1999 (misc. crops)	Squire, 1990 (misc. perennial)
Rapeseed	0.3	0.73	0.8	Hay, 1995	Smil, 1999 (oilcrops)	Squire, 1990 (misc. annual)
Raspberries	0.3	0.13	0.75	Goudriaan and van Laar, 1994	National Research Council, 2003	Goudriaan and van Laar, 1994
Rice	0.4	0.89	0.8	Hicke and Lobell, 2004	National Research Council, 2003	Hicke and Lobell, 2004
Roots and Tubers, other	0.4	0.2	0.8	Smil, 1999 (roots)	Smil, 1999 (roots)	Squire, 1990 (misc. annual)
Rye	0.35	0.88	0.76	Bradford et al., 2005	National Research Council, 2003	Bradford et al., 2005
Rye Grass for Forage and Silage	1	0.2	0.65	na	see alfalfa	Squire, 1990 (mean misc.annual/perennial)
Safflower Seed	0.52	0.91	0.8	Smil, 1999 (oilcrops)	National Research Council, 2003	Squire, 1990 (misc. annual)
Seed Cotton	0.55	0.92	0.86	Bradford et al., 2005	National Research Council, 2003	Bradford et al., 2005
Sesame Seed	0.52	0.92	0.8	Smil, 1999 (misc. crops)	National Research Council, 2003	Squire, 1990 (misc. annual)
Sisal	0.28	0.8	0.5	Smil, 1999 (misc. crops)	Smil, 1999 (misc. crops)	Squire, 1990 (misc. perennial)
Sorghum	0.4	0.89	0.8	Hicke and Lobell, 2004	National Research Council, 2003	Hicke and Lobell, 2004
Sorghum for Forage and Silage	1	0.35	0.85	na	see maize for silage	see maize for silage
Sour Cherries	0.3	0.14	0.75	Goudriaan and van Laar, 1994	National Research Council, 2003	Goudriaan and van Laar, 1994
Soybeans	0.42	0.91	0.85	Bradford et al., 2005	National Research Council, 2003	Bradford et al., 2005
Spices, other	0.28	0.8	0.5	Smil, 1999 (misc. crops)	Smil, 1999 (misc. crops)	Squire, 1990 (misc. perennial)
Spinach	0.45	0.08	0.85	Goudriaan and van Laar, 1994	National Research Council, 2003	Goudriaan and van Laar, 1994

Crop	Harvest index (HI)	Dry matter fraction	Above-ground fraction	Source of harvest index	Source of dry fraction	Source of above-ground fraction
Stone Fruit other, Fresh	0.3	0.19	0.75	Goudriaan and van Laar, 1994	Goudriaan and van Laar, 1994	Goudriaan and van Laar, 1994
Strawberries	0.3	0.08	0.75	Goudriaan and van Laar, 1994	National Research Council, 2003	Goudriaan and van Laar, 1994
String Beans	0.45	0.13	0.85	Goudriaan and van Laar, 1994	Goudriaan and van Laar, 1994	Goudriaan and van Laar, 1994
Sugar Beet	0.4	0.12	0.8	Hicke and Lobell, 2004	National Research Council, 2003	Hicke and Lobell, 2004
Sugar Cane	0.85	0.15	0.85	Larcher, 1995	National Research Council, 2003	Goudriaan and van Laar, 1994
Sugar Crops, other	0.28	0.56	0.85	Smil, 1999 (misc. crops)	Smil, 1999 (misc. crops)	Goudriaan and van Laar, 1994
Sunflower Seed	0.39	0.94	0.94	Bradford et al., 2005	National Research Council, 2003	Hicke and Lobell, 2004
Swedes for Fodder	1	0.13	0.85	na	National Research Council, 2003	Goudriaan and van Laar, 1994
Sweet Potatoes	0.5	0.25	0.8	Gruneberg et al., 2004	Gruneberg et al., 2004	Squire, 1990 (misc. annual)
Tangerines and Mandarins	0.3	0.19	0.75	Goudriaan and van Laar, 1994	Goudriaan and van Laar, 1994	Goudriaan and van Laar, 1994
Taro	0.4	0.2	0.8	Smil, 1999 (roots)	Smil, 1999 (roots)	Squire, 1990 (misc. annual)
Tea	0.28	0.8	0.5	Smil, 1999 (misc. crops)	Smil, 1999 (misc. crops)	Squire, 1990 (misc. perennial)
Tobacco Leaves	0.28	0.8	0.8	Smil, 1999 (misc. crops)	Smil, 1999 (misc. crops)	Squire, 1990 (misc. annual)
Tomatoes	0.45	0.06	0.85	Goudriaan and van Laar, 1994	National Research Council, 2003	Goudriaan and van Laar, 1994
Triticale	0.46	0.9	0.8	Hay, 1995	National Research Council, 2003	Squire, 1990 (misc. annual)
Tung Nuts	0.28	0.8	0.5	Smil, 1999 (oilcrops)	Smil, 1999 (oilcrops)	Squire, 1990 (misc. perennial)
Turnips for Fodder	1	0.13	0.85	na	National Research Council, 2003	Goudriaan and van Laar, 1994
Vanilla	0.28	0.8	0.5	Smil, 1999 (misc. crops)	Smil, 1999 (misc. crops)	Squire, 1990 (misc. perennial)
Vegetables Fresh, other	0.45	0.13	0.85	Goudriaan and van Laar, 1994	Goudriaan and van Laar, 1994	Goudriaan and van Laar, 1994
Vegetables & Roots for Fodder	1	0.13	0.85	na	National Research Council, 2003	Goudriaan and van Laar, 1994
Vetches	0.49	0.9	0.85	Smil, 1999 (pulses)	Goudriaan and van Laar, 1994	Goudriaan and van Laar, 1994
Walnuts	0.28	0.91	0.75	Smil, 1999 (misc. crops)	National Research Council, 2003	Goudriaan and van Laar, 1994 (fruit)
Watermelons	0.45	0.09	0.85	Goudriaan and van Laar, 1994	National Research Council, 2003	Goudriaan and van Laar, 1994
Wheat	0.39	0.89	0.81	Bradford et al., 2005	National Research Council, 2003	Bradford et al., 2005
Yams	0.4	0.3	0.8	Smil, 1999 (roots)	National Research Council, 2003	Squire, 1990 (misc. annual)
Yautia	0.4	0.2	0.8	Smil, 1999 (roots)	Smil, 1999 (roots)	Squire, 1990 (misc. annual)

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Appendix 3 Livestock types, amount and farms

This appendix provides the total amount of livestock for different types (number) in the Netherlands in the period 2005-2021. It is based on *Landbouw; gewassen, dieren, grondgebruik en arbeid op nationaal niveau* from CBS statistics (2022).

Livestock types	2005	2010	2015	2019	2020	2021
Cattle, total	3796780	3975190	4133850	3810250	3837990	3820580
Youngstock for dairy, total	1142020	1238960	1336870	923670	935120	966440
Youngstock for dairy, < 1 year, f	499940	545420	598800	409530	438800	451400
Youngstock for dairy, < 1 year, m	33780	28860	41160	43430	41090	40730
Youngstock for dairy, 1-2 year, f	515970	563970	581770	388290	373490	399470
Youngstock for dairy, 1-2 year, m	18150	13810	12690	8250	8160	9630
Youngstock for dairy, > 2 year, f	74180	86910	102450	74180	73590	65210
Veal, total	828740	927700	909230	1065500	1071280	1046510
Veal Rose < 1 year	204230	293900	357960	382380	383500	355430
Veal white < 1 year	624510	633800	551270	683120	687780	691070
Youngstock for beef, total	220500	197340	172080	166300	166490	167510
Youngstock for beef, < 1 year, f	43110	39230	32680	31170	32460	32020
Youngstock for beef, < 1 year, m	66450	48790	42520	47200	46190	41680
Youngstock for beef, 1-2 year, f	43200	43080	35150	27300	28450	32470
Youngstock for beef, 1-2 year, m	52630	46390	42100	36000	35680	37870
Youngstock for beef, > 2 year, f	15110	19850	19620	24640	23710	23470
Dairy cows	1433200	1478640	1621770	1577960	1593070	1571340
Other cattle, total	.	.	80440	62550	58310	55930
Beef	61130	37140	.	.	.	.
Suckler cows	89660	78200	.	.	.	.
Bulls, total	.	.	13470	14270	13730	12860
Bulls for breeding	12380	7760	.	.	.	.
Bulls for beef	9150	9460	.	.	.	.
Sheeps, total	1360510	1129500	946180	918210	890470	860150
Sheep (till 2018)|Lambs	684970	546210	395420	.	.	.
Sheeps (till 2018)|ewes	646990	558180	523100	.	.	.
Sheeps (till 2018)|Rams	28540	25110	27650	.	.	.
Sheeps (from 2018)|, 0-7 months	.	.	.	334610	340590	337760
Sheeps (from 2018)|milk, 7 mnd - 1 year	.	.	.	2060	1430	1040
Sheeps (from 2018)|milk, older than 1 year	.	.	.	14250	13610	14360
Sheeps (from 2018)|other, 7 mnd - 1 year	.	.	.	102640	78970	71630
Sheeps (from 2018)|other, older than 1 year	.	.	.	437420	431610	413250
Sheeps (from 2018)|Rams, >= 7 months	.	.	.	27240	24260	22110
Goats, total	291890	352830	469750	614650	632620	643360
Goats (till 2018)|Milk, total	172160	247980	327650	.	.	.
Goats (till 2018)|Milk, younger than 1 year	.	26010	35600	.	.	.
Goats (till 2018)|Milk, older than 1 year	.	221980	292050	.	.	.
Goats (till 2018)|Other, total	119730	104850	142100	.	.	.
Goats (till 2018)|Other, younger than 1 jaar	.	76400	109460	.	.	.
Goats (till 2018)|Other, older than 1 year	.	28450	32630	.	.	.
Goats (from 2018)|, 0-7 months	.	.	.	132750	132440	137430
Goats (from 2018)|milk, 7 mnd - 1 year	.	.	.	36910	35150	32330
Goats (from 2018)|milk, older than 1 year	.	.	.	419660	441070	450610
Goats (from 2018)|other, 7 mnd - 1 year	.	.	.	2070	1580	1420

Livestock types	2005	2010	2015	2019	2020	2021
Goats (from 2018)|other, older than 1 year	.	.	.	13490	12230	11100
Goats (from 2018)|Rams, >= 7 months	.	.	.	9780	10160	10480
Horses and ponies, total	132550	142530	118390	87570	90390	97600
horses, total	87570	93700	81970	62690	64500	69070
horses, younger than 3 years	29320	28400	20960	19020	18800	19530
horses, older than 3 years	58250	65300	61010	43670	45700	49540
ponies, total	44990	48830	36420	24880	25890	28530
ponies, younger than 3 years	11160	11550	6950	4310	4730	5380
ponies, older than 3 years	33820	37280	29470	20570	21160	23160
pigs, total	11311560	12254970	12602890	12269150	11950240	11456830
piglets, total	4562990	5123810	5597810	5548880	5413680	5169370
piglets, max 20 kg at sow	1825750	1999470	2262350	2174920	2117970	1977970
piglets, max 20 kg not at sow	2737240	3124340	3335460	3373960	3295710	3191400
Breeding pigs, total	1244270	1226990	1201390	1102740	1090610	1025770
breeding, 20-50kg	103740	122140	90480	84900	82950	80770
breeding sows, >50 kg, not preg	170340	110120	132900	121860	129890	127340
breeding sows, >50 kg preg	722670	755940	734420	673280	662190	614900
sows with piglets	179900	177250	188460	173110	168750	155380
Sows, > 50 kg, gust	43900	50360	47150	42830	39930	41930
Boar, > 50 kg, not adult	6490	3950	2170	1730	1220	1150
Boar, > 50 kg, adult	17240	7230	5820	5050	5690	4290
fattening pigs, total	5504300	5904170	5803700	5617530	5445950	5261680
fattening pigs, 20-50 kg	2179560	1839970	1777100	1725320	1663090	1574670
fattening pigs, > 50 kg	3324730	4064200	4026600	3892210	3782850	3687010
fattening pigs, 50-80 kg	.	2023180	1896430	1739740	1678670	1613270
fattening pigs, 80-110 kg	.	1737550	1735260	1671730	1592330	1535410
fattening pigs, >110 kg	.	303470	394910	480740	511860	538340
Chickens, total	92914200	101247700	106762900	101741200	101863100	99887500
laying hens, total	41047700	47904100	47684400	44319400	43166000	43160200
laying hens, breeding	10534900	12594400	12083200	10916100	11166800	10108600
laying hens, breeding < 20 months	28220300	33406100	33117600	29988800	28505900	30090900
laying hens, breeding > 20 months	2292500	1903600	2483600	3414500	3493200	2960700
parents laying hens, total	1582000	1252300	1452800	1574300	1674300	1795700
parents laying hens, breeding	252400	414100	334000	382000	384800	484500
parents laying hens, laying	1329600	838200	1118700	1192300	1289500	1311200
Broilers	44496100	44747900	49107200	48684300	49228500	47056100
parents broilers, total	5788400	7343500	8518600	7163100	7794300	7875400
parents broilers, breeding	2191700	2896000	3393000	2543600	2831000	2992700
parents broilers, laying	3596700	4447500	5125600	4619600	4963300	4882700
Turkeys	1245400	1036300	863000	531600	585100	604100
Ducks	1030900	1087000	932200	968000	819200	632300
other poultry	274600	250300	49700	201900	33300	32000
Rabbits, total	360500	298800	381100	336300	335000	321300
Rabbits, meat	312400	260300	333000	288500	296700	282900
rabbits, f parent	48000	38500	48200	47900	38300	38400
fur animals	703700	963800	1023000	807500	707200	

Source: https://opendata.cbs.nl/statline/#/CBS/nl/dataset/81302ned/table?fromstatweb. Centraal Bureau voor de Statistiek, Den Haag/Heerlen/Bonaire, 2022.

The following table provides the total amount of livestock farms (number) for different type of livestock (CBS, 2022).

Livestock farms	2005	2010	2015	2019	2020	2021
Cattle, total	37300	32830	28840	24610	24020	23530
younstock for dairy	26510	22880	20760	17950	17370	16910
Veal	3330	2060	1910	1680	1670	1620
Younstoch for beef	10490	8900	7030	5730	5890	5990
Dairy cows	23530	19810	18270	16260	15730	15250
Other cattle, total	.	.	7900	4440	4340	4280
Bulls, older than 2	.	.	5740	5470	5290	5000
Sheeps, total	14360	12870	11380	8370	8280	8250
Sheep (till 2018)|ewes	13700	12770	11260	.	.	.
Sheeps (till 2018)|lambs	11900	9980	6910	.	.	.
Sheeps (till 2018)|Rams	7260	5970	4860	.	.	.
Sheeps (from 2018)|, 0-7 months	.	.	.	5480	5550	5520
Sheeps (from 2018)|milk, 7 months - 1 year	.	.	.	100	80	80
Sheeps (from 2018)|milk, older than 1 year	.	.	.	160	140	140
Sheeps (from 2018)|other, 7 months - 1 year	.	.	.	4800	4420	4250
Sheeps (from 2018)|other, older than 1 year	.	.	.	.	.	.
Sheeps (from 2018)|Rams, >= 7 months	.	.	.	5640	5520	5440
Goats, total	4550	3720	3190	3040	3050	3190
Goats (till 2018)|Milk, total	730	580	550	.	.	.
Goats (till 2018)|Milk, younger than 1 year	.	220	180	.	.	.
Goats (till 2018)|Milk, older than 1 year	.	550	510	.	.	.
Goats (till 2018)|Other, total	4320	3570	3030	.	.	.
Goats (till 2018)|Other, younger than 1 year	.	1200	870	.	.	.
Goats (till 2018)|Other, older than 1 year	.	3430	2900	.	.	.
Goats (from 2018)|, 0-7 months	.	.	.	880	890	960
Goats (from 2018)|milk, 7 months - 1 year	.	.	.	410	390	410
Goats (from 2018)|milk, older than 1 year	.	.	.	570	560	620
Goats (from 2018)|other, 7 months - 1 year	.	.	.	600	590	570
Goats (from 2018)|other, older than 1 year	.	.	.	2330	2380	2450
Goats (from 2018)|Rams, >= 7 months	.	.	.	570	580	570
Horses and ponies, total	17680	14610	11040	7680	7890	8600
horses, total	12210	10710	8480	5970	6160	6610
horses, younger than 3 years	6700	5430	3300	2400	2430	2630
horses, older than 3 years	11580	9990	8100	5700	5910	6350
ponies, total	10810	9190	6770	4670	4890	5470
ponies, younger than 3 years	4030	3240	1790	930	990	1130
ponies, older than 3 years	9920	8200	6090	4430	4620	5190
pigs, total	9690	7030	4930	4090	3560	3410
piglets, total	3880	2850	2090	1710	1590	1450
piglets, max 20 kg at sow	3770	2700	1880	1510	1420	1280
piglets, max 20 kg not at sow	3780	2790	2020	1650	1530	1390
Breeding pigs, total	4040	2950	2100	1740	1630	1510
breeding, 20-50 kg	1310	1110	840	740	710	710
breeding sows, >50 kg, not preg	3160	1760	1390	1170	1160	1050
breeding sows, >50 kg preg	3790	2740	1930	1570	1460	1340
sows with piglets	3770	2700	1880	1510	1420	1280
Sows, > 50 kg, gust	3060	2180	1610	1320	1250	1150
Boar, > 50 kg, not adult	340	290	250	250	220	210
Boar, > 50 kg, adult	3480	2370	1670	1300	1240	1110
fattening pigs, total	8600	5950	4030	3370	2880	2770
fattening pigs, 20-50 kg	6920	4340	2940	2520	2280	2120
fattening pigs, > 50 kg	7350	5450	3650	3080	2660	2540
fattening pigs, 50-80 kg	.	4630	3030	2590	2290	2140
fattening pigs, 80-110 kg	.	4280	2960	2530	2240	2140
fattening pigs, >110 kg	.	1640	1490	1540	1540	1470

Livestock farms	2005	2010	2015	2019	2020	2021
Chickens, total	2840	2430	2050	1770	1770	1720
laying hens, total	1730	1440	1120	870	860	830
laying hens, breeding	300	220	200	140	140	130
laying hens, breeding < 20 months	1330	1120	870	730	700	700
laying hens, breeding > 20 months	270	180	140	80	90	70
parents laying hens, total	100	90	80	50	50	60
parents laying hens, breeding	20	20	10	10	10	10
parents laying hens, laying	80	70	70	40	40	50
Broilers	760	640	600	640	640	620
parents broilers, total	290	300	280	230	250	240
parents broilers, breeding	90	90	90	60	70	70
parents broilers, laying	220	220	200	180	190	180
Turkeys	90	60	40	30	30	30
Ducks	90	80	50	50	50	40
Other poultry	80	40	20	20	10	10
Rabbits, total	150	90	70	40	40	30
Rabbits, meat	130	70	60	40	40	30
Rabbits, f parent	110	70	50	30	30	30
Fur animals	180	160	150	130	110	

Appendix 4 Age Classes present in the Databases

This appendix provides age classes present in the Databases/Fisheries and potential derivative measures (if conversion factors are available).

Age	Age class description
BMS	Below Minimum Size (Wild Caught only
AMS	Above Minimum Size (Wild Caught Only)
AQI	Aquaculture Live Inputs (Wild Caught Farm Inputs)
AQA	Aquaculture Production Adult (by Definition Fresh)
AQJ	Aquaculture Production of Juveniles (by hatcheries and nurseries)
AQE	Aquaculture Production of Eggs (either for human consumption or as a result of hatcheries and nurseries)

Appendix 5 Overview of all fish species in the databases on fish landings

This appendix provides an overview of all fish species contained in the databases on fish landings by vessel registered under the Dutch nationality or landed by other vessels in the Netherlands from Eurostat. Data was obtained by matching the ASFIS 3A codes in the considered Eurostat databases with the supplementary contained in the 2021 version of the ASFIS list of species for fishery statistics purposes.

ASFIS 3A CODE	ISSCAAP CODE	TAXOCODE	Scientific name	English name	Family	Order	EUROSTAT ISSCAAP CODE
ABK	11	1400233301	Blicca bjoerkna	White bream	Cyprinidae	CYPRINIFORMES	F11
ABV	33	1920101901	Alabes parvulus	Pygmy shore-eel	Gobiesocidae	GOBIESOCIFORMES	F33
ABZ	33	1720400205	Ammodytes tobianus	Small sandeel	Ammodytidae	TRACHINOIDEI	F33
AES	45	2280400205	Pandalus montagui	Aesop shrimp	Pandalidae	NATANTIA	F45
ALA	37	1702309003	Alectis alexandrina	Alexandria pompano	Carangidae	PERCOIDEI	F37
ALB	36	1750102605	Thunnus alalunga	Albacore	Scombridae	SCOMBROIDEI	F36
ALF	34	16102003XX	Beryx spp	Alfonsinos nei	Berycidae	BERYCIFORMES	F34
ANE	35	1210600201	Engraulis encrasicolus	European anchovy	Engraulidae	CLUPEIFORMES	F35
ANF	34	19501XXXXX	Lophiidae	Anglerfishes nei	Lophiidae	LOPHIIFORMES	F34
ARG	34	12305015XX	Argentina spp	Argentines	Argentinidae	SALMONIFORMES	F34
ARU	34	1230501503	Argentina silus	Greater argentine	Argentinidae	SALMONIFORMES	F34
ARY	34	1230501504	Argentina sphyraena	Argentine	Argentinidae	SALMONIFORMES	F34
ASD	24	1210501104	Alosa alosa	Allis shad	Clupeidae	CLUPEIFORMES	F24
ASU	11	1400211501	Aspius aspius	Asp	Cyprinidae	CYPRINIFORMES	F11
BEP	36	1750100104	Sarda chiliensis	Eastern Pacific bonito	Scombridae	SCOMBROIDEI	F36
BFT	36	1750102601	Thunnus thynnus	Atlantic bluefin tuna	Scombridae	SCOMBROIDEI	F36
BGR	33	1703620918	Pomadasys incisus	Bastard grunt	Haemulidae	PERCOIDEI	F33
BHG	34	1320802401	Benthosema glaciale	Glacier lantern fish	Myctophidae	MYCTOPHIFORMES	F34
BIB	32	1480403203	Trisopterus luscus	Pouting(=Bib)	Gadidae	GADIFORMES	F32
BIL	36	17503XXXXX	Istiophoridae	Marlins.sailfishes.etc. nei	Istiophoridae	SCOMBROIDEI	F36
BLI	32	1480400502	Molva dypterygia	Blue ling	Gadidae	GADIFORMES	F32
BLL	31	1830506401	Scophthalmus rhombus	Brill	Scophthalmidae	PLEURONECTIFORMES	F31
BLU	37	1702021301	Pomatomus saltatrix	Bluefish	Pomatomidae	PERCOIDEI	F37

