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D7.8 – Business concept case study in the context of a Northern German city

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DECISIVE

A DECENTRALISED MANAGEMENT SCHEME FOR INNOVATIVE VALORISATION OF URBAN BIOWASTE

This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 689229.

A Decentralised Management Scheme for Innovative Valorisation of Urban Biowaste

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Table of content

DECISIVE

Abbreviations

BMC	Business model canvas
BW	Biowaste
BWB	Biowaste bin
CAPEX	Capital costs
EBL	Lübeck waste management (Entsorgungsbetriebe Lübeck)
EEG	Erneuerbare-Energien-Gesetz (Renewable energy sources act)
FS	Food services
FW	Food waste
GDP	Gross domestic product
GW	Green waste
HH	Household
mAD	Micro-anaerobic digestion
NPV	Net present value
OPEX	Operational costs
PESTLE	Political-Economic-Social-Technological-Legal-Environmental analysis
RoI	Return on investment
RW	Residual waste
RWB	Residual waste bin
SWOT	Strengths-Weaknesses-Opportunities-Threats analysis

Executive summary

This report gives a business outlook on the implementation of the DECISIVE technical concept with the case study of Lübeck, Germany. The concept implementation is sub-divided into three scenarios which include building blocks from household food waste sorting over collection until treatment.
The three scenarios comprise the following sub-concepts:

1. Sub-concept 1: Simplified food waste separation for residents
2. Sub-concept 2: Proximity food waste collection by alternative transportation means
3. Sub-concept 3: Food waste treatment by micro-anaerobic digestion technology

While scenario 1 is only the implementation of sub-concept 1, scenario two comprises sub-concept 1 and sub-concept 2 and scenario 3 comprises all sub-concepts.
The deliverable begins with a definition of the case study including the drivers, limitations and potential success factors for a transition towards decentralised elements in biowaste management.
It continues with a detailed description of each sub-concept including its specific goals and a description of current related issues that are aimed at being solved by the respective concept.
The following stakeholder analysis includes a description of the main ones to be involved in each sub-concept and their business opportunities. Furthermore, their influence on each sub-concept is analysed by means of a power-interest grid.
PESTLE and SWOT analysis were conducted to determine external and internal factors influencing the business concept. The market analysis identified potential markets, its competitors and customers.
With regard to the previous analysis, the implementation strategy was described following. First, a business model canvas gives an overview of the key elements of the overall business model. A description of the chosen scenarios for which the business model was developed is presented in order to describe the following financial indicators, which is the core of the business model. The financial indicators include a description of such, the overall costing of each scenario and the results for the chosen financial indicators. The overall costing is based on CAPEX, OPEX, revenues and additional funding necessary to run the concept economically viable. The financial indicators are net present value, return on investment and payback time. It was concluded that scenario one and two can be economically viable a short time after their implementation. However, scenario 2 needs some compensation since the revenue stream of waste fees reduced due to better sorting by inhabitants. It was generally assumed that the waste fee system remains as usual. Scenario 3 can be economically viable in the last quarter of its project lifetime. However, besides the compensation for decreased waste fees, additional funding would be necessary to achieve this net benefit.
It was found that, in addition to the financial revenue generated in the case study described, external financial benefits can also be achieved if the scenarios are used as an educational tool to promote better sorting throughout the region. Furthermore, a strong social and environmental impact, which so far can only be monetised indirectly, is an important aspect for the implementation of the whole DECISIVE concept.

1. Introduction and context

1.1 Background

In DECISIVE, a multi-disciplinary and multi-regional consortium designed an innovative management scheme based on a decentralised approach for the valorisation of urban and peri-urban biowaste (DECISIVE 2021). The core element of the concept is a micro-anaerobic digestion (mAD) unit. This unit can treat biowaste (BW) from households (HH) and/or food services (FS) of a small district to generate biogas and fertiliser. In order to do so, one important condition is BW with high quality. That means it has to be almost free of impurities to allow a trouble-free operation of the unit without intense pre-treatment of BW. Therefore, a further core element of the DECISIVE concept is a collection system with a smart design in order to support a high-quality BW. The DECISVE consortium decided that these two elements are the core elements of the projects' business concept.
Further optional parts include technology such as a plant for bio-pesticide production from the solid digestate via solid state fermentation (SSF). As non-technical parts, a decision support tool or communication campaigns are possible parts of the business concept as well.

The collection, mAD and general concept were investigated in detail within DECISIVE. Results are to be found in various reports:

Collection:

- Manns et al. (2017) D3.5: Survey on waste collection systems with evaluations for decentralised applications
- Schermuly et al. (2018) D3.6: Report on results for household food waste collection and decentralised shredding in the "Lübeck-case"
- Walk et al. (2020) D3.7: Scenarios for decentralised biowaste collection chains with a waste collection database for representative situations
- Walk and Körner (2021) D6.6: Report on collection set-up performance
-

Micro-anaerobic digestion:

- Degueurce et al. (2017) D4.1: Definition of general specifications for micro-anaerobic digestion in a concept of decentralised management of urban biowaste.

The overall DECISIVE concept:

- Martinez Sanchez et al. (2018) D5.1: Methodology for the planning of decentralised biowaste management.
- Chifari et al. (2018) D6.1: Methodology of characterisation of the biowaste management system in the DECISIVE demonstