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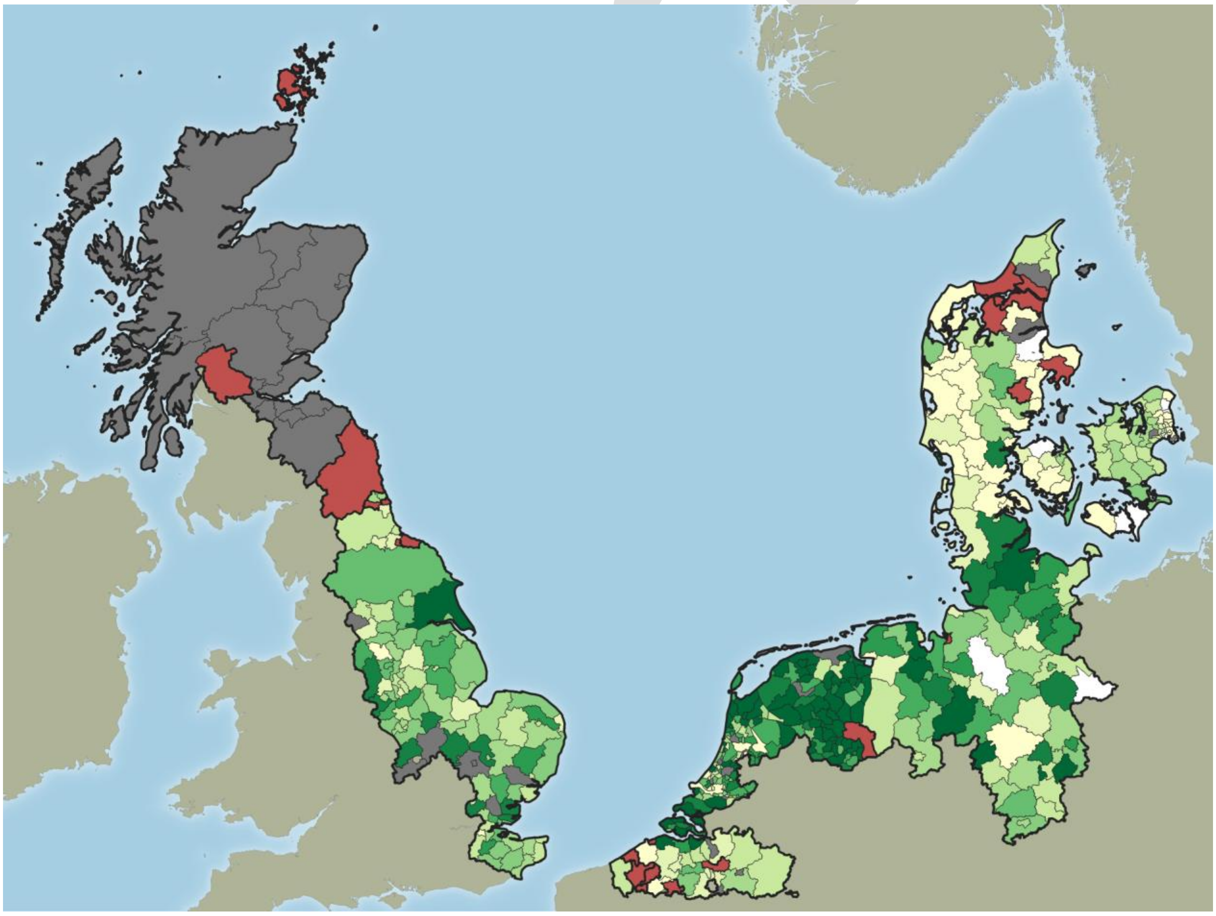
Phillipp Lüssenhop, Steffen Walk, Selen Asina, Ina Körner

Waste streams as resource for composting -

Visualisation and assessment of quantity and quality data on biowaste streams in SOILCOM countries.



Report in the SOILCOM-Project:
Sustainable soils by quality compost with defined properties

Workpackage 4:
Waste streams

Technische Universität Hamburg, 2023

Phillipp Lüssenhop, Steffen Walk, Ina Körner
Waste streams as resource for composting -
Visualisation and assessment of quantity and quality data on biowaste streams in SOILCOM countries, TUHH, September 2023

Contact:
Hamburg University of Technology (TUHH)
Institute of Wastewater Management and Water Protection (AWW)
Bioresource Management Group (BIEM), Eissendorfer Str. 42, 21073 Hamburg

PD Dr. habil. Ina Körner (ORCID ID: 0000-0002-8937-5970), i.koerner@tuhh.de
Phillipp Lüssenhop (ORCID ID: 0000-0002-7056-6988, phillipp.luessenhop@tuhh.de

Further involved:
TUHH: Charitha Nelaturi, Özüm Su Baykan
VLACO: Vlaco vzw

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Content

Short summary

The SOILCOM project devoted workpackage (WP) 4 to the examination of waste streams for composting in the North Sea region. Specifically, the challenging household biowaste collection was investigated closely. This report summarizes the finding about the status of biowaste generation, collection of household biowaste for composting across SOILCOM countries It provides a comprehensive analysis of biowaste collection systems together with the resulting qualitites and quantities. The collected data was organised with the Bioresource Information Tool (BRIT), which was equipped with the new *Household Waste Collection* module, which allowes for collaborative data collection on waste streams into a homogenized database for the whole North Sea Region (NSR) and Europe. All raw data is publicly available and constantly expanded through the tool, building the foundation for the assessment and monitoring of the availability and efficacy of biowaste collection systems for composting, identifying underutilized streams, and identifying potentials to enable the production of various compost types. Beneficiaries and Associate Beneficiaries contributed data and expertise from all participating nations.

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Abbreviations

API:	Application Programming Interface
BGK:	Bundesgütegemeinschaft Kompost e.V.
BRIT:	Bioresource Information Tool
BW:	Biowaste
CRS:	Coordinate Reference System
ECN:	Europen Compost Network
EPSG:	European Petroleum Survey Group
ERD:	Entity Relation Diagram
FM:	Fresh Matter
FW:	Food Waste
GFT:	Groente-, fruit- en tuinafval (vegetable, fruit and garden waste)
GIS:	Geographic Information System
GW:	Green Waste
LAU:	Local Area Unit
LCA:	Life Cycle Assessment
MFA:	Material Flow Analysis
NSR:	North Sea Region
NUTS:	Nomenclature des unités territoriales statistiques
GPS:	Global Positioning System
TUHH:	Technische Universität Hamburg
WP:	Work Package

1 Introduction

This report summarizes the works and results of Work Package (WP) 4 “Waste Streams” of the SOILCOM project. It involves an evaluation of biowaste generation and collection, resulting biowaste quantities and qualities as well as the destination for treatment in the case of Northern Germany. The study area lies within the SOILCOM participating countries: Belgium, Denmark, Germany, The Netherlands and the United Kingdom, speficically in the North Sea Regions within these countries as defined by the INTERREG North Sea Programme 2014 – 2020 (keep.eu, 2023). The studied regions are shown in Figure 1.

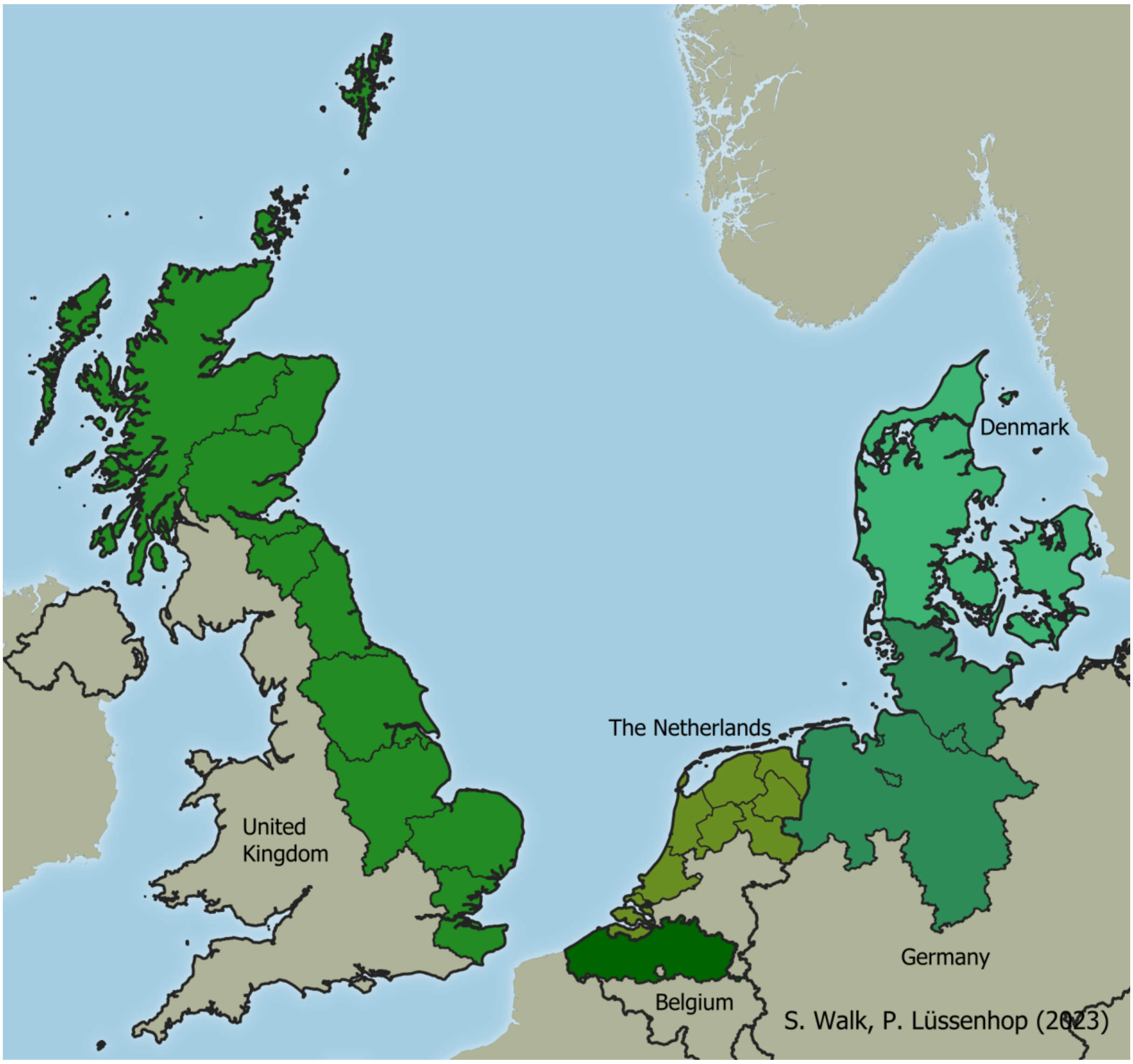

Figure 1: Participating regions in the SOILCOM project

Within these regions, waste streams, specifically food waste (FW), green waste (GW) and comingled biowaste (BW) were analysed, their suitability for composting was assessed, and the availability for composting purposes was illustrated.

"Municipal waste represents only around 10 % of the total waste generated in the EU, but it is one of the most complex streams to manage due to its diverse composition, its large amount of producers and fragmentation of responsibilities." (European Union, 2023)

This statement in the most recent *Early Warning Report* on the implementation of the Waste Framework Directive of the European Union underscores the challenges that management of food waste still presents in the EU.

At the same time it is technically a difficult resource for compost production. Pollution with plastic and other impurities (also see Körner et al. 2023), as well as high salt content and a large fraction of easily degradable organics present challenges for the composting plant operators to produce high quality compost from it. Additionally, there are conflicts of interest that need to be balanced. Initiatives to improve separation quantity, such as allowing or even providing biodegradable bags for the collection, can actually compromise the quality of the collected waste. Efforts to reduce overall food waste can influence both its amount and quality of available food waste for composting.

Despite these challenges, the European Union has set the goal for all member states that "by 2035, the preparing for re-use and the recycling of municipal waste shall be increaded to a minimum of 65% by weight (Council Directive (EU) 2018/851). However, according to the Early Warning Report of the European Commission, only 9 out of 27 member states are on track achieving the target numbers by 2035 (European Union, 2023). While all SOILCOM participating countries are regarded as low risk of missing the targets, there are large regional differences within this region and diversity in the biowaste management approaches and also in national statistics it shows clearly that there is a significant untapped potential. For example, in Germany, 40% of the waste in regular bins is food waste, which means there are opportunities to gain resources for composting while reducing residual waste that is not recycled. Organisations like the European Compost Network (ECN) are very interested in monitoring the regional differences and the developments to identify hurdles and best practices in order to help their members improve and be able to give fact-based high quality policy advice.

These factors collectively underline the importance of concentrating efforts on food waste. Therefore, WP4 of the SOILCOM project focused heavily on the generation and collection of household food waste streams as resource for composting to and the possibilities to improve the available quality and quantity through management practices.

The objective of this WP can be summarized as follows: collect data about collections and correlate it to quality and quantity data in order to have a large dataset, open to the public and transparent in all datasources. This will allow to identify success factors of high quality food waste management systems and describe best practices.

With the completion of WP4, a comprehensive understanding of the role of biowaste in composting and ways to maximize its usage have been developed, which will be beneficial for the subsequent stages of the SOILCOM project.

Maps serve a fundamental role in bioresource management by converting complex data into visual formats, thereby facilitating understanding across various stakeholders. They are especially useful for identifying regional trends, such as areas of high waste generation or low waste separation. This information is crucial for policy makers in identifying areas that may require targeted interventions. In the planning stage, maps can show the proximity of different types of bioresources, aiding in the formation of alliances or networks and informing investment decisions in treatment and recycling processes. Moreover, maps act as effective tools for public communication, providing residents with a clearer understanding of new programs, such as bio-waste recycling initiatives. They also play a role in monitoring and evaluation by visually tracking changes over time, which can inform subsequent policy and investment choices.

Central to the data organization in this work package is the Bioresource Information Tool (BRIT)[1], which was extended with a Household Waste Collection module alongside major refactoring of the existing modules to suit the purpose of the SOILCOM project. BRIT serves as a unified database that accommodates data from all North Sea Region countries. Data in BRIT is publicly available, and the tool itself is open-source. It offers functionalities for collaborative data collection and provides mapping and modelling capabilities for bioresources. The database is designed to be dynamically expandable while maintaining data comparability across different sources. BRIT enables contributions from both Beneficiaries and Associate Beneficiaries from participating nations.

[1] The Bioresource Inventory Tool (BRIT) holds the collected SOILCOM dataset and is available at https://brit.bioresource-tools.net

2 The Bioresource Information Tool

A significant part of the data collection involved the use of the Bioresource Information Tool (BRIT). This tool was extended with the Household Waste Collection module in order to serve as a platform for collaborative data collection of waste stream data within WP4 of SOILCOM.

BRIT is a modular system that provides infrastructure for collaborative data collection and its evaluation as well as visualisation for the domain of bioresource management. Its core principles are:

Modularity:
BRIT is not a monolithic tool but can be understood as a modular ecosystem in which each part serves its specific function. Each module should be as independent form the others as possible. This is the foundation for organic growth. Other developers should be able to easily expand the functionality of BRIT by simple adding more independent tools rather than having to understand the whole code base before being enabled to participate in the development. The modules of the core can be seen in Figure 2.

Interoperability:
A large focus during the development lied on creating a general purpose data structure. In the example of the household waste collection module that means that the database is able to describe waste collections as accurate as possible, while at the same time providing a scheme which is suitable for all household waste collections. This is achieved by the modelling strategy as outlined below in section 3.2. At the same time, the database should hold as much information as possible and provide the means to export the data into formats used by other tools, such as Material Flow Analysis or Life Cycle Assessment. BRIT should be the medium of information flow between existing data sources and existing tools as automated as possible

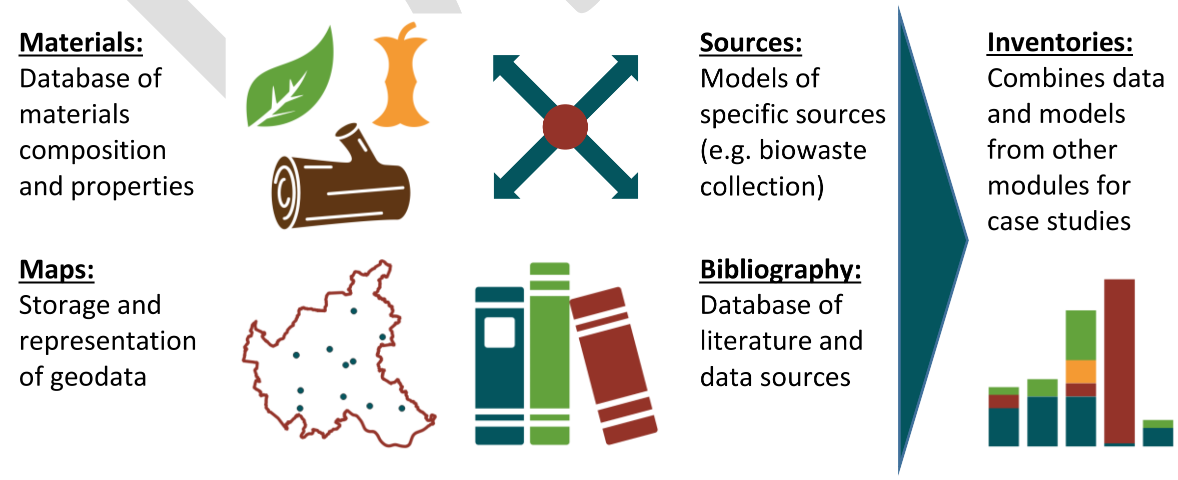

Figure 2: Core modules of the Biresource Information Tool

2.1 Purpose

The Bioresource Information Tool (BRIT) is a browser-based tool, designed to improve the understanding and management of biogenic residue waste streams. BRIT aims to offer stakeholders - from households and businesses to researchers and policymakers - a comprehensive view of the entire waste generation, collection, and processing landscape using mapping and visualization approaches. It is easily accessible and free to use. The available data can be explored via interactive maps in the browser. However, an integral part of BRIT's vision is to establish data sharing standards and unified structure models with in the bioresource management sector, enabling easy integration with other tools for purposes such as visualisation with a Geographic Information System (GIS) or modelling with Material Flow Analysis (MFA), Life Cycle Assessment (LCA), and Logistical Modeling tools through Application Programming Interfaces (API).

BRIT can effortlessly scale up as the demand on database size or traffic increase, thanks to its modular Docker containers and PostgreSQL database architecture.

BRIT is supposed to be a data source and link between existing monitoring and modelling structure, which holds to potential to automate many use cases for a diverse group of stakeholders, some of which are:

1. **Waste Producers (households, businesses, institutions):**
The tool is accessible through any standard web browser without the need for special hardware or software, making it easy for these users to learn about waste generation and collection in their region or anywhere else. In future versions, will be also include educational resources to help users reduce waste and recycle more effectively.

2. **Waste Collection and Processing Companies:**
The scalability and modular nature of BRIT allow it to adapt to businesses of different sizes and complexities. Even as their operations grow, the tool can handle increasing volumes of data and user traffic. Herein lie future business cases for the sustainable financing of the tool.

3. **Policy Makers and Regulators:**
The tool can provide them with reliable, accurate data collected and curated by experts in the field. This data can inform policy development and enable effective tracking of effectiveness of waste management practices. Future integrations with other tools (such as MFA and LCA) will provide even more valuable insights.

4. Environmental and Community Groups:
The transparency of the tool can facilitate their advocacy work. They can access accurate and comprehensive data about waste generation and management in their area. Since it's free to use and doesn't require any specialized hardware or software, it's accessible for groups with limited resources.

5. Researchers and Academics:
Researchers can use BRIT to identify trends in waste production or collection, or to study the impact of specific policies or social behaviors on waste production and management. With

its collaborative platform, BRIT offers the potential to build a community of researchers contributing and utilizing a growing database for their studies.

6. Investors and Industry Stakeholders:
The data provided by BRIT can identify investment and business opportunities in the waste management and bioresource industry. The planned customizability of the tool will enable stakeholders to tailor the data and visualizations to their specific needs.

2.2 Development context and history

The Bioresource Information Tool (BRIT) was developed through several international projects. These projects identified the need for this tool and contributed to its development and improvement. The SOILCOM project, in particular, was important for adding the Household Waste Collection module and improving existing modules of BRIT.

Initially, the DECISIVE project, funded by the European Union's Horizon 2020 program, aimed to develop a decentralized management scheme for urban biowaste. The project addressed the management of an estimated 96 million metric tons of urban organic waste in Europe by 2020. The need for a tool as data source for the various existing process and logistics models, capable of collaborative data collection and maintenance was first identified.

The FLEXIBI project, funded through the FACCE SURPLUS program, focused on the potential use of various types of organic residues as feedstocks for small-scale biorefineries. During this project, the proof of concept was accomplished that a tool for data collection and inventories could be built as easy to use online-tool, relying only open-source libraries. The name Bioresource Information Tool was coined and the first prototype was built.

In the SOILCOM project, BRIT was significantly improved, especially the user interface and usability across all modules. The tool was extended with the Household Waste Collection module, which was immediately applied for the collaborative data collection on biowaste collection systems in the North Sea Region. The practival application led to valuable user feedback, which in turn allowed improvements in the user interface and debugging. Towards the end of the project, collaboration for long term growth and maintenance of the collection database was started with the European Compost Network.

Future projects include the HOOU BioCycle project, which aims to improve BRIT's user experience and educational features. The proposed CLOSECYCLE project plans to expand the team, implement new interfaces, and add more data to the database. BRIT is expected to play a role in planning and data exchange in biorefinery networks.