ASFIS 3A CODE	ISSCAAP CODE	TAXOCODE	Scientific name	English name	Family	Order	EUROSTAT ISSCAAP CODE
BOC	34	1620300201	Capros aper	Boarfish	Caproidae	ZEIFORMES	F34
BOG	33	1703926101	Boops boops	Bogue	Sparidae	PERCOIDEI	F33
BOL	34	1711503101	Bothrocara alalongum		Zoarcidae	ZOARCOIDEI	F34
BON	36	1750100101	Sarda sarda	Atlantic bonito	Scombridae	SCOMBROIDEI	F36
BOR	34	16203XXXXX	Caproidae	Boarfishes nei	Caproidae	ZEIFORMES	F34
BPQ	37	1702700303	Brama japonica	Pacific pomfret	Bramidae	PERCOIDEI	F37
BRB	33	1703906302	Spondyliosoma cantharus	Black seabream	Sparidae	PERCOIDEI	F33
BRF	34	1780101703	Helicolenus dactylopterus	Blackbelly rosefish	Scorpaenidae	SCORPAENIFORMES	F34
BRU	37	1702700302	Brama australis	Southern rays bream	Bramidae	PERCOIDEI	F37
BSB	33	1700208102	Centropristis striata	Black seabass	Serranidae	PERCOIDEI	F33
BSE	33	17006345XX	Dicentrarchus spp	Seabasses nei	Moronidae	PERCOIDEI	F33
BSF	34	1750601201	Aphanopus carbo	Black scabbardfish	Trichiuridae	SCOMBROIDEI	F34
BSH	38	1080200401	Prionace glauca	Blue shark	Carcharhinidae	CARCHARHINIFORMES	F38
BSS	33	1700634503	Dicentrarchus labrax	European seabass	Moronidae	PERCOIDEI	F33
BUA	37	1702326801	Chloroscombrus chrysurus	Atlantic bumper	Carangidae	PERCOIDEI	F37
CAA	34	1710200101	Anarhichas lupus	Atlantic wolffish	Anarhichadidae	ZOARCOIDEI	F34
CAP	37	1230400201	Mallotus villosus	Capelin	Osmeridae	SALMONIFORMES	F37
CAS	34	1710200103	Anarhichas minor	Spotted wolffish	Anarhichadidae	ZOARCOIDEI	F34
CAT	34	17102001XX	Anarhichas spp	Wolffishes(=Catfishes) nei	Anarhichadidae	ZOARCOIDEI	F34
CAX	33	14102XXXXX	Ariidae	Sea catfishes nei	Ariidae	SILURIFORMES	F33
CCT	38	1060200501	Carcharias taurus	Sand tiger shark	Odontaspididae	LAMNIFORMES	F38
CDX	33	17037XXXXX	Sciaenidae	Croakers. drums nei	Sciaenidae	PERCOIDEI	F33
CDZ	32	14804002XX	Gadus spp	Northern cods nei	Gadidae	GADIFORMES	F32
CEC	33	1290100304	Elops lacerta	West African ladyfish	Elopidae	ELOPIFORMES	F33
CEP	57	321XXXXXXX	Cephalopoda	Cephalopods nei		CEPHALOPODA	F57
CGX	37	17023XXXXX	Carangidae	Carangids nei	Carangidae	PERCOIDEI	F37
CJM	37	1702300405	Trachurus murphyi	Chilean jack mackerel	Carangidae	PERCOIDEI	F37
CLB	56	3161202001	Spisula solidissima	Atlantic surf clam	Mactridae	BIVALVIA	F56
CLU	35	121XXXXXXX020	Clupeoidei	Clupeoids nei		CLUPEIFORMES	F35
CLX	56	316XXXXXXX	Bivalvia	Clams. etc. nei		BIVALVIA	F56
CLZ	13	1411803003	Clarias gariepinus	North African catfish	Clariidae	SILURIFORMES	F13
CNZ	45	22823003XX	Crangon spp	Crangon shrimps nei	Crangonidae	NATANTIA	F45
COA	34	1431300104	Conger oceanicus	American conger	Congridae	ANGUILLIFORMES	F34
COC	56	3162300203	Cerastoderma edule	Common edible cockle	Cardiidae	BIVALVIA	F56

ASFIS 3A CODE	ISSCAAP CODE	TAXOCODE	Scientific name	English name	Family	Order	EUROSTAT ISSCAAP CODE
COD	32	1480400202	Gadus morhua	Atlantic cod	Gadidae	GADIFORMES	F32
COE	34	1431300101	Conger conger	European conger	Congridae	ANGUILLIFORMES	F34
COX	34	14313XXXXX	Congridae	Conger eels. etc. nei	Congridae	ANGUILLIFORMES	F34
CRA	42	231XXXXXXX	Brachyura	Marine crabs nei		BRACHYURA	F42
CRE	42	2310901006	Cancer pagurus	Edible crab	Cancridae	BRACHYURA	F42
CRG	42	2311109001	Carcinus maenas	Green crab	Portunidae	BRACHYURA	F42
CRR	42	2314300112	Chaceon quinquedens	Red crab	Geryonidae	BRACHYURA	F42
CRU	47	299XXXXXXX013	Crustacea	Marine crustaceans nei		CRUSTACEA MISCELLANEA	F47
CSH	45	2282300303	Crangon crangon	Common shrimp	Crangonidae	NATANTIA	F45
CSQ	38	1080101404	Apristurus canutus	Hoary catshark	Scyliorhinidae	CARCHARHINIFORMES	F38
CTC	57	3210200202	Sepia officinalis	Common cuttlefish	Sepiidae	CEPHALOPODA	F57
CTL	57	32102XXXXX026	Sepiidae. Sepiolidae	Cuttlefish. bobtail squids nei		CEPHALOPODA	F57
CTZ	34	1780200304	Chelidonichthys lastoviza	Streaked gurnard	Triglidae	SCORPAENIFORMES	F34
CUT	34	17506XXXXX	Trichiuridae	Hairtails. scabbardfishes nei	Trichiuridae	SCOMBROIDEI	F34
CVJ	37	1702304429	Caranx hippos	Crevalle jack	Carangidae	PERCOIDEI	F37
CYO	38	1090101601	Centroscymnus coelolepis	Portuguese dogfish	Squalidae	SQUALIFORMES	F38
DAB	31	1830202405	Limanda limanda	Common dab	Pleuronectidae	PLEURONECTIFORMES	F31
DEA	33	1703906010	Dentex angolensis	Angolan dentex	Sparidae	PERCOIDEI	F33
DEC	33	1703906006	Dentex dentex	Common dentex	Sparidae	PERCOIDEI	F33
DEL	33	1703906002	Dentex macrophthalmus	Large-eye dentex	Sparidae	PERCOIDEI	F33
DEX	33	17039060XX	Dentex spp	Dentex nei	Sparidae	PERCOIDEI	F33
DGH	38	10901XXXXX040	Squalidae. Scyliorhinidae	Dogfishes and hounds nei		SQUALIFORMES	F38
DGS	38	1090100704	Squalus acanthias	Picked dogfish	Squalidae	SQUALIFORMES	F38
DGX	38	10901XXXXX	Squalidae	Dogfish sharks nei	Squalidae	SQUALIFORMES	F38
DGZ	38	10901007XX	Squalus spp	Dogfishes nei	Squalidae	SQUALIFORMES	F38
DIG	33	1703903301	Diplodus argenteus	South American silver porgy	Sparidae	PERCOIDEI	F33
DOL	37	1702807101	Coryphaena hippurus	Common dolphinfish	Coryphaenidae	PERCOIDEI	F37
DPX	34	199XXXXXXX012	Perciformes	Demersal percomorphs nei		PISCES MISCELLANEA	F34
DPY	34	1320801802	Diaphus brachycephalus	Short-headed lantern fish	Myctophidae	MYCTOPHIFORMES	F34
DUS	38	1080201016	Carcharhinus obscurus	Dusky shark	Carcharhinidae	CARCHARHINIFORMES	F38
EDR	34	1705700701	Pseudopentaceros richardsoni	Pelagic armourhead	Pentacerotidae	PERCOIDEI	F34
ELE	22	1430200201	Anguilla anguilla	European eel	Anguillidae	ANGUILLIFORMES	F22
ELP	33	1711500401	Zoarces viviparus	Eelpout	Zoarcidae	ZOARCOIDEI	F33
EOI	57	3210902401	Eledone cirrhosa	Horned octopus	Octopodidae	CEPHALOPODA	F57

ASFIS 3A CODE	ISSCAAP CODE	TAXOCODE	Scientific name	English name	Family	Order	EUROSTAT ISSCAAP CODE
EQE	56	3161600503	Ensis ensis	Pod razor shell	Solenidae	BIVALVIA	F56
ERS	41	2311302803	Eriocheir sinensis	Chinese mitten crab	Grapsidae	BRACHYURA	F41
FBM	11	1400200102	Abramis brama	Freshwater bream	Cyprinidae	CYPRINIFORMES	F11
FCG	11	1400203501	Ctenopharyngodon idellus	Grass carp(=White amur)	Cyprinidae	CYPRINIFORMES	F11
FCP	11	1400200201	Cyprinus carpio	Common carp	Cyprinidae	CYPRINIFORMES	F11
FID	11	1400202001	Leuciscus idus	Orfe(=Ide)	Cyprinidae	CYPRINIFORMES	F11
FIN	39	199XXXXXXX009	Actinopterygii	Finfishes nei		PISCES MISCELLANEA	F39
FLE	31	1830204802	Platichthys flesus	European flounder	Pleuronectidae	PLEURONECTIFORMES	F31
FPE	13	1701400201	Perca fluviatilis	European perch	Percidae	PERCOIDEI	F13
FPI	13	1240300101	Esox lucius	Northern pike	Esocidae	ESOCIFORMES	F13
FPP	13	1701436103	Sander lucioperca	Pike-perch	Percidae	PERCOIDEI	F13
FRF	13	199XXXXXXX001	Actinopterygii	Freshwater fishes nei		PISCES MISCELLANEA	F13
FRI	36	1750102301	Auxis thazard	Frigate tuna	Scombridae	SCOMBROIDEI	F36
FRO	11	1400201801	Rutilus rutilus	Roach	Cyprinidae	CYPRINIFORMES	F11
FRZ	36	17501023XX018	Auxis thazard. A. rochei	Frigate and bullet tunas	Scombridae	SCOMBROIDEI	F36
GAG	38	1080401103	Galeorhinus galeus	Tope shark	Triakidae	CARCHARHINIFORMES	F38
GAR	37	1470100101	Belone belone	Garfish	Belonidae	BELONIFORMES	F37
GBR	33	1703620705	Plectorhinchus mediterraneus	Rubberlip grunt	Haemulidae	PERCOIDEI	F33
GDG	32	1480402507	Gadiculus argenteus	Silvery pout	Gadidae	GADIFORMES	F32
GFB	32	1480400601	Phycis blennoides	Greater forkbeard	Gadidae	GADIFORMES	F32
GHL	31	1830200501	Reinhardtius hippoglossoides	Greenland halibut	Pleuronectidae	PLEURONECTIFORMES	F31
GRB	33	1703626303	Brachydeuterus auritus	Bigeye grunt	Haemulidae	PERCOIDEI	F33
GRO	39	199XXXXXXX007	Actinopterygii	Groundfishes nei		PISCES MISCELLANEA	F39
GRX	33	17036XXXXX	Haemulidae (=Pomadasyidae)	Grunts. sweetlips nei	Haemulidae	PERCOIDEI	F33
GUG	34	1780207001	Eutrigla gurnardus	Grey gurnard	Triglidae	SCORPAENIFORMES	F34
GUP	38	1090100801	Centrophorus granulosus	Gulper shark	Squalidae	SQUALIFORMES	F38
GUR	34	1780200303	Chelidonycthys cuculus	Red gurnard	Triglidae	SCORPAENIFORMES	F34
GUU	34	1780200302	Chelidonichthys lucerna	Tub gurnard	Triglidae	SCORPAENIFORMES	F34
GUX	34	17802XXXXX	Triglidae	Gurnards. searobins nei	Triglidae	SCORPAENIFORMES	F34
GUY	34	17802002XX	Trigla spp	Gurnards nei	Triglidae	SCORPAENIFORMES	F34
HAD	32	1480401001	Melanogrammus aeglefinus	Haddock	Gadidae	GADIFORMES	F32
HAL	31	1830200201	Hippoglossus hippoglossus	Atlantic halibut	Pleuronectidae	PLEURONECTIFORMES	F31
HER	35	1210500105	Clupea harengus	Atlantic herring	Clupeidae	CLUPEIFORMES	F35
HKE	32	1480500401	Merluccius merluccius	European hake	Merlucciidae	GADIFORMES	F32

ASFIS 3A CODE	ISSCAAP CODE	TAXOCODE	Scientific name	English name	Family	Order	EUROSTAT ISSCAAP CODE
HKW	32	1480400803	Urophycis tenuis	White hake	Gadidae	GADIFORMES	F32
HMM	37	1702300408	Trachurus mediterraneus	Mediterranean horse mackerel	Carangidae	PERCOIDEI	F37
HMY	37	1702304442	Caranx rhonchus	False scad	Carangidae	PERCOIDEI	F37
HOM	37	1702300401	Trachurus trachurus	Atlantic horse mackerel	Carangidae	PERCOIDEI	F37
ILL	57	32105010XX	Illex spp	Shortfin squids nei	Ommastrephidae	CEPHALOPODA	F57
INV	77	699XXXXXXX	Invertebrata	Aquatic invertebrates nei		INVERTEBRATA AQUATICA MISCELL.	F77
JAX	37	17023004XX	Trachurus spp	Jack and horse mackerels nei	Carangidae	PERCOIDEI	F37
JDP	38	1100500326	Dasyatis pastinaca	Common stingray	Dasyatidae	RAJIFORMES	F38
JOD	34	1620100101	Zeus faber	John dory	Zeidae	ZEIFORMES	F34
KCX	44	23020XXXXX	Lithodidae	King crabs. stone crabs nei	Lithodidae	ANOMURA	F44
KLK	56	3161100601	Callista chione	Smooth callista	Veneridae	BIVALVIA	F56
KTT	56	3162300105	Acanthocardia tuberculata	Tuberculate cockle	Cardiidae	BIVALVIA	F56
LBE	43	2294200718	Homarus gammarus	European lobster	Nephropidae	REPTANTIA	F43
LEE	37	1702307202	Lichia amia	Leerfish	Carangidae	PERCOIDEI	F37
LEF	31	18301XXXXX	Bothidae	Lefteye flounders nei	Bothidae	PLEURONECTIFORMES	F31
LEM	31	1830204504	Microstomus kitt	Lemon sole	Pleuronectidae	PLEURONECTIFORMES	F31
LEZ	31	18305003XX	Lepidorhombus spp	Megrims nei	Scophthalmidae	PLEURONECTIFORMES	F31
LHT	34	1750600302	Trichiurus lepturus	Largehead hairtail	Trichiuridae	SCOMBROIDEI	F34
LIN	32	1480400501	Molva molva	Ling	Gadidae	GADIFORMES	F32
LIO	42	2311119501	Necora puber	Velvet swimcrab	Portunidae	BRACHYURA	F42
LNG	33	1700214501	Planctanthias longifilis		Serranidae	PERCOIDEI	F33
LNZ	32	14804005XX	Molva spp	Lings nei	Gadidae	GADIFORMES	F32
LTA	36	1750102401	Euthynnus alletteratus	Little tunny(=Atl.black skipj)	Scombridae	SCOMBROIDEI	F36
LUM	34	1782000301	Cyclopterus lumpus	Lumpfish(=Lumpsucker)	Cyclopteridae	SCORPAENIFORMES	F34
LUS	11	1400202011	Leuciscus souffia	Vairone	Cyprinidae	CYPRINIFORMES	F11
LYY	33	1772000301	Callionymus lyra	Dragonet	Callionymidae	OTHER PERCIFORMES	F33
MAA	37	1750100207	Scomber australasicus	Blue mackerel	Scombridae	SCOMBROIDEI	F37
MAC	37	1750100205	Scomber scombrus	Atlantic mackerel	Scombridae	SCOMBROIDEI	F37
MAX	37	17501XXXXX	Scombridae	Mackerels nei	Scombridae	SCOMBROIDEI	F37
MAZ	37	17501002XX	Scomber spp	Scomber mackerels nei	Scombridae	SCOMBROIDEI	F37
MCD	34	1320800301	Ceratoscopelus maderensis	Madeira lantern fish	Myctophidae	MYCTOPHIFORMES	F34
MEG	31	1830500301	Lepidorhombus whiffiagonis	Megrim	Scophthalmidae	PLEURONECTIFORMES	F31
MGC	33	1650101202	Liza ramada	Thinlip grey mullet	Mugilidae	MUGILIFORMES	F33
MGI	33	1650100122	Mugil incilis	Parassi mullet	Mugilidae	MUGILIFORMES	F33

ASFIS 3A CODE	ISSCAAP CODE	TAXOCODE	Scientific name	English name	Family	Order	EUROSTAT ISSCAAP CODE
MGS	33	16501001XX	Mugil spp		Mugilidae	MUGILIFORMES	F33
MGU	33	1650100121	Mugil curema	White mullet	Mugilidae	MUGILIFORMES	F33
MLR	33	1650100202	Chelon labrosus	Thicklip grey mullet	Mugilidae	MUGILIFORMES	F33
MNZ	34	19501001XX	Lophius spp	Monkfishes nei	Lophiidae	LOPHIIFORMES	F34
MOL	58	399XXXXXXX016	Mollusca	Marine molluscs nei		MOLLUSCA MISCELLANEA	F58
MON	34	1950100101	Lophius piscatorius	Angler(=Monk)	Lophiidae	LOPHIIFORMES	F34
MOP	37	19008002XX	Mola spp	Sunfish	Molidae	TETRAODONTIFORMES	F37
MOX	37	1900800201	Mola mola	Ocean sunfish	Molidae	TETRAODONTIFORMES	F37
MUF	33	1650100102	Mugil cephalus	Flathead grey mullet	Mugilidae	MUGILIFORMES	F33
MUI	33	14306XXXXX	Muraenidae	Morays nei	Muraenidae	ANGUILLIFORMES	F33
MUL	33	16501XXXXX	Mugilidae	Mullets nei	Mugilidae	MUGILIFORMES	F33
MUR	33	1704100701	Mullus surmuletus	Surmullet	Mullidae	PERCOIDEI	F33
MUS	54	3161000105	Mytilus edulis	Blue mussel	Mytilidae	BIVALVIA	F54
MUT	33	1704100702	Mullus barbatus	Red mullet	Mullidae	PERCOIDEI	F33
MUX	33	17041007XX	Mullus spp	Surmullets(=Red mullets) nei	Mullidae	PERCOIDEI	F33
MZZ	39	199XXXXXXX010	Actinopterygii	Marine fishes nei		PISCES MISCELLANEA	F39
NEP	43	2294200602	Nephrops norvegicus	Norway lobster	Nephropidae	REPTANTIA	F43
NHA	32	1480500407	Merluccius productus	North Pacific hake	Merlucciidae	GADIFORMES	F32
NOP	32	1480403201	Trisopterus esmarkii	Norway pout	Gadidae	GADIFORMES	F32
OCC	57	3210900507	Octopus vulgaris	Common octopus	Octopodidae	CEPHALOPODA	F57
OCT	57	32109XXXXX	Octopodidae	Octopuses. etc. nei	Octopodidae	CEPHALOPODA	F57
OCZ	57	32109005XX	Octopus spp	Octopuses nei	Octopodidae	CEPHALOPODA	F57
ODL	33	1650104201	Oedalechilus labeo	Boxlip mullet	Mugilidae	MUGILIFORMES	F33
OMZ	57	32105XXXXX	Ommastrephidae	Ommastrephidae squids nei	Ommastrephidae	CEPHALOPODA	F57
OPP	34	1780100109	Sebastes alutus	Pacific ocean perch	Scorpaenidae	SCORPAENIFORMES	F34
OYC	53	31607008XX	Crassostrea spp	Cupped oysters nei	Ostreidae	BIVALVIA	F53
OYF	53	3160700205	Ostrea edulis	European flat oyster	Ostreidae	BIVALVIA	F53
OYG	53	3160701201	Magallana gigas	Pacific cupped oyster	Ostreidae	BIVALVIA	F53
PAC	33	1703900802	Pagellus erythrinus	Common pandora	Sparidae	PERCOIDEI	F33
PDZ	45	22804XXXXX	Pandalidae	Pandalid shrimps nei	Pandalidae	NATANTIA	F45
PEE	52	3070100101	Littorina littorea	Common periwinkle	Littorinidae	GASTROPODA	F52
PEL	39	199XXXXXXX008	Actinopterygii	Pelagic fishes nei		PISCES MISCELLANEA	F39
PEN	45	22801001XX	Penaeus spp	Penaeus shrimps nei	Penaeidae	NATANTIA	F45
PER	52	30701001XX	Littorina spp	Periwinkles nei	Littorinidae	GASTROPODA	F52

ASFIS 3A CODE	ISSCAAP CODE	TAXOCODE	Scientific name	English name	Family	Order	EUROSTAT ISSCAAP CODE
PEW	25	1700600603	Morone americana	White perch	Moronidae	PERCOIDEI	F25
PIL	35	1210506401	Sardina pilchardus	European pilchard(=Sardine)	Clupeidae	CLUPEIFORMES	F35
PLA	31	1830201401	Hippoglossoides platessoides	Amer. plaice(=Long rough dab)	Pleuronectidae	PLEURONECTIFORMES	F31
PLE	31	1830200405	Pleuronectes platessa	European plaice	Pleuronectidae	PLEURONECTIFORMES	F31
POA	37	1702700301	Brama brama	Atlantic pomfret	Bramidae	PERCOIDEI	F37
POC	32	1480401901	Boreogadus saida	Polar cod	Gadidae	GADIFORMES	F32
POK	32	1480401501	Pollachius virens	Saithe(=Pollock)	Gadidae	GADIFORMES	F32
POL	32	1480401502	Pollachius pollachius	Pollack	Gadidae	GADIFORMES	F32
POP	37	1702304706	Trachinotus ovatus	Pompano	Carangidae	PERCOIDEI	F37
POR	38	1060800301	Lamna nasus	Porbeagle	Lamnidae	LAMNIFORMES	F38
POX	37	17023047XX	Trachinotus spp	Pompanos nei	Carangidae	PERCOIDEI	F37
PRA	45	2280400203	Pandalus borealis	Northern prawn	Pandalidae	NATANTIA	F45
PRC	33	170XXXXXXX	Percoidei	Percoids nei		PERCOIDEI	F33
QSC	55	3160800105	Aequipecten opercularis	Queen scallop	Pectinidae	BIVALVIA	F55
RAJ	38	11004XXXXX	Rajidae	Rays and skates nei	Rajidae	RAJIFORMES	F38
RAZ	56	31616003XX	Solen spp	Solen razor clams nei	Solenidae	BIVALVIA	F56
RDR	38	1100500305	Dasyatis brevicaudata	Short-tail stingray	Dasyatidae	RAJIFORMES	F38
REB	34	1780100112	Sebastes mentella	Beaked redfish	Scorpaenidae	SCORPAENIFORMES	F34
RED	34	17801001XX	Sebastes spp	Atlantic redfishes nei	Scorpaenidae	SCORPAENIFORMES	F34
REG	34	1780100101	Sebastes norvegicus	Golden redfish	Scorpaenidae	SCORPAENIFORMES	F34
RJA	38	1100404301	Rostroraja alba	White skate	Rajidae	RAJIFORMES	F38
RJB	38	1100402003	Dipturus batis	Blue skate	Rajidae	RAJIFORMES	F38
RJC	38	1100400102	Raja clavata	Thornback ray	Rajidae	RAJIFORMES	F38
RJE	38	1100400109	Raja microocellata	Small-eyed ray	Rajidae	RAJIFORMES	F38
RJF	38	1100404402	Leucoraja fullonica	Shagreen ray	Rajidae	RAJIFORMES	F38
RJG	38	1100400434	Amblyraja hyperborea	Arctic skate	Rajidae	RAJIFORMES	F38
RJH	38	1100400105	Raja brachyura	Blonde ray	Rajidae	RAJIFORMES	F38
RJI	38	1100404401	Leucoraja circularis	Sandy ray	Rajidae	RAJIFORMES	F38
RJK	38	1100404206	Rajella lintea	Sailray	Rajidae	RAJIFORMES	F38
RJM	38	1100400104	Raja montagui	Spotted ray	Rajidae	RAJIFORMES	F38
RJN	38	1100404403	Leucoraja naevus	Cuckoo ray	Rajidae	RAJIFORMES	F38
RJR	38	1100400435	Amblyraja radiata	Starry ray	Rajidae	RAJIFORMES	F38
RJT	38	1100400189	Raja ocellata	Winter skate	Rajidae	RAJIFORMES	F38
RPJ	34	1780100134	Sebastes proriger	Redstripe rockfish	Scorpaenidae	SCORPAENIFORMES	F34