2.3 Access

The source code is open sourced under MIT license and accessible through the GitHub platform: https://github.com/lueho/BRIT

Anyone is free to download the code and run their own instance. It is also possible to fork the code and customize it. However anyone who sees some room for improvement is encouraged to help and submit pull requests to the original repository to improve the original source for everyone.

A public instance, which incorporates the database that has been established in the development history is hosted by TUHH through the TU-Tech Gmbh. The funding for the host servers is secured for at least the next 5 years. Funding for the developer for maintenance and improvements is secured until the end of 2023 through the HOOU BioCycle project. Further maintenance and improvements would be secured until 2027 if the CLOSECYCLE project is approved. Apart from these concrete options, the plane is to further elaborate the tool, grow the database over time and keep the public instance running indefinitely. This instance is accessible through the web at:

https://brit.bioresource-tools.net/

As explained, the database is accessible through the tool either by visualizing it directly in the tool or by exporting it to csv or xlsx files. Both options are implemented in the tool and are accessible for registered users only to prevent excessive traffic through bots.

Apart from the live database, which will endure constant updates and maintenance, the 2022 snapshot of the household waste collection module will be accessible as file export as raw data publication on the TUHH TORE system.

https://tore.tuhh.de/home

3 Methodology

In WP4 of the SOILCOM project, a variety of tools and methods was utilized to achieve its objectives. The methodology was designed to gather, evaluate, and visualize data on biowaste generation, collection, and composting in the North Sea Region.

3.1 Mapping

For the purpose of structuring waste stream data, the Nomenclature of Territorial Units for Statistics (NUTS) and Local Administrative Units (LAU) classifications were used. The georeferenced datasets of the borders of administrative units are described by the NUTS and LAU geodatasets provided by Eurostat's GISCO service (Eurostat, 2013). These hierarchical systems are used within the European Union for statistical and administrative purposes. NUTS3 corresponds to smaller regions like counties, whereas LAU focuses on municipal-level units.

Utilizing NUTS3 and LAU serves multiple methodological purposes. First, it ensures data standardization across diverse geographical scales, enabling comparative analyses. Second, the granularity of these classifications allows for localized data collection and analysis, which is crucial given the varied waste management practices across regions. Third, this structured approach assists in targeted policy planning and resource allocation. Lastly, consistent categorization facilitates ongoing monitoring and evaluation.

For the combined use of different georeferenced datasets as applied by BRIT, using a common coordinate reference system (CRS) is crucial. The coordinate reference systems are commonly organised by a registry originating from the European Petroleum Survey Group (EPSG), called the Geodetic Parameter Dataset. Unique CRS are identified by EPSG: followed by a code.

For the purpose of this study, the newest at the start of the project extension SOILCOM+ available datasets were used. These are the LAU region borders and population numbers of 2020 and the NUTS dataset of 2021, both in the version with scale 1m and coordinate reference system EPSG:4326, which is the system that the Global Positioning System (GPS) applies.

In the Netherlands, several municipality merges took place on 1st of January 2022. These new borders are not yet reflected in the available georeferenced datasets on GISCO. This was corrected using a correspondence table provided by Eurostat. (Eurostat, 2022)

In some cases, the borders of waste management responsibilities do not match the exact borders of regular administrative units. This is especially the case, when municipalities organise their waste management jointly. In that case, new borders where created

3.2 Biowaste collection modelling

The modeling of the separate biowastewaste collections followed a structured, multi-step approach:

1. **Data Collection:**
Websites from responsible waste collecting entities containing sorting instructions, collection calendars as well as waste management concepts were collected and analysed to provide foundational data. A total of 3930 separate websites were assessed describing waste collections in the SOILCOM project area (see section 1) as well as the rest of Germany and Belgium, respectively.

2. **Ontology Creation:**
In the context of system or structure modeling, an ontology serves as a schematic representation of a particular knowledge domain. It delineates the existing concepts within that domain, outlines their interrelationships, and specifies the governing rules. An ontology was developed, specifying key aspects such as the collection system and waste categories, to guide further modeling.

3. **ERD Development:**
The Entity-Relationship Diagram (ERD) is a conceptual tool used in database design to visualize and describe data interrelations. A normalized ERD was created to schematically represent the waste collection data.

4. **Model Integration:**
To ensure that the newly created ERD was compatible and scalable with existing models, it was integrated into the pre-established model ecosystem.

5. **Database Implementation:**
The ERD was imported into the PostGIS database, chosen for its geospatial capabilities.

6. **Data Entry:**
Information, conforming to the ontology and ERD, was input into the PostGIS database.

7. **User Feedback & Adaptation:**
The database was refined based on feedback from users who were responsible for the data input and found edge cases that were not considered in the original data structure.

3.3 Embedding of statistics

The base dataset of collection was expaned with statistics about collected waste amounts. These numbers stem from various sources, such as national statistical bureaus of SOILCOM participating countries, open data services or direct publications from the waste collectors. The respective datasources are described in the result section, together with the maps.

3.4 Data visualisation

QGIS, an open-source GIS software, was employed for the specialized visualization of waste collection data, which had been organized using the BRIT. The data could be retrieved directly from the PostGIS database created be BRIT, using QGIS' ability to create SQL layers.

Within QGIS, the data from BRIT was visualized, highlighting various facets of waste collection such as administrative level, collection system and per capita amounts.

4 Biowaste collection systems

In the North Sea Regions of the SOILCOM participating countries 507 individual waste collection catchments where identified, of which 471 had established some kind of separate collection for food waste collection, either completely separate or comingled with green waste as mixed biowaste. These collections plus found collections in the rest of Belgium and Germany, respectively, were analysed and categorized.

The following categories where found as suitable ontonology for the description of separate biowaste collections in the identified areas.

1. COLLECTOR:
This entity represents the individual or organization responsible for waste collection. They organize collections and are responsible for specific catchment areas.

2. CATCHMENT:
This entity represents a specific geographical area where waste is collected. Each catchment area is managed by a collector and has collections organized within it.

3. COLLECTION:
This entity represents the act of waste collection. It is organized by a collector, occurs in a catchment area, collects specific waste streams, applies a collection system, has a frequency, and is described by a waste flyer.

4. WASTESTREAM:
This entity represents a specific type of waste that is collected. Each waste stream belongs to a waste category and allows or forbids certain materials.

5. COLLECTIONSYSTEM:
This entity represents the system or method used for the collection. It is applied in a collection.

6. FREQUENCY:
This entity represents how often the collection occurs. It is associated with a collection and has specific seasons and options.

7. WASTEFLYER:
This entity represents a document or information source that describes a collection.

8. WASTECATEGORY:
This entity represents a category of waste. Each waste stream belongs to a specific waste category.

9. MATERIAL:
This entity represents the types of materials that are allowed or forbidden in a waste stream.

10. SEASON:
This entity represents a specific time of the year. It is associated with the frequency of a collection.

11. OPTIONS:
This entity represents the different options available for a frequency.

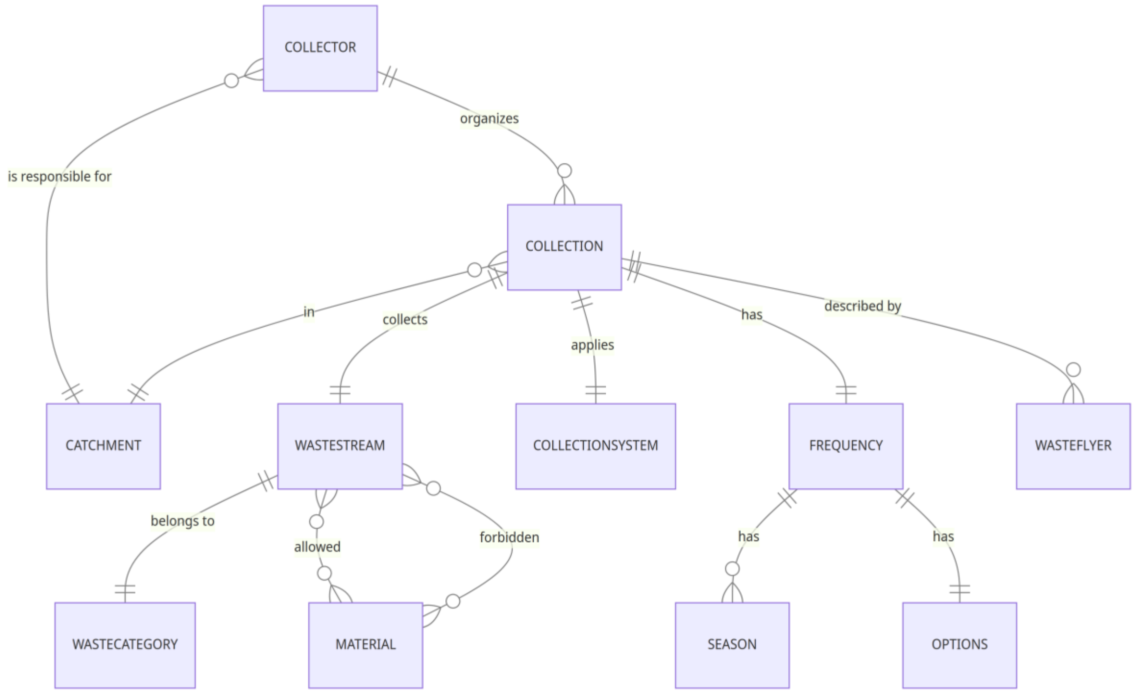

Figure 3: Simplified ERD of the household waste collection module database

The simplified ERD of the collection model, that was created following the procedure described in section 3.2 is shown in Figure 3. The complete data structure and integration into the BRIT database can be seen in the BRIT Github repository (see section 2.3). This data structure could describe all collections for which information was available at the end of SOILCOM. However, it must be noted that not for all collections within the target region all information was found, yet. The level of detail to which the regions are modelled varies country by country (see Table 2) for details.

The first thing to note is the administrative level at which the collectors operate. As can be seen in Figure 4, Denmark and The Netherlands organise their collection entirely on the local level, which corresponds to the LAU regions. The waste collection in Belgium is organised by public private partnerships that have individual borders of operations, that can be described as a merger of various municipalities. In Northern Germany, the waste collections is mostly organised on the county level, with few exceptions. The United Kingdom generally organises on the LAU level but has exceptions. Notably, the north of Scotland has an individual solution.