ASFIS 3A CODE	ISSCAAP CODE	TAXOCODE	Scientific name	English name	Family	Order	EUROSTAT ISSCAAP CODE
RSC	37	1702300411	Trachurus lathami	Rough scad	Carangidae	PERCOIDEI	F37
RUI	38	1101300204	Urolophus circularis	Circular stingaree	Urolophidae	RAJIFORMES	F38
RZV	37	1900800101	Ranzania laevis	Slender sunfish	Molidae	TETRAODONTIFORMES	F37
SAA	35	1210501210	Sardinella aurita	Round sardinella	Clupeidae	CLUPEIFORMES	F35
SAE	35	1210501217	Sardinella maderensis	Madeiran sardinella	Clupeidae	CLUPEIFORMES	F35
SAL	23	1230100401	Salmo salar	Atlantic salmon	Salmonidae	SALMONIFORMES	F23
SAN	33	17204002XX	Ammodytes spp	Sandeels(=Sandlances) nei	Ammodytidae	TRACHINOIDEI	F33
SBA	33	1703900803	Pagellus acarne	Axillary seabream	Sparidae	PERCOIDEI	F33
SBG	33	1703923508	Sparus aurata	Gilthead seabream	Sparidae	PERCOIDEI	F33
SBR	33	1703900801	Pagellus bogaraveo	Blackspot seabream	Sparidae	PERCOIDEI	F33
SBX	33	17039XXXXX	Sparidae	Porgies. seabreams nei	Sparidae	PERCOIDEI	F33
SBY	34	1780100131	Sebastes brevispinis	Silvergray rockfish	Scorpaenidae	SCORPAENIFORMES	F34
SCB	55	3160803002	Argopecten irradians	Atlantic bay scallop	Pectinidae	BIVALVIA	F55
SCE	55	3160800309	Pecten maximus	Great Atlantic scallop	Pectinidae	BIVALVIA	F55
SCL	38	10801003XX	Scyliorhinus spp	Catsharks. nursehounds nei	Scyliorhinidae	CARCHARHINIFORMES	F38
SCR	42	2312100501	Maja squinado	Spinous spider crab	Majidae	BRACHYURA	F42
SCY	43	2291500903	Scyllarus arctus	Lesser slipper lobster	Scyllaridae	REPTANTIA	F43
SDH	38	1090101402	Deania hystricosa	Rough longnose dogfish	Squalidae	SQUALIFORMES	F38
SDS	38	1080400715	Mustelus asterias	Starry smooth-hound	Triakidae	CARCHARHINIFORMES	F38
SDU	38	1090101403	Deania profundorum	Arrowhead dogfish	Squalidae	SQUALIFORMES	F38
SDV	38	10804007XX	Mustelus spp	Smooth-hounds nei	Triakidae	CARCHARHINIFORMES	F38
SFD	34	1780100122	Sebastes diploproa	Splitnose rockfish	Scorpaenidae	SCORPAENIFORMES	F34
SFV	34	1780100102	Sebastes viviparus	Norway redfish	Scorpaenidae	SCORPAENIFORMES	F34
SHD	24	12105011XX059	Alosa alosa. A. fallax	Allis and twaite shads	Clupeidae	CLUPEIFORMES	F24
SHR	33	1703903307	Diplodus puntazzo	Sharpsnout seabream	Sparidae	PERCOIDEI	F33
SHX	38	109XXXXXXX	Squaliformes	Dogfish sharks. etc. nei		SQUALIFORMES	F38
SHZ	24	12105011XX	Alosa spp	Shads nei	Clupeidae	CLUPEIFORMES	F24
SIX	35	12105012XX	Sardinella spp	Sardinellas nei	Clupeidae	CLUPEIFORMES	F35
SKA	38	11004001XX	Raja spp	Raja rays nei	Rajidae	RAJIFORMES	F38
SKH	38	199XXXXXXX053	Selachimorpha (Pleurotremata)	Various sharks nei		PISCES MISCELLANEA	F38
SKJ	36	1750102501	Katsuwonus pelamis	Skipjack tuna	Scombridae	SCOMBROIDEI	F36
SLT	36	1750102701	Allothunnus fallai	Slender tuna	Scombridae	SCOMBROIDEI	F36
SMA	38	1060800201	Isurus oxyrinchus	Shortfin mako	Lamnidae	LAMNIFORMES	F38
SMC	33	1410200614	Arius heudelotii	Smoothmouth sea catfish	Ariidae	SILURIFORMES	F33

ASFIS 3A CODE	ISSCAAP CODE	TAXOCODE	Scientific name	English name	Family	Order	EUROSTAT ISSCAAP CODE
SMD	38	1080400713	Mustelus mustelus	Smooth-hound	Triakidae	CARCHARHINIFORMES	F38
SME	23	1230400301	Osmerus eperlanus	European smelt	Osmeridae	SALMONIFORMES	F23
SNS	34	1510300401	Macroramphosus scolopax	Longspine snipefish	Macroramphosidae	SYNGNATHIFORMES	F34
SOL	31	1830300701	Solea solea	Common sole	Soleidae	PLEURONECTIFORMES	F31
SOO	31	18303007XX	Solea spp		Soleidae	PLEURONECTIFORMES	F31
SOS	31	1830309303	Pegusa lascaris	Sand sole	Soleidae	PLEURONECTIFORMES	F31
SOX	31	18303XXXXX	Soleidae	Soles nei	Soleidae	PLEURONECTIFORMES	F31
SPG	34	1780100115	Sebastes pinniger	Canary rockfish	Scorpaenidae	SCORPAENIFORMES	F34
SPR	35	1210506601	Sprattus sprattus	European sprat	Clupeidae	CLUPEIFORMES	F35
SPU	33	1700634501	Dicentrarchus punctatus	Spotted seabass	Moronidae	PERCOIDEI	F33
SQA	57	3210501003	Illex argentinus	Argentine shortfin squid	Ommastrephidae	CEPHALOPODA	F57
SQC	57	32104001XX	Loligo spp	Common squids nei	Loliginidae	CEPHALOPODA	F57
SQE	57	3210505801	Todarodes sagittatus	European flying squid	Ommastrephidae	CEPHALOPODA	F57
SQF	57	3210400113	Loligo forbesii	Veined squid	Loliginidae	CEPHALOPODA	F57
SQI	57	3210501001	Illex illecebrosus	Northern shortfin squid	Ommastrephidae	CEPHALOPODA	F57
SQL	57	3210400105	Loligo pealeii	Longfin squid	Loliginidae	CEPHALOPODA	F57
SQM	57	3210501002	Illex coindetii	Broadtail shortfin squid	Ommastrephidae	CEPHALOPODA	F57
SQR	57	3210400109	Loligo vulgaris	European squid	Loliginidae	CEPHALOPODA	F57
SQS	57	3210506001	Martialia hyadesi	Sevenstar flying squid	Ommastrephidae	CEPHALOPODA	F57
SQU	57	32105XXXXX036	Loliginidae. Ommastrephidae	Various squids nei		CEPHALOPODA	F57
SQZ	57	32104XXXXX	Loliginidae	Inshore squids nei	Loliginidae	CEPHALOPODA	F57
SRA	34	17802020XX	Prionotus spp	Atlantic searobins	Triglidae	SCORPAENIFORMES	F34
SRE	11	1400201901	Scardinius erythrophthalmus	Rudd	Cyprinidae	CYPRINIFORMES	F11
SRX	38	110XXXXXXX	Rajiformes	Rays. stingrays. mantas nei		RAJIFORMES	F38
SSB	33	1703927702	Lithognathus mormyrus	Sand steenbras	Sparidae	PERCOIDEI	F33
STJ	33	1703906303	Spondyliosoma emarginatum	Steentjie seabream	Sparidae	PERCOIDEI	F33
STU	21	11701XXXXX	Acipenseridae	Sturgeons nei	Acipenseridae	ACIPENSERIFORMES	F21
SVE	56	3161100105	Chamelea gallina	Striped venus	Veneridae	BIVALVIA	F56
SWA	33	1703903303	Diplodus sargus	White seabream	Sparidae	PERCOIDEI	F33
SWD	34	1780100130	Sebastes reedi	Yellowmouth rockfish	Scorpaenidae	SCORPAENIFORMES	F34
SWO	36	1750400301	Xiphias gladius	Swordfish	Xiphiidae	SCOMBROIDEI	F36
SYC	38	1080100301	Scyliorhinus canicula	Small-spotted catshark	Scyliorhinidae	CARCHARHINIFORMES	F38
SYT	38	1080100302	Scyliorhinus stellaris	Nursehound	Scyliorhinidae	CARCHARHINIFORMES	F38
SYX	38	10801XXXXX	Scyliorhinidae	Catsharks. etc. nei	Scyliorhinidae	CARCHARHINIFORMES	F38

ASFIS 3A CODE	ISSCAAP CODE	TAXOCODE	Scientific name	English name	Family	Order	EUROSTAT ISSCAAP CODE
TBR	33	1706306901	Ctenolabrus rupestris	Goldsinny-wrasse	Labridae	PERCOIDEI	F33
TIG	38	1080201703	Galeocerdo cuvier	Tiger shark	Carcharhinidae	CARCHARHINIFORMES	F38
TLP	12	17059051XX	Oreochromis spp	Tilapias nei	Cichlidae	PERCOIDEI	F12
TOZ	33	1721202001	Echiichthys vipera	Lesser weever	Trachinidae	TRACHINOIDEI	F33
TRI	33	19010XXXXX	Balistidae	Triggerfishes. durgons nei	Balistidae	TETRAODONTIFORMES	F33
TRR	23	1230100909	Oncorhynchus mykiss	Rainbow trout	Salmonidae	SALMONIFORMES	F23
TSD	24	1210501105	Alosa fallax	Twaite shad	Clupeidae	CLUPEIFORMES	F24
TUN	36	17501XXXXX043	Thunnini	Tunas nei	Scombridae	SCOMBROIDEI	F36
TUR	31	1830506403	Scophthalmus maximus	Turbot	Scophthalmidae	PLEURONECTIFORMES	F31
UBA	37	1760600103	Cubiceps caeruleus	Blue fathead	Nomeidae	STROMATEOIDEI. ANABANTOIDEI	F37
ULO	56	3161202005	Spisula solida	Solid surf clam	Mactridae	BIVALVIA	F56
USB	33	1706300501	Labrus bergylta	Ballan wrasse	Labridae	PERCOIDEI	F33
USK	32	1480400101	Brosme brosme	Tusk(=Cusk)	Gadidae	GADIFORMES	F32
VAD	37	1702352601	Campogramma glaycos	Vadigo	Carangidae	PERCOIDEI	F37
VMA	37	1750100209	Scomber colias	Atlantic chub mackerel	Scombridae	SCOMBROIDEI	F37
WEG	33	1721201002	Trachinus draco	Greater weever	Trachinidae	TRACHINOIDEI	F33
WEX	33	17212010XX	Trachinus spp	Weevers nei	Trachinidae	TRACHINOIDEI	F33
WHB	32	1480403301	Micromesistius poutassou	Blue whiting(=Poutassou)	Gadidae	GADIFORMES	F32
WHE	52	3070800101	Buccinum undatum	Whelk	Buccinidae	GASTROPODA	F52
WHG	32	1480403401	Merlangius merlangus	Whiting	Gadidae	GADIFORMES	F32
WIT	31	1830201102	Glyptocephalus cynoglossus	Witch flounder	Pleuronectidae	PLEURONECTIFORMES	F31
WRA	33	17063XXXXX	Labridae	Wrasses. hogfishes. etc. nei	Labridae	PERCOIDEI	F33
WRF	34	1700505801	Polyprion americanus	Wreckfish	Polyprionidae	PERCOIDEI	F34
WRO	34	1780100103	Sebastes entomelas	Widow rockfish	Scorpaenidae	SCORPAENIFORMES	F34
YEL	31	1830202404	Limanda ferruginea	Yellowtail flounder	Pleuronectidae	PLEURONECTIFORMES	F31
YFT	36	1750102610	Thunnus albacares	Yellowfin tuna	Scombridae	SCOMBROIDEI	F36
YRO	34	1780100104	Sebastes flavidus	Yellowtail rockfish	Scorpaenidae	SCORPAENIFORMES	F34

Appendix 6 Presentation forms in Eurostat databases

This appendix gives presentation forms reported on in the Eurostat Databases. For most species, conversion factors are available for (a select portion) of the codes in Fresh or Frozen presentation forms (see Section 4.5.1).

Major Presentation from (Eurostat code)	Major Presentation from class (description)	Minor Presentation form (Eurostat code)	Minor Presentation form (description)
-	-	CLA	Claws
-	-	COK	Cooked
FRE	Fresh	FRE_ALI	Fresh. alive
		FRE_FIL	Fresh. filleted
		FRE_GUH	Fresh. gutted and headed
		FRE_GUT	Fresh. gutted
		FRE_NSP	Fresh. not specified
		FRE_OTH	Fresh. other
		FRE_TAL	Fresh. tails
		FRE_WHL	Fresh. whole
FRO	Frozen	FRO_GUH	Frozen. gutted and headed
		FRO_GUT	Frozen. gutted
		FRO_NSP	Frozen. not specified
		FRO_OTH	Frozen. other
		FRO_TAL	Frozen. tails
		FRO_WHL	Frozen. whole
		ROE	Roes
SAL	Salted	SAL_GUT	Salted. gutted
		SAL_OTH	Salted. other
TOTAL	All presentation forms	-	-

Appendix 7 Species reported by CVO for Below Minimum Size Landings

This appendix shows all the species that were reported in the aggregation of the Below Minimum Size (BMS) data from Rijksdienst voor Ondernemend Nederland (RVO) as aggregated by the Center for Fisheries Research (CVO) at Wageningen Marine Research. The full list here shows if any BMS was found (BMS weight > 0).

ASFIS 3A_CODE	Scientific Name	English_name	BMS weight > 0
ANE	*Engraulis encrasicolus*	European anchovy	FALSE
ARU	*Argentina silus*	Greater argentine	FALSE
BLL	*Scophthalmus rhombus*	Brill	TRUE
BOC	*Capros aper*	Boarfish	FALSE
BSS	*Dicentrarchus labrax*	European seabass	FALSE
CAA	*Anarhichas lupus*	Atlantic wolffish	FALSE
COD	*Gadus morhua*	Atlantic cod	TRUE
DAB	*Limanda limanda*	Common dab	TRUE
DGS	*Squalus acanthias*	Picked dogfish	FALSE
ELE	*Anguilla anguilla*	European eel	FALSE
FLE	*Platichthys flesus*	European flounder	TRUE
GAG	*Galeorhinus galeus*	Tope shark	FALSE
GFB	*Phycis blennoides*	Greater forkbeard	FALSE
GHL	*Reinhardtius hippoglossoides*	Greenland halibut	TRUE
GUG	*Eutrigla gurnardus*	Grey gurnard	TRUE
GUR	*Chelidonichthys cuculus*[1]	Red gurnard	TRUE
HAD	*Melanogrammus aeglefinus*	Haddock	TRUE
HAL	*Hippoglossus hippoglossus*	Atlantic halibut	TRUE
HER	*Clupea harengus*	Atlantic herring	TRUE
HKE	*Merluccius merluccius*	European hake	TRUE
HOM	*Trachurus trachurus*	Atlantic horse mackerel	TRUE
LEM	*Microstomus kitt*	Lemon sole	TRUE
LIN	*Molva molva*	Ling	FALSE
MAC	*Scomber scombrus*	Atlantic mackerel	TRUE
MEG	*Lepidorhombus whiffiagonis*	Megrim	FALSE
MON	*Lophius piscatorius*	Angler(=Monk)	TRUE
MUR	*Mullus surmuletus*	Surmullet	FALSE
NEP	*Nephrops norvegicus*	Norway lobster	TRUE
NOP	*Trisopterus esmarkii*	Norway pout	FALSE
PIL	*Sardina pilchardus*	European pilchard(=Sardine)	FALSE
PLE	*Pleuronectes platessa*	European plaice	TRUE
POK	*Pollachius virens*	Saithe(=Pollock)	FALSE
POL	*Pollachius pollachius*	Pollack	FALSE
POR	*Lamna nasus*	Porbeagle	FALSE
REB	*Sebastes mentella*	Beaked redfish	FALSE
REG	*Sebastes norvegicus*	Golden redfish	FALSE
RJB	*Dipturus batis*	Blue skate	FALSE
RJC	*Raja clavata*	Thornback ray	FALSE
RJH	*Raja brachyura*	Blonde ray	FALSE
RJM	*Raja montagui*	Spotted ray	FALSE
RJN	*Leucoraja naevus*	Cuckoo ray	FALSE
RJR	*Amblyraja radiata*	Starry ray	FALSE
SBR	*Pagellus bogaraveo*	Blackspot seabream	FALSE

ASFIS 3A_CODE	Scientific Name	English_name	BMS weight > 0
SDS	*Mustelus asterias*	Starry smooth-hound	FALSE
SOL	*Solea solea*	Common sole	TRUE
SPR	*Sprattus sprattus*	European sprat	FALSE
SYC	*Scyliorhinus canicula*	Small-spotted catshark	FALSE
TUR	*Scophthalmus maximus*	Turbot	TRUE
WHB	*Micromesistius poutassou*	Blue whiting(=Poutassou)	TRUE
WHG	*Merlangius merlangus*	Whiting	TRUE
WIT	*Glyptocephalus cynoglossus*	Witch flounder	FALSE

[1] 'Chelidon**i**chthys cuculus' was spelled different as 'Chelidon**y**chthys cuculus' in the ASFIS species code list. Based on the same English name and the minimal changes in the name (a single letter) in both datasets it was assumed this species are one and the same.

Appendix 8 Datawarehouse as base for enhancing the MFM

A8.1 What is a datawarehouse?

A datawarehouse is a structural storage of data that is obtained from different sources and statistics. It is a type of database solution that offers a consolidated view of heterogeneous source systems and restructures the data for analytical purposes. It integrates data from multiple heterogeneous sources into a single database, using a common vocabulary. It provides a consolidated view of the data. Once entered in the warehouse, data will usually not be deleted or changed (non-volatile). The time factor is explicitly modelled in the datawarehouse as all data elements have a validity period. There are multiple advantages of datawarehousing, like:

- Data entering the warehouse are stored and thus analyses are reproducible over time.
- Many data operations can be automated when added to the warehouse. This reduces errors and improves repeatability.
- It provides a central view of data within the organisation.
- It makes it possible to link data from multiple sources.
- It i makes it easy to navigate available data via the common interface.
- It generally provides fast query performance.

A8.2 Datawarehouse of Wageningen Economic Research and how to implement and extract data?

The Datawarehouse (DWH) of Wageningen Economic Research consists of multiple boxes (Figure A8.1).

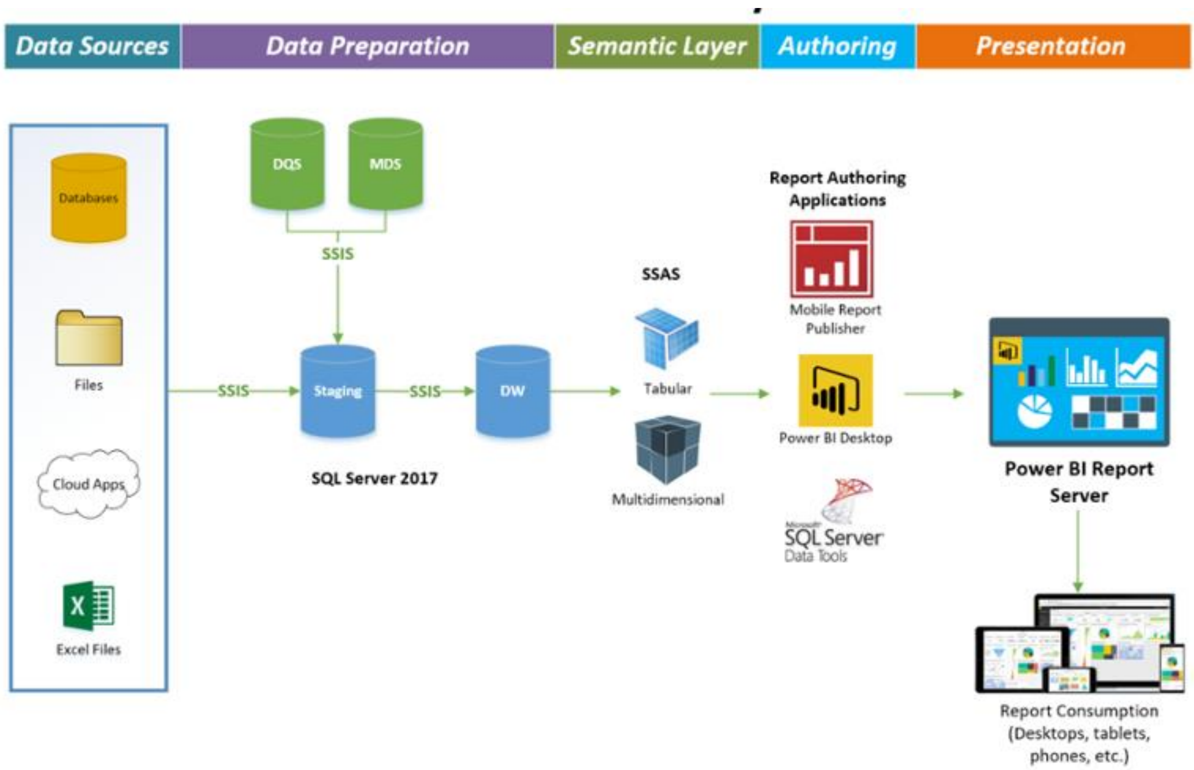

Figure A8.1 *Datawarehouse system of Wageningen Economic Research*

First, data are added to the system using SQL Server Integration services (SSIS). They are converted and processed via Data Quality Services (DQS) and Meta Data Services (MDS) and next stored in the Data warehouse. Second, data are derived in the semantic layer. Finally, data are accessible (authoring) by using multiple applications such as SQL, Power-BI, R and Python. With the Power-BI report server visualisations of project data can be made available to users within Wageningen Economic Research or external clients via predefined figures and tables. To facilitate specific selection and visualisation of data for external users, OData webservices are being developed (not yet in Figure A8.1). Users must authorise for it.