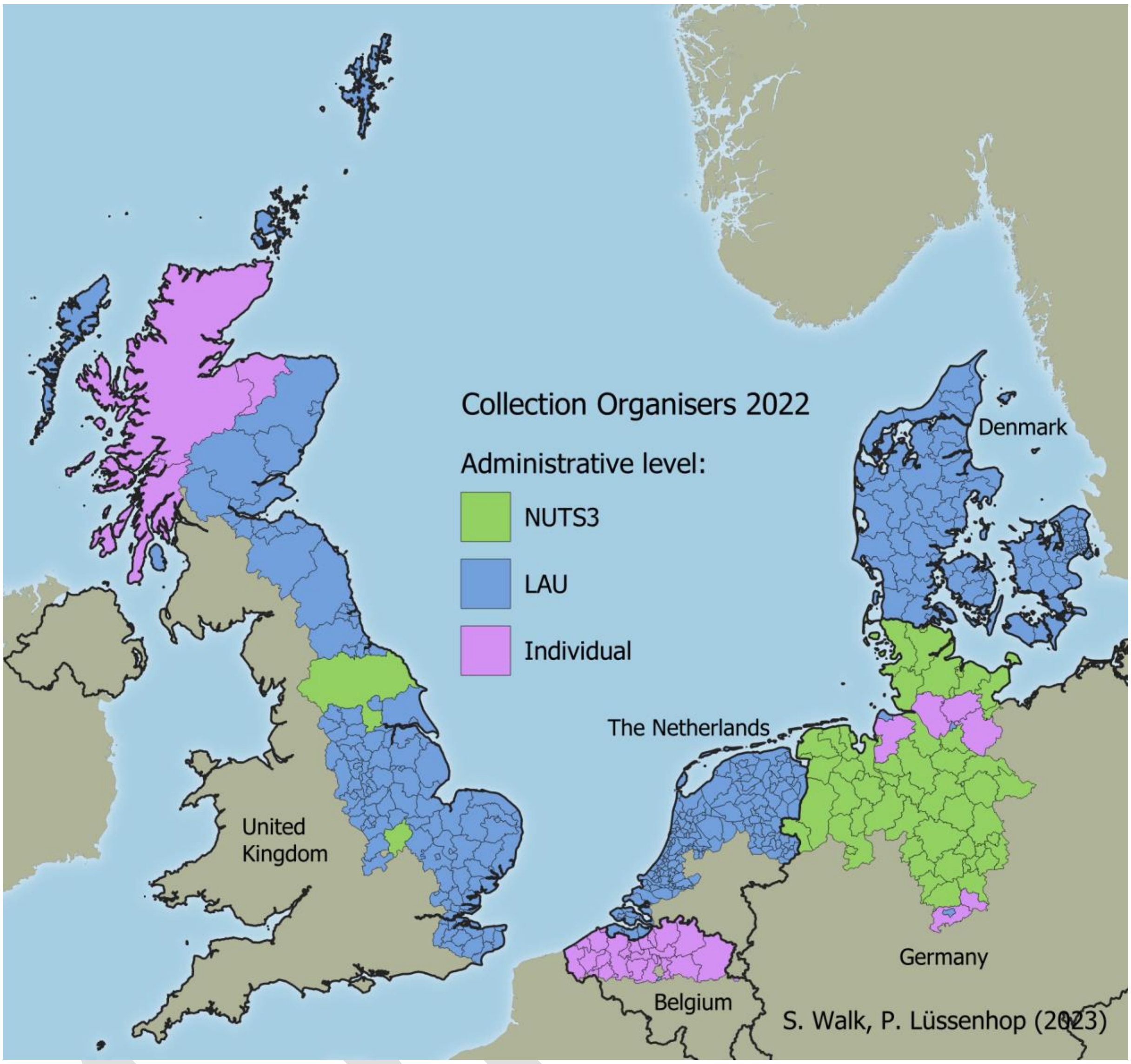

Figure 4: Levels of organisation of BW separate collection in the NSR

For further clarification on what the LAU and NUTS3 regions mean in each of the countries, Table 1 outlines the equivalent local expression for the administration level for LAU and NUTS3 in each country respectively

Table 1. Equivalences of regional administrative level of LAU and NUTS3 regions

Country	**LAU**	**NUTS3**
Belgium	Gemeenten (Municipalities)	Arrondissementen (Districts)
Denmark	Kommuner (Municipalities)	Landsdele (Regions)
Germany	Gemeinden (Municipalities)	Kreise (Counties)
Netherlands	Gemeenten (Municipalities)	COROP Regio's (Cooperation Regions)
United Kingdom	Lower tier authorities (Districts)	Upper tier authorities (Counties)

For the majority of collection catchments in the investigated North Sea Region, at the end of 2022 there was a separate collection of food waste available through a door to door collection system. This is in accordance with the low risk of failing the goals of the Waste

Framework Directive attested by the most recent early warning report (European Comission, 2023).

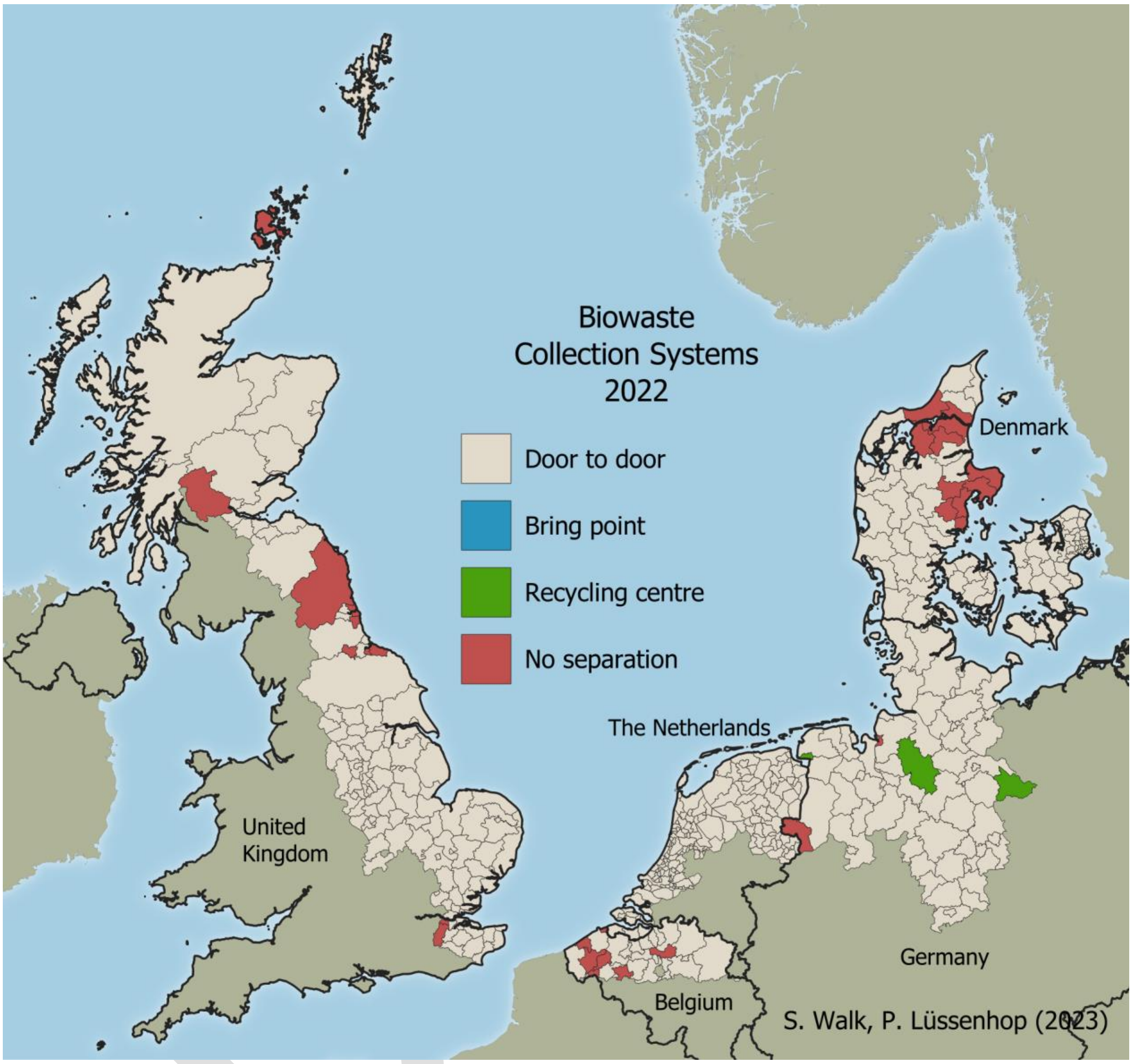

Figure 5: Collection systems for separate BW collection in the NSR

The environmental ministry of Denmark has published a detailed plan on the connection of Danish municipalities to such a system. By the end of 2024 all municipalities will have a food waste separation system established (MST, 2022). Several British regions that had no separate collection at the time had announced the start. It can be said, that the whole region is finishing its process of establishing separate collection systems and there is movement in the topic. Hence, maintaining the database in the BRIT tool and giving annual updates on the progress would be appropriate.

The quality of the data collected for the waste collections system analysis presented varying degrees of complexity across regions. The local variance of the collection systems, especially in Germany was broader than initially anticipated, leading to a few challenges. Language barriers, particularly in the Netherlands, Denmark, and Belgium, added a layer of difficulty to the data collection process. In contrast, native German language proficiency proved beneficial, simplifying the data gathering task. Furthermore, we experienced a reduced level of participation from our British partners than previously planned, which slightly impacted the comprehensiveness of our data. On a positive note, our strong network connections through VLACO in Belgium significantly facilitated data collection, underscoring the importance of local partnerships in such endeavors.

Table 2. Collected waste stream data quality rating in SOILCOM by country

Factors	Data Level of Detail	Language	Contact
DE	+++	+++ (native)	+++
BE	++	-	++
GB	+	++	--
NL	+	-	-
DK	++	-	-

Raw data on several more aspects of the waste collections is available within the BRIT database. E.g. for whole Germany the complete fee system and collection frequency data as well as allowed and forbidden materials are available. For Belgium, the complete fee system is available. Due to the varying level of detail of the available data, it was not sensible at this point to create a map of every aspect. However, the data collection continues beyond the scope of the SOILCOM project and an update for the state 2023 is planned.

5 Biowaste quantity

Quantity and quality of the collected biowaste are the two most important factors to determine the efficacy of the separate collection system and its usefulness for gathering valuable resources for composting. The aim of the biowaste management is to improve both. Though in many cases this can mean optimizing for two contradictory goals. Measures to increase the collected quanitity, e.g. by providing convenient underground collection bins for multi family homes can lead to a decreased quality e.g. through misuse enabled by greater anonymity.

Data on collected waste amounts is collected by authorities in all SOILCOM participating regions. Its availability and usability varies, though. While for the Denmark, The Netherlands and the United Kingdom, biowaste collection statistics on a regional level are available online (MST 2022; CBS 2023; WasteDataFlow 2023), in Germany, the regional waste data is not published in a central accessible location. The data from the individual collectors is collected and aggregated by the responsible minitstry in the respective federal state but not necessarily published on a regional level. On request, however, the data could be gathered either from the individual collectors or the respective ministry. The complete dataset for Belgium could be provided by VLACO.

Figure 6 displays the specific collected biowaste for all North Sea Regions where it was available at the time of writing. Not all datasets where available for both years, 2020 and 2021. In order to give a complete picture, the average of the years 2020 and 2021 was calculated.

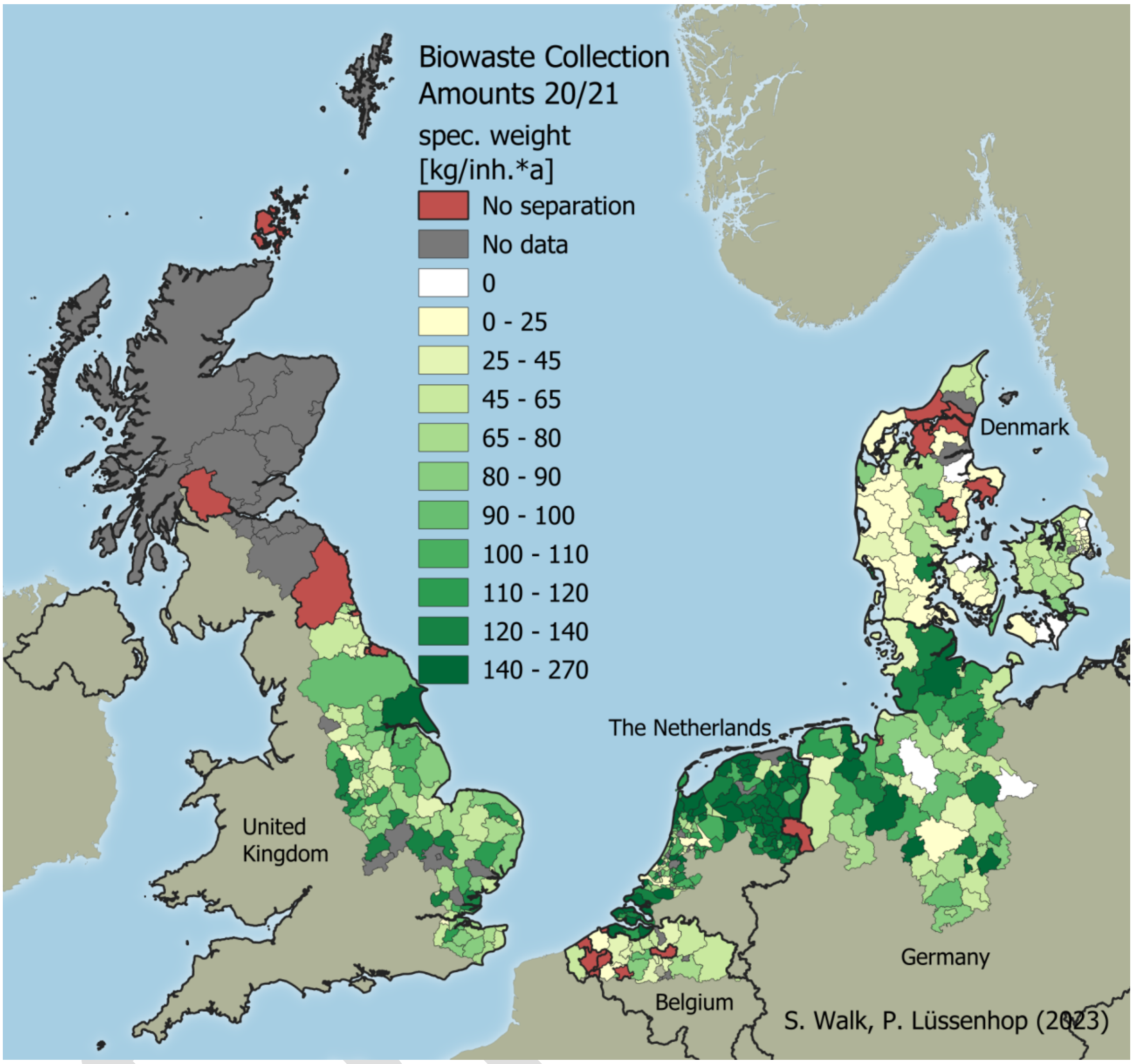

Figure 6: Collected BW amounts as kg per inh. per year in the NSR in 2021/2022

As can be seen in the map in Figure 6, specific biowaste collected ranges from 0 to 270 kg per inhabitant per year. The highest numbers are reported in The Netherlands. Denmark and Belgium report lower values and more regions, which have not implemented any separate household biowaste collection. One major factor that leads to the discrepancy is the waste category of the collection system. In many regions in Denmark the separate collection is explicitly for kitchen waste and not for garden waste. The official number published by the MST refer to that. In Germany and The Netherlands, commonly kitchen waste from households is comingled with garden waste. In The Netherlands, Groente-, fruit- en tuinafval (GFT), which means vegetable, fruit and garden waste and, contrary to the name may also include anibmal-based food waste, depending on the guidelines of the collector. or Biomüll (DE). In Germany, Bioabfall means the same. However, there is a large variance among the individual catchments in Northern Germany about which materials are allowed in the biobins.

Notably, the UK has an outstanding reporting system. Contrary to the others, the main report is about the amount of waste, which was recycled and in which plant and with witch process. Additionally, the numbers are collected quarterly and the whole record is publicly available in the WasteDataFlow database (WasteDataFlow, 2023). This procedure leads to some problems homogenizing the data with reports from the other countries. However, this way of reporting allows to map waste streams from source to sink, which is in line with the long term goals of BRIT. It is therefore a valuable data source for this purpose.

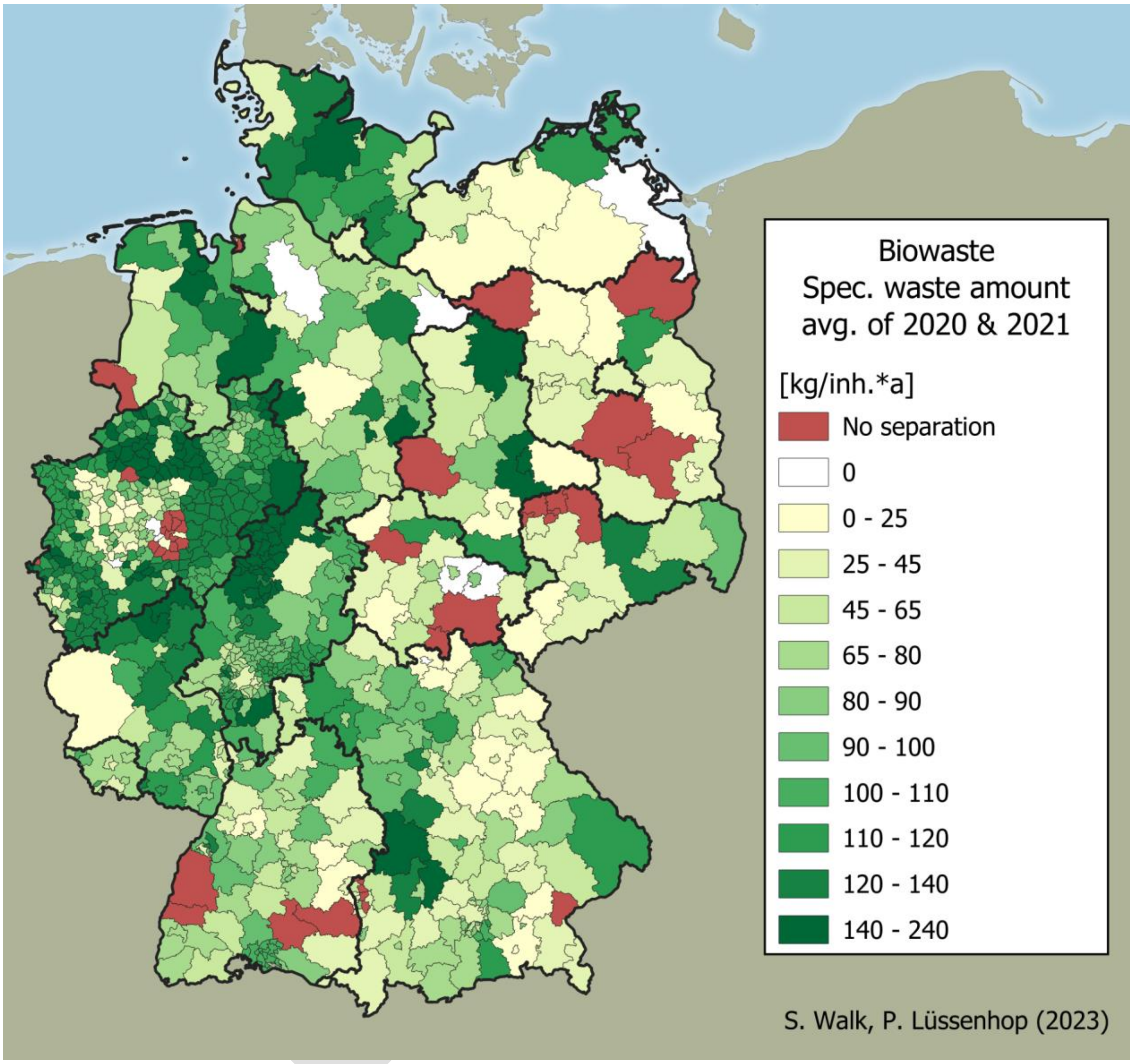

Figure 7: Collected BW amounts as kg per inh. per year in Germany in 2021/2022

For comparison, the map in Figure 7 shows the specific waste collected for whole Germany. It becomes clear that even within a country, the regional differences are vast and a national average by no means reflects the efficiency of a system if the variance within the system is as large as is the case in Germany. Higher waste collection values typically result from mixed biowaste collection. This is, for example, especially the case in Germany where mixed biowaste collections constitute the vast majority of separations systems for households (see section 3). This plays into the quality of the waste and the options for processing. As discussed in the beginning of this section, the quantity must be looked at together with the quality.

Despite data constraints, the insights from the available data underscore the importance of understanding biowaste collection patterns. To foster sustainable bioresource management and effective composting practices, there's a pressing need for more consistent data collection and an appreciation of the significance of biowaste components. Future studies should delve deeper into countries with limited data to offer a holistic view of the NSR's biowaste landscape.

6 Biowaste quality

As indicated in section 1, the existing separate collection systems in the North Sea Region fail to captrure a significant amount of the biowaste's potential. At the same time, many farmers display reluctance toward using compost derived from biowaste, which includes kitchen waste. A survey disseminated among northern German farmers was conducted to evaluate their attitudes and experiences with compost. A major finding was the prevalent concern regarding contamination of compost, particularly microplastics. An in-depth discussion of these survey results is available in the report of Workpackage 5 (Körner et al. 2023).

In the initial stages of the SOILCOM project, German farmers exhibited reservations about using composts, mainly due to concerns over contaminants like plastics. However, a significant proportion were cognizant of the benefits of compost. These observations were gathered from a SOILCOM questionnaire distributed in 2020, aiming to understand both the patterns of compost usage among farmers and their reasoning behind such practices, including any hesitance to use compost (Körner et al. 2023).

While there are quality criteria and established licencing bodies for compost in all SOILCOM participating countries quality criteria for biowaste are hardly regulated. Among the SOILCOM participating countries only Germany has control values for impurities anchored in regulation. The control value for all impurities is 3 weight-% and 1 weight-% for plastics BioAbfV (2022).

As the effort of waste analyses is high and there is not regulatory pressure, there is little data that is published about biowaste quality. The used data was found either puhlished directly online or provided voluntarily by the responsible collection organizing company. It can be assumed that other companies conduct analyses as well but keep them completely internally.