Current DWH of Wageningen Economic Research contains data tables collected from official statistical organisations such as CBS, Eurostat and FAO. Tables are either available for common use or for specific individuals or groups with the option to add new tables. Information from tables can be selected via the query editor and combined in a so called *data model.* The data model is created in *Adagio*, which is the software organising the data management, such as the release of selected data. The data model is connected to source data table(s) by a sort of 'live link', i.e. updates of the source data are permanently processed in the data model and consequently automatically update outcomes. Outcomes of the data model are linkable to other programs, such as MS-Excel, Power-BI and HighCharts for use of data visualisations, e.g., Sankey diagrams (Figure A8.2).

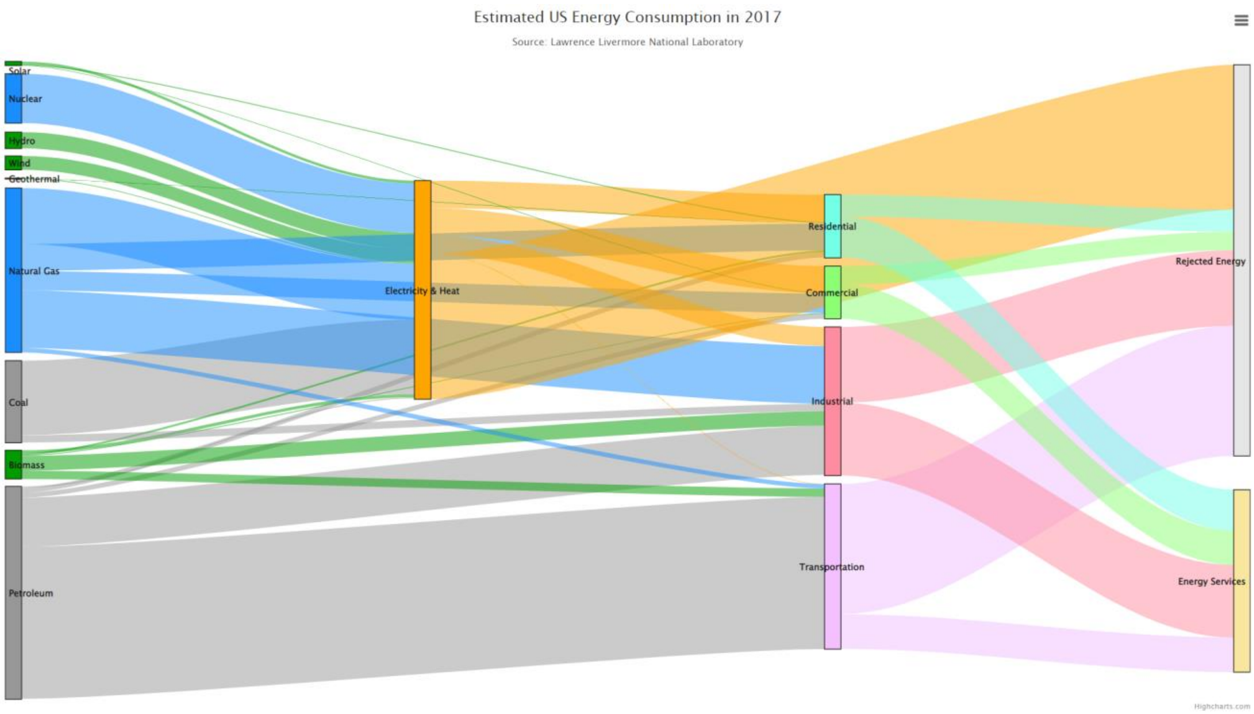

Figure A8.2 *Example of a Sankey created by Highcharts*
Source https://www.highcharts.com/blog/chartchooser/sankey-categorical-flow/

A8.3 Product coding structure and mapping to MFM

An important aspect of creating the data model regards the linkage of product information obtained from multiple datasets. A product in a specific database has a unique identifier, i.e. text or numerical coding structure, however may have different coding structures per database. Therefore, mappings must be made between the different identifiers, taking into account that the final data flow from DWH to MFM must align with classifications/definitions of the MFM. Products in the MFM are classified according to the CPA-classification which is an European coding system for products (see Appendix 9). The distinguished products described in Chapters 2 to 5 already have received unique CPA-codes. This is either an existing code in case the biomass product already is in the CPA classification system, or a new code – in line with the CPA coding structure - in case the biomass product (mostly a residue product) is not in yet.

A8.4 Procedure for data delivery from Datawarehouse to MFM

The collected data in Chapters 2 to 5 serve as base for creating our 'data model'. Among others, data include crop, animal and fish production, parameters for attributes, mapping lists. When delivered to the DWH, output can be assessed by different-to-different programs (e.g. Power-BI/HighCharts) for making visualisations, possibly accessible by a (web-linked) dashboard. Another option is to send data to existing(or a new model for further processing, for instance to create the WUR version of the MFM. More specifically, the procedural approach of enhancing the MFM goes from data selection, to data mapping, data extraction via a data model, and data adapting.

Data selection

The procedure starts with defining which data is needed, based on the wish list provided in Chapters 2 to 5. Three ways of data processing are considered (Figure A8.3):

- Data that are already in the DWH.
- Data from official statistical organisations, but not yet integrated in the DWH.
- Other data not available in the DWH.

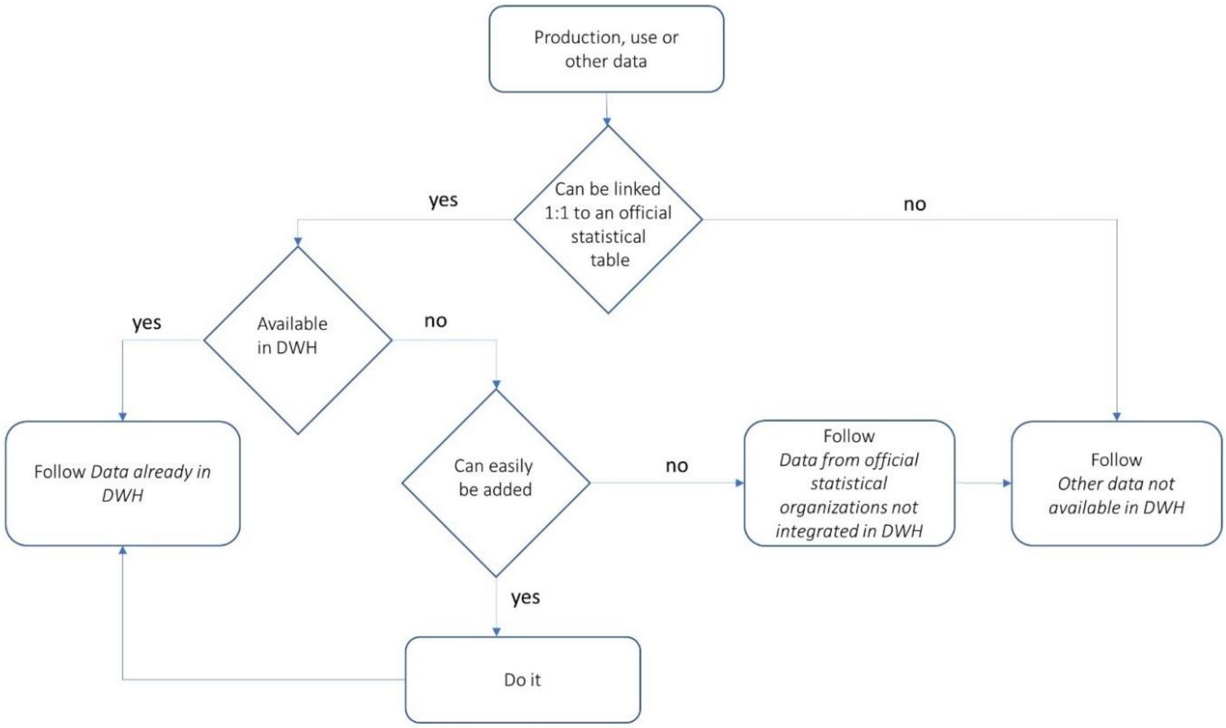

Figure A8.3 *Selection card how to cope with multiple datasets connected to DWH*
Source: Authors.

Data already in DWH: data obtained from official statistical, such as Annual Censuses, Eurostat and COMTRADE. A data model makes a direct reference to these tables. Advantages are automatic maintenance and processing updates.

Data from official statistical organisations not yet integrated in DWH: Adagio is assessed to include new data with an OData-link (Wageningen Economic Research, 2022) via an URL-connection between data source and DWH. In this case it is not needed to first download the data from the source website and next to implement these in the DWH. Data updates at the source site are automatically processed. A disadvantage of not having the data in de DWH is that there is no automatic maintenance, such as changing identifiers and variables over time. If data is inaccessible by an OData-link, they must be downloaded, put in a csv-format, and instructions must be followed (see following section *Other Data not available in DWH*).

Other data not available in DWH. Data needed from tables that remain outside the warehouse or not approachable via an OData-link must be as follows structured in a stand-alone file:

- Readme sheet that includes: goal of data, source(s) of data (e.g. year of data), creator of the file, and description of units.
- Data sheets with a unique name with format: first column contains the derived CPA-code; second column contains the identifier with the official (statistical) source (if available), the third column has the name of the biomass supply/use. Next columns contain the data with column names.

Examples of this other data category are:

- Data from official organisations not included in the Warehouse and not approachable by an OData-link.
- Mappings of products with new WUR defined code or modified CPA-code. Parameters or attributes, such as parameters to calculate different residual biomass flows, residue to product ratio for straw production.

Data Mapping. Either product data from official statistics in the DWH get the codes used in those statistics, or products follow the CPA coding. A code mapping stricture for same products in CPA and DWH must be developed and provided as xlsx-file with following information:

- Readme sheet that includes: goal of data, source(s) of data (e.g. year of data), creator of the file, and description of units.
- Data sheets with a unique name with format: first column contains the product name (product_id), second column contains the code of the statistical table (Stats_id),and third column contains the code from derived CPA (CPA_id).

Data on product properties. These reflect information on e.g., carbon content, mineral content, dry matter content and must also be provided in a xlsx-file that include data sheets with unique names with following format:

- Columns with product properties with the same unit: first column contains the biomass product (biomass_id), second column contains the biomass product name (product_id), next columns contain product properties. Note that the *product-id* is unique and must match with the mapping list of products.
- Contents are expressed as a percentage of dry matter content; dry matter content is expressed as a percentage of weight. For example: a product with *Y* tonne of material X, and dry matter contents *z,* and a carbon content *c* means that material X contains (Y * z * c)/10,000 tonne of *C*.

Data delivery to the MFM.

In the last stage, all MS-Excel files with selected data from the DWH are transferred into a GAMS program specifically developed to integrate the new data in the MFM.

Appendix 9 Sectors and products in MFM

The MFM developed by CBS consists of a supply table and a use table with product flows in the Netherlands. Both tables are two-dimensional with products in the rows and production sectors in the columns. Supply and use tables are compiled according to internationally agreed principles and definitions conform the guidelines of the System for Environmental Economic Accounting (SEEA) which is the international statistical standard for the environmental accounts (Berkel et al, 2019). As a result, the volume figures of CBS's MFM are consistent with the system of National Accounts (Berkel et al, 2019; Delahaye et al, 2015).

The sectors in the MFM (Standaard Bedrijven Indeling (SBI) classification) are based on NACE Rev2 (Berkel and Delahaye, 2019 and CBS(2023)). Products in the MFM are based on the product groups in the National Accounts of CBS which are based on CPA version 2.1. Codes are available at website Europa - RAMON - Classification Detail List or (from 2023 onwards) cpa21 - EU Vocabularies - Publications Office of the EU (europa.eu).