From the time frame of 2016 to 2022, 65 waste composition analyses could be found, distributed in Germany as shown in Figure 8. These cover 26% of the German population. Analyses were available for 50 areas concerning biowaste and for 53 areas concerning residual waste. Of these, both BW and RW were analyzed in 38 regions, representing 14% of the population. Regions analyzed solely for BW represented 3% of the population, while those solely for RW represented 8%. Regarding urbanization levels, 44% of the analyses were from rural areas (≤ 300 inhabitants per km²), 36% from intermediate areas (> 300 and ≤ 1500 inhabitants per km²), and 20% from urban areas (> 1500 inhabitants per km²). When evaluated for representativeness among federal states, the greatest coverage was noted in Niedersachsen and Schleswig-Holstein which lie within the North Sea Region as well as Rheinland-Pfalz, while Hessen and Mecklenburg-Vorpommern showed lower representativeness.

Additionally, two regions employ a bringpoint collection system for biowaste, and one region utilizes an recycling centre collection system, although collected quantities were not reported for the latter. One region does not have a separate collection system for biowaste.

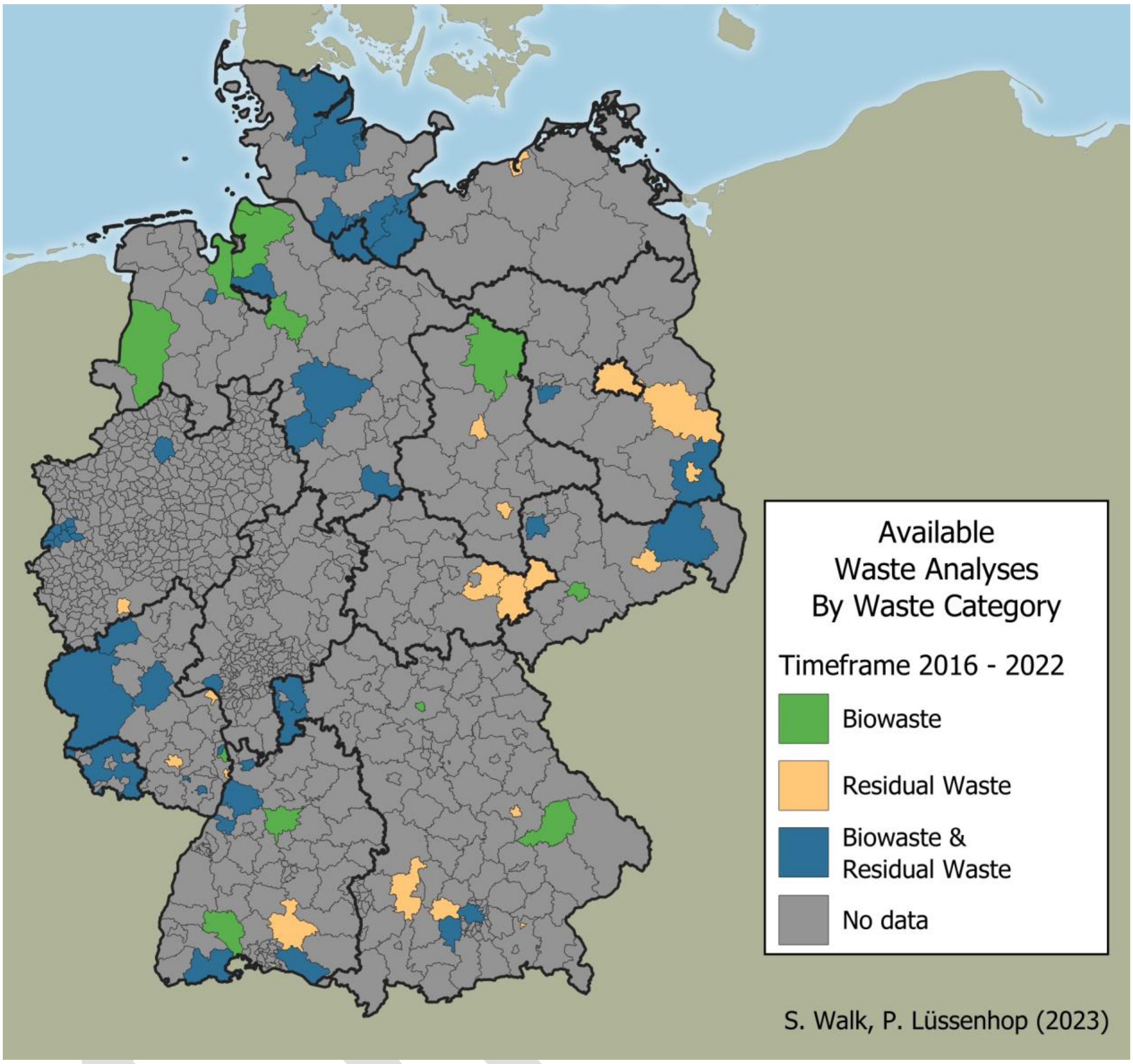

Figure 8: Regions in Germany with available waste quality data.

Many collectors don't publish their data and hand it out only on request. In order to comply with the wish not to publish any data that could be traced directly to the waste collecting entity, the data is presented without any link to the actual source. For the same reason, only a selected number of analyses can be published in the BRIT database. Figure 9 shows the results of eligible waste analyses with respect to their level of impurities compared to the control values of the waste ordinance. 33 out of 50 analysed the specific plastic impurity level, the rest only total impurities. The result is mixed. 37 stay below the required total impurity level of 3%, while 13 are above. Four of the too high values are even above 6% i.e. double the control value. Out of the 33 entities who reported on plastic impurities, 28 comply and 5 are above the line.

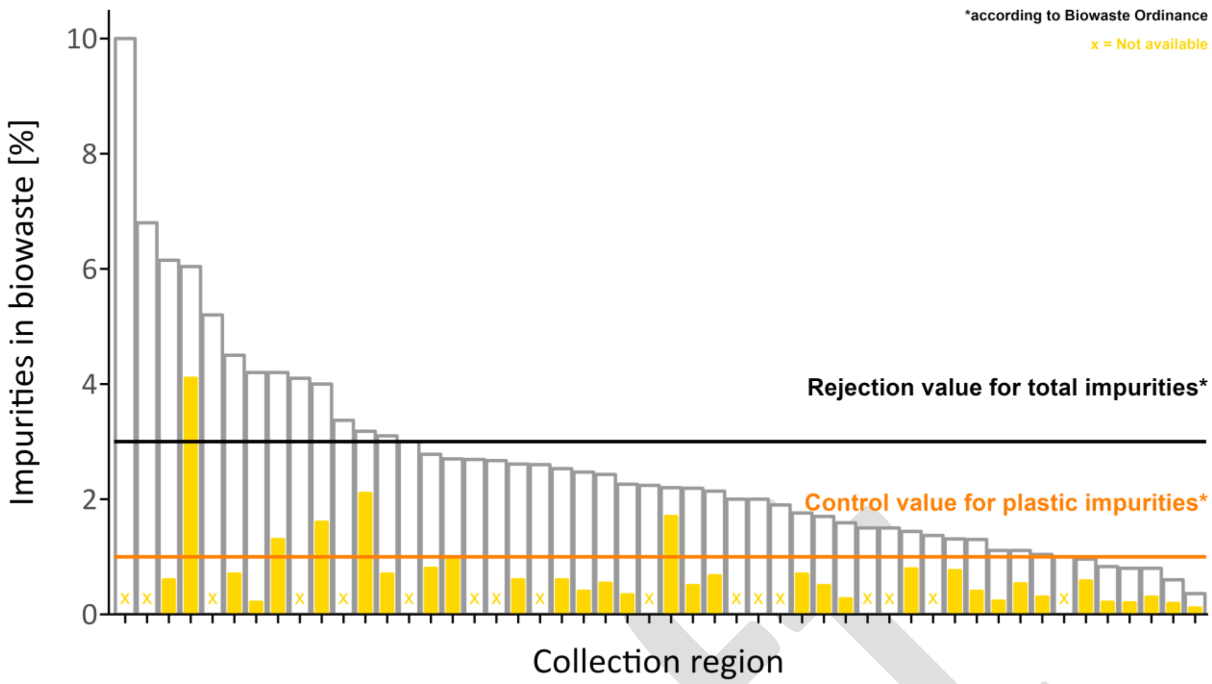

Figure 9: Impurities and cotroll values in BW analyses in Germany

The majority of published waste analyses in Germany remain under the threshold of 1% that is mandated by the ordinance. However, it must be noted that waste collectors conduct waste analyses for their own purposes and are not obligated to publish them. Due to that fact, it can be assumed that there is a certain publication bias, as waste collectors might be hesitant to hand out analysis results if they don't comply with regulation.

Figure 10. displays the same samples as histograms. It appears that exactly at the control values, there is a steep edge where published results dramatically reduce in numbers. One could expect a more homogeneous distribution in reality. This seems to support the hypothesis of a publication bias that limits access to bad results.

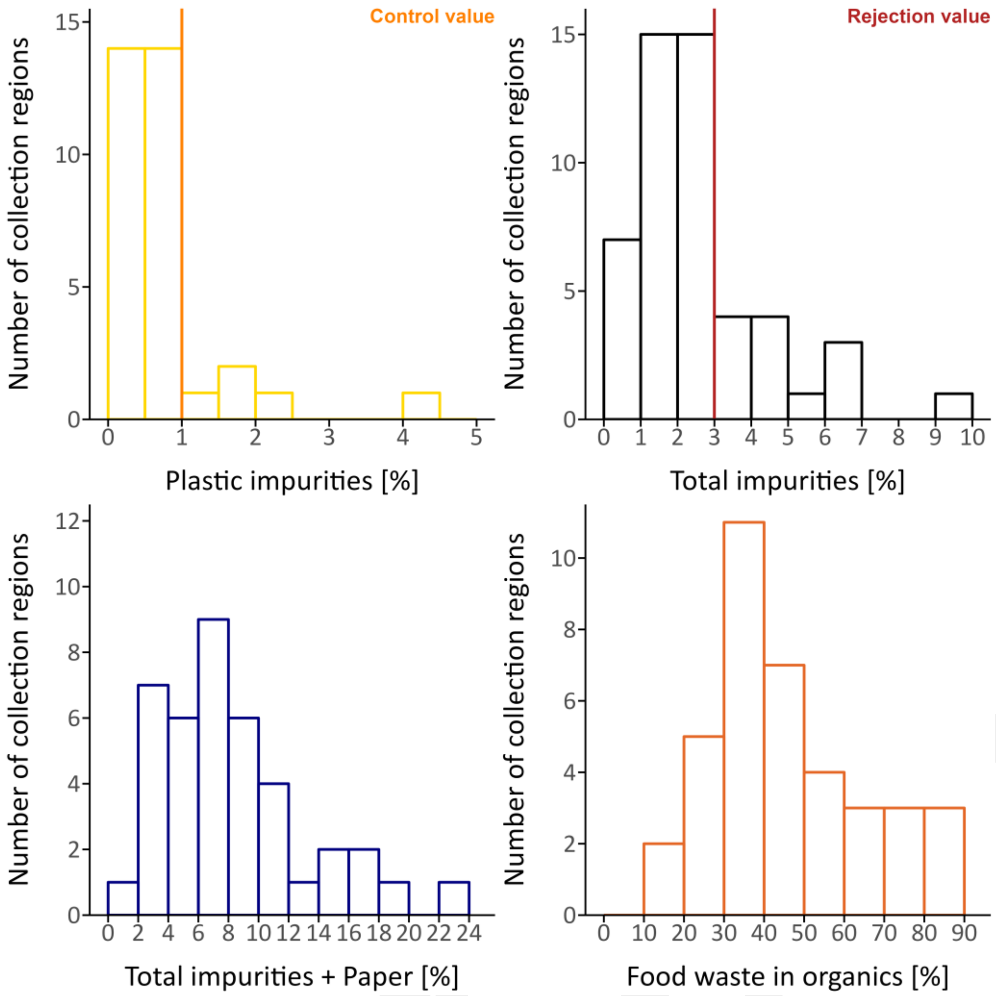

Figure 10: Measured impurites in biowaste compositin analyses in Germany 2016 – 2022

7 Biowaste treatment facilities

Germany:

There are two organisations in Germany that have a good overview over the treatment facilities that are used for biowaste treatment in Germany.

- BGK: Bundesgütegemeinschaft Kompost is the compost certification agency in Germany. All composting plants that want to distribute licenced compost must be registered with the organisation and therefore, they have an ubundant dataset about composting plants in northern Germany. Composting plants that are operated for own consumption, e.g. by municipal gardening and landscaping companies might not be registered and might be missing in the dataset. The data is proprietary to the organisation and thus cannot be included as open data into BRIT. However, a map visualisation of the data is published on the website and can be explored there. (BGK, 2023)
- Witzenhausen Institut: The institute has a comprehensive dataset of biogas plants that are used for the treatment of residues. The data is proprietary and thus cannot be puclished in BRIT. It is however published on a bi-annual basis by Witzenhausen Institute in a printed form. The main data for this report could (Kern & Raussen, 2021)

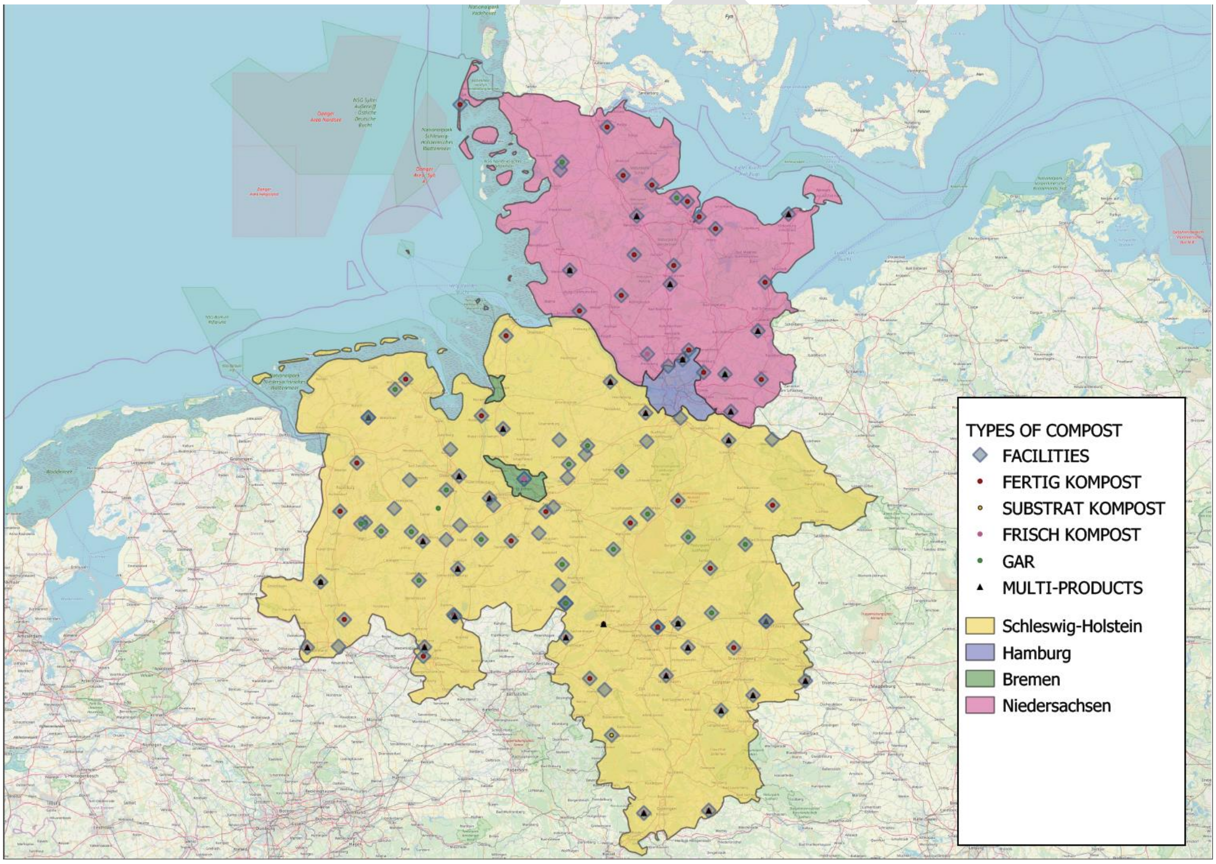

Figure 11: Map on the investigated biowaste processing facilities in Northern Germany

The "Biogas Compendium 2021/22" is a manual on waste-to-biogas plants in Germany and Europe, which is being updated for the third time and published in English for the first time. It includes 123 plants in Germany and 162 in other European countries, with a focus on biogas plants that utilize organic waste, excluding those based on energy crops. The manual highlights the optimistic outlook for the waste management sector, where biogas is seen as a central player in a renewable energy economy. The potential for biogenic waste fermentation and energy recovery remains high, and biowaste fermentation can help limit climate change by generating renewable energy and preserving essential raw materials. The aim of the Biogas Compendium is to provide an updated overview of biogas plants for biogenic waste from households and commercial sectors in Germany and Europe, though the documentation may not be complete and may be further expanded in the future (Kern & Raussen, 2021). General Information about the Plants There are in total 18 biogas plants that run on biowaste in the federal states of Lower Saxony and Schleswig-Holstein. The study area also covered the city-states Hamburg and Bremen, however, there are no biogas plants covered in the manual in these cities. This is understandable as these plants often raise nuance complaints and it is challenging to select a site to construct treatment plants in populated cities (Mazzanti et al., 2021). Overall, the total planned capacity of all plants is 750,000 t/a while the total used capacity is approximately 650,000 t/a. 80% of the input comes from food waste while the rest is mostly consisting of garden waste and some commercial waste. The total amount of marketed compost generated by the plants is 176,000 t/a with RAL certificate. It is important to state that 6 of these plants did not report any amount of marketed compost as output. Used Capacity The used capacity is an important parameter to understand the size of the plants. It is also a good indicator of the amount of marketed compost as there is generally a positivecorrelation between the amount of inputand output. The intervals for differentsize classes were selected using thequantile (equal count) mode toapproximately have similar numbers ofplants in each size class. The smallestplant has a used capacity of 2,000 t/awhich is an outlier in the dataset whilethe biggest plant has a used capacity of122,000 t/a. Most of the plants are in therange of 15,000 to 60,000 t/a used capacity.

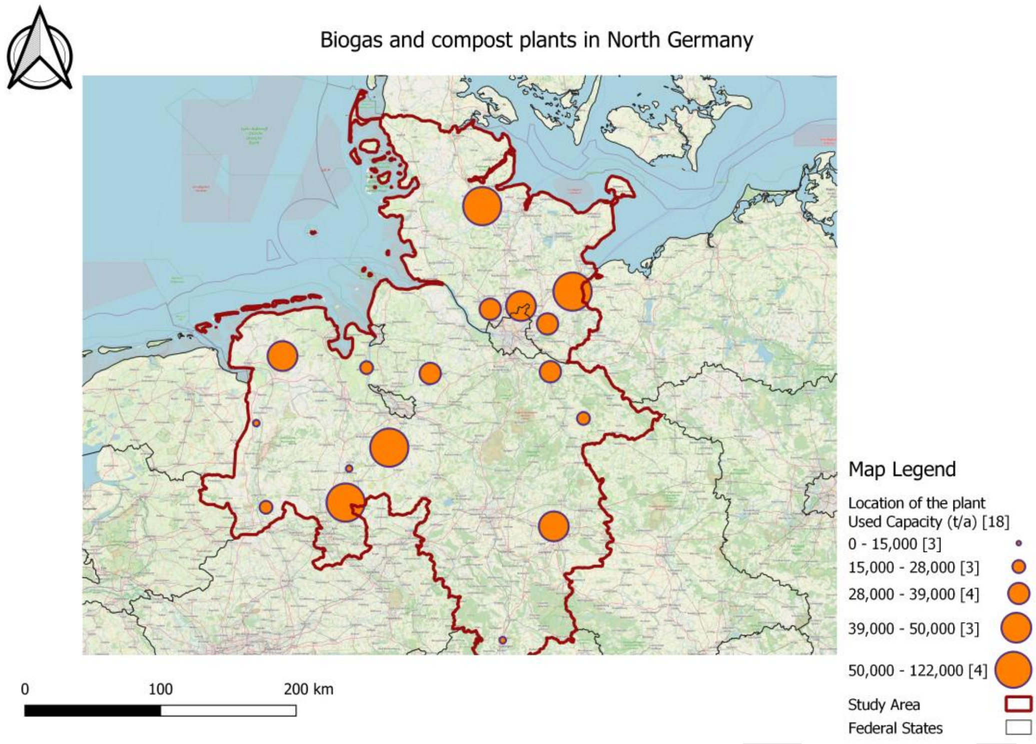

Figure 12: Used capacity of biowaste processing facilities in Northern Germany

Hygienisation of biowaste is an important concern for the land application of compost. Pathogens are deactivated during the process through elevated temperatures and microbial competition which results in stable humus-like products (Gurtler et al., 2018). Anaerobic digestion (AD) is also a widely utilized process for the stabilization of biosolids that is highly effective in rendering viable pathogens, including parasites and viruses, inactiveand reducing the presence of those harboring antibiotic-resistance genes (Zhao & Liu, 2019). As can be seen in Figure 13, composting is the mostcommon hygienisation method with 11 plants implementing it. It is followed by fermentation while some plant simplement less common methods.

Figure 14 displays the amount of marketed compost in the North Sea Regions in Northern Germany, which is an important parameter to quantify the potential of compost that is currently available to growers and farmers in this region. 6 of the plants have not reported the amount of marketedcompost. The range of size classes was again selected using the quantile mode in QGIS. The amount of compost ranges between 3,000 t/afor the smallest plant to 33,000 t/a. It can evidently be seen that the plants which receive more input generate more compost than the plants with lower input.