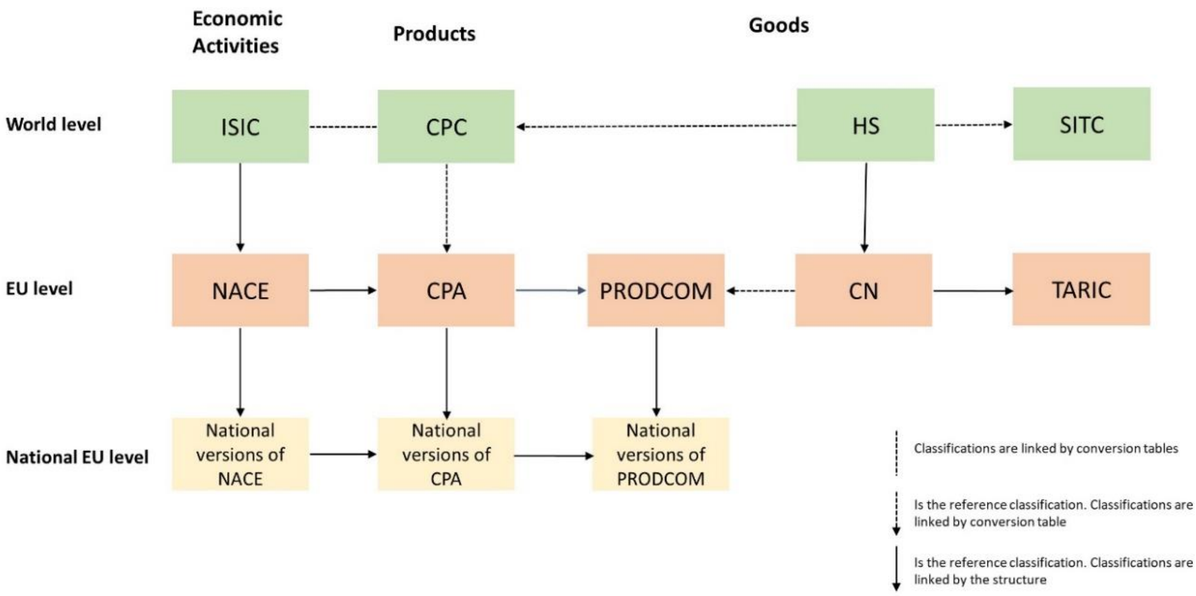

Figure A9.1 *Classification at EU and World level*
Source: Eurostat (2008).

Products and sectors in the detailed MFM of CBS are structured as follows:

- The rows of the supply and demand tables contain about 400 commodity groups (Appendix 1 in Delahaye and Zult, 2013). Note that:
  - These commodities can be divided according to the level of production: 1) raw materials, 2) semi-finished products, and 3) end products.
  - In addition to physical data, there are also monetary data from the national data for each commodity group available. These commodity groups are associated with 16 different waste categories (Appendix 3 in Delahaye and Zult, 2013) and 10 types of raw materials extracted in the Netherlands (Appendix 4 in Delahaye and Zult, 2013).
  - Last lines in the MFM are balance sheet items, such as CO_2 emissions, O_2 intake for combustion, and water intake in products.
- The columns of the supply and use tables contain about 130 business classes (Appendix 2, Delahaye and Zult, 2013). In addition to these business classes, households are also included as well as imports and exports.

Appendix 10 Computer Program to transfer straw data in the MFM

Appendix 10 describes the additional modification and programming coding that automates the integration of straw flows in the MEM, i.e. all straw producing crops and the whole stubble. Calculation of straw production, straw uses, and flows of straw from users to end-users takes place in the Data Warehouse and are hereafter transferred to the MFM. Table A10.1 highlights the situation of straw flows in 2020: the first column shows the producers and second column the users. Table A10.2 shows how producers of products are aggregated to sectors conform in the MFM.

Table A10.1 *Flows of straw (kg DM) in the Netherlands, 2020*

From	To	Volume (kg DM)
Straw production in the Netherlands	To the soil	454350
Straw production in the Netherlands	Harvested	308590
Harvested	Total used	308595
Imported	Total used	419440
Total use	Flower bulbs	118496
Total use	Forage for animals (feed)	133714
Total use	Mushroom production	216955
Total use	Other bio-based use	16714
Total use	Straw for stables of horses	221737
Total use	Straw for stables of other animals	134663
Total use	Strawberries	39054
Harvested	Exported	44625
Mushroom production	Exported	81268
Straw for tables of horses	Mushroom production	108477
Used by mushrooms	To air	82253
Used by bio-based products	To air	16714
Mushroom production	To the soil	53434
Strawberries	To the soil	39053
Flower bulbs	To the soil	118495
Forage for animals (feed)	To the soil	133714
Straw for stables of horses	To the soil	113260
Straw for stables of other animals	To the soil	134663

Table A10.2 *Mapping of straw product to supplying and using sectors in the MFM*

Products in the extended Sankey	Sector in MFM	Sector code in MFM
Flower bulbs	Horticulture	C1209
Strawberries	Horticulture	C1209
Mushroom production	Horticulture	C1209
Forage for animals (feed)	Livestock	C1400
Straw for stable horses	Livestock	C1400
Straw for stable horses	Sport and Leisure	C93000
Straw for stable other animals	Livestock	C1400
Other bio-based uses	Other agriculture	C1500
To soil	Environment	C999999
To air	Environment	C999999

Straw is used by sectors Horticulture (C1209), Livestock (C1400), Other Agriculture (C1500) and Sport and Leisure (C93000). About 80% of the horses are kept outside agriculture (CBS and Koninklijke Nederlandse Hypische Sportfederatie), i.e. kept at riding schools and firms for competition horses. These subsectors are part of 'Sports and leisure' (C93000) and therefore straw consumption is partly assigned to Livestock and partly to the Sports and leisure.

The product *Other bio-based uses* is hard to link to a sector as it could be used for energy production, construction and other purposes, while the size of the product is rather small compared to other users of straw (Table B5.1). It is assumed to be connected to the sector 'Other farming as statistics don't show where other straw is going to.

Next, Table A10.1 shows that there are additional users of straw, namely *soil* and *air*. Soil and air are both represented in the MFM by the sector 'Environment' (C999999).

To make all flows visible in the MFM, two other sectors are added: *waste straw* (AfvalStro – RAS) *and recycle straw* (recycle stro – RCS). Production of waste straw represents the flow from sectors to soil and air. Production of recycle straw reflects the flow of own use, export and straw from horse stables to mushrooms. User of the waste straw is the sector Environment, while recycle straw is used by the environment, export and the sector horticulture.

Based on the new products and sectors the data of Table B5.1 have been mapped to MFM flows (Table A10.3).

Table A10.3 *Mapping flows related to straw in the Netherlands in 2020 to sector levels in MFM*

From producers	To users	Volume (kg DM)
Straw production in the Netherlands	To the soil	454350
Straw production in the Netherlands	Harvested	308595
Harvested	Total used	308595
Imported	Total used	419440
Total use	Horticulture	374504
Total use	Other agriculture	16714
Total use	Livestock farming	312724
Total use	Sport and leisure	177390
Harvested	Exported	44625
Livestock farming	Horticulture	21695
Sports and leisure	Horticulture	86782
Horticulture	Used by Horticulture	82253
Other agriculture	Used by Other agriculture	16714
Horticulture	To the soil	210982
Livestock farming	To the soil	291029
Sport and leisure	To the soil	90608
Horticulture	Exported	81268

GAMS program code that automates the data transfer into the MFM

***! Step 0:**
Around 80% of the horses is kept outside agriculture. This fraction is calculated as the quotient of horses in agriculture and total number of horses (including ponies).
F_horse_agri = 90/450;

***! Step 1 - Primary supply from arable sector plus imports**

```
pst_vol("R119300","C1109")      = FlowDataStro_vol("field","harvested","x") +
                                      FlowDataStro_vol("field","to_soils","x");
pst_vol("R119300","C411000")   = FlowDataStro_vol("imported","total_used","x");
```

The next step calculates the secondary supply that is left on the soil after users of straw. We link this data to a product called AfvalStro (RAS)

```
*! Step 2 – Secondary supply
        pst_vol("RAS","C1209")          = FlowDataStro_vol("Mushroom_production","to_soils","x") +
                                  FlowDataStro_vol("Strawberries","to_soils","x") +
                                  FlowDataStro_vol("Flower_bulbs","to_soils","x");
        pst_vol("RAS","C1400")          = FlowDataStro_vol("Forage_animals","to_soils","x")+
                                  FlowDataStro_vol("Stables_for_horses","to_soils","x")* f_horse_agri+
                                  FlowDataStro_vol("stables_other_animals","to_soils","x");
        pst_vol("RAS","C93000")         = FlowDataStro_vol("Stables_for_horses","to_soils","x")*
                                  (1-f_horse_agri);
* RCS us a help variable RCS that reflects this part of the straw (KT)
        pst_vol("RCS","C1209")          =
        FlowDataStro_vol("Mushroom_production","used_by_mushrooms","x") +
                FlowDataStro_vol("Mushroom_production","exported","x");
        pst_vol("RCS","C1400")          =
                FlowDataStro_vol("Stables_for_horses","Mushroom_production","x")*f_horse_agri;
        pst_vol("RCS","C1500")          =
                FlowDataStro_vol("Other_biobased_uses","used_by_biobased_products","x");
        pst_vol("RCS","C93000")         =
                FlowDataStro_vol("Stables_for_horses","Mushroom_production","x")*(1-f_horse_agri);
```

Next step defines and calculates the use of the gross production in horticulture, livestock, Sports, export, environment and other agriculture.

```
*! Step 3 – Use of straw from primary production (R119300)
*! Export
        put_vol("R119300","C311000")    = FlowDataStro_vol("harvested","exported","x");
*! Environment
        put_vol("R119300","C999999")    = FlowDataStro_vol("field","to_soils","x");
*! Horticulture with correction for double counting for horses and export
        put_vol("R119300","C1209")      = FlowDataStro_vol("total_used","Strawberries","x") +
                                  FlowDataStro_vol("total_used","Flower_bulbs","x") +
                                  FlowDataStro_vol("total_used","Mushroom_production","x")-
                                  FlowDataStro_vol("Stables_for_horses","Mushroom_production","x");
*! Animal farming
        put_vol("R119300","C1400")      = FlowDataStro_vol("total_used","Forage_animals","x") +
                                  FlowDataStro_vol("total_used","Stables_for_horses","x")*F_horse_agri +
                                  FlowDataStro_vol("total_used","stables_other_animals","x");
*! Horses in sport
        put_vol("R119300","C93000")     = FlowDataStro_vol("total_used","Stables_for_horses","x")*(1-
                                  F_horse_agri);
*! Other bio-based applications
        put_vol("R119300","C1500")      = FlowDataStro_vol("total_used","Other_biobased_uses","x");
*! Corrections for double counting
        put_vol("R119300","C340009")    = -FlowDataStro_vol("Mushroom_production","exported","x");
```

Next step shows the calculation of the RAS and RCS uses and adds the supply to the original sectors.

***! Step 4 - Use of recycled straw**

```
put_vol("RCS","C999999")        =
        FlowDataStro_vol("Mushroom_production","used_by_mushrooms","x")+
                FlowDataStro_vol("Other_biobased_uses","used_by_biobased_products","x");
put_vol("RCS","C1209")          =
        FlowDataStro_vol("Stables_for_horses","Mushroom_production","x");
put_vol("RCS","C311000")        = FlowDataStro_vol("Mushroom_production","exported","x");
put_vol("RAS","C999999")        = pst_vol("RAS","C1209")+ pst_vol("RAS","C93000") +
            pst_vol("RAS","C1400");
```

***! Step 5 – Uses minus double counting to soil and air**

```
        put_vol("R301","C1109")         = put_vol("R301","C1109")+
                                                pst_vol("R119300","C1109")   ;
```

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Report 2024-035

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