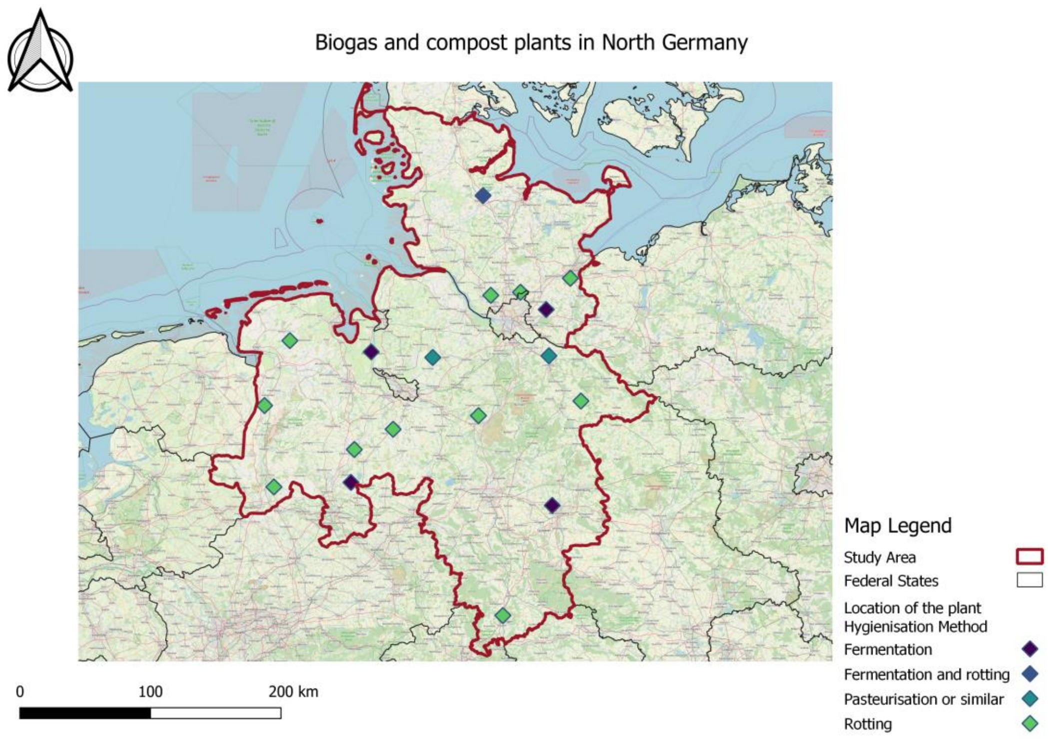

Figure 13: Hygienisation methods biowaste processing facility in Northern Germany

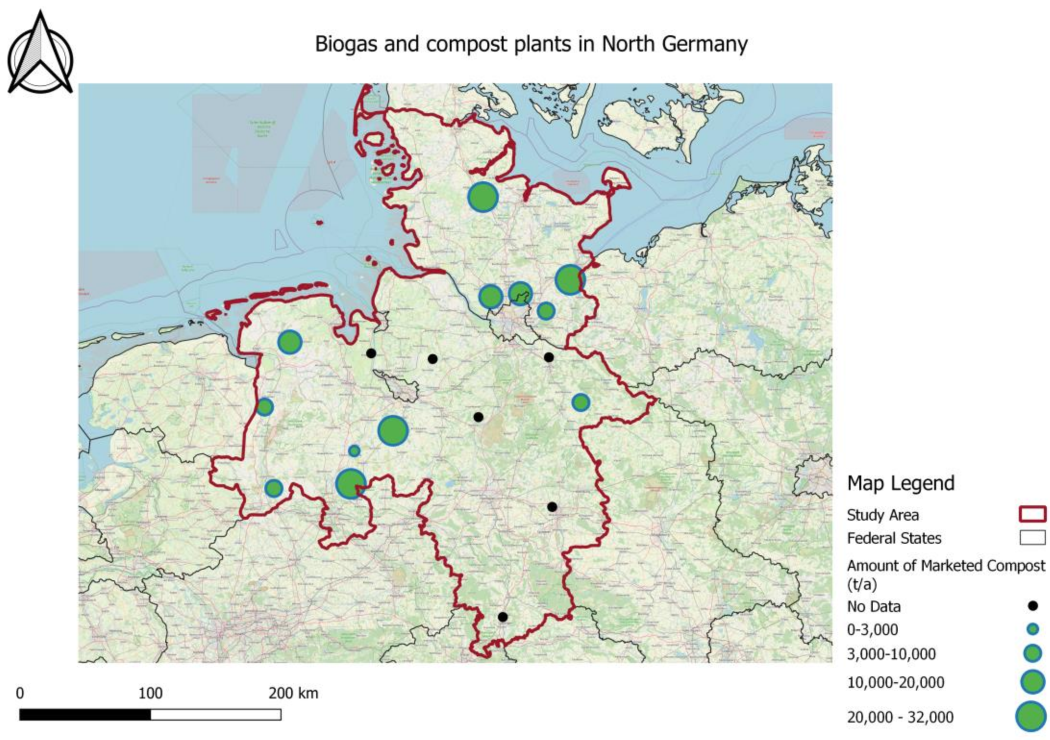

Figure 14: Marketed compost by BW processing facility in Northern Germany

Figure 15 shows the unused capacity of biowaste processing facilities in Northern Germany, which was derived from the difference between the planned capacity for marketed compost. Most of the plants are run at less than their full capacity meaning that if all the plants were run under full capacity, the total input toplants would be approximately 100,000 t/a more organic waste. As can be seen in Figure 15, 3 plants are already run at their full capacity while there are 4 plants that have a free capacity between 10,500 t/a to 25,000 t/a. It must be stated that one of the plants namely Bioabfallvergärungsanlage Bomlitz/Benefeld has 25,000 t/a free capacity and was in the planning phase when the book was published and started operation at the beginning of 2022, suggesting that the data for this plant must be updated for more accurate results (Kompotec, n.d.). Using the linear interpolation method, the amount of compost if all the plants were run at full capacity is estimated at approximately 200,000 t/a.

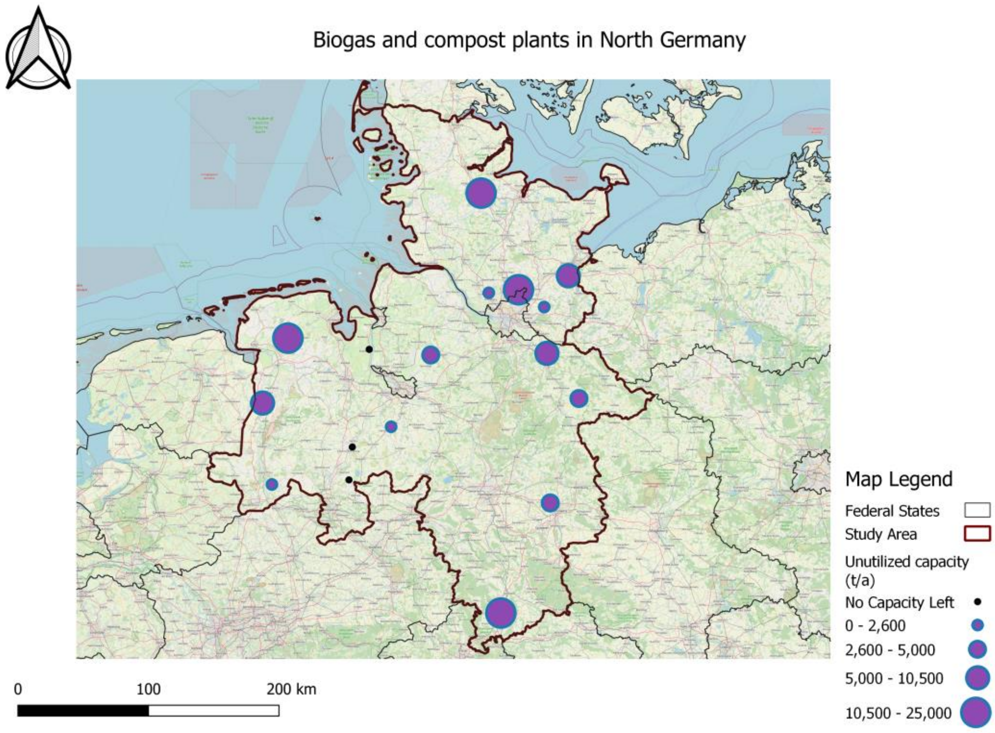

Figure 15: Map of free capacity of biowaste processeing facilities in Northern Gemany

8 Conclusion

Mapping waste streams remains complicated because of the diverse data that is not collected in one place. The aim of BRIT is to fix this and provide a single place where data is collected collaboratively by all stakeholders who also benefit from the common data source.

Finding a methodology to combine the various different data sources was not easy. However, with BRIT in place and the interest of the Stakeholders, the data collection can continue and improve within the North Sea Region and be applied to other EU countries as well.

This shows that there is a demand for open science and open data approaches, which is one of the main issues addressed by BRIT. It is to be noted that there is a publication bias, where owners of data prefer publishing data that sets them in the right light and withholding other data that would be suitable to bring possible problems to the light. One example here would be biowaste quality data, that might expose collectors

SOILCOM proved to be valueable to create a communicative bridge between waste management companies and growers. Already in the beginning of the project it became clear that both worlds face a different reality that they have to adapt. Waste management has not yet seen the compost it produces as a valuable product to their clients that can be optimized not only for speed and cost of production (in the eyes of waste management waste treatment) but also for the benefit of the growsers. At the same time, during the course of the project, the value of compost has increased during the course of the project. While in the beginning, compost producers at times had difficultis finding comsumers for their compost, during the last years of SOILCOM, the situation as improved a lot and compost has become a rare resource that farmers would like to get their hands on. While this is partly a good sign, one must not overlook the fact that this development is largely driven by economic factors, such as high fertilizer prices after the energy crisis caused by the invasion of Russia into Ukraine. Especially, as the widespread adoption of composte from waste streams is developing, it becomes more important to tap the unused potential of currently unseparated waste while at the same time getting the pollution problem, especially with plastic under control in order to actually keep the promise of soil improvement rather the soil pollution with compost. The key challenges remain in the regional biowaste management, for which SOILCOM has contributed tools for improvement.

9 Outlook

The SOILCOM project was a great achievement to collect a lot of data already and build a network. With the European Compost Network Separate Collection Task Group, already a strong partner is on board with dedication to maintain an promote the content. The database structure is in place and BRIT is operational. With the cooperation with ECN and its members, the dataset can now continuously improve and grow within the North Sea bordering countries as well as spread to other countries. With the growing dataset and growing interest, possibilities for isolating best practices through big data analysis or directed searches become more.

In the future, the extended application of the tools developed in SOILCOM will have to be increased in order to reach their full potential and have a large scale impact on the soil quality in the North Sea Region and Europe.

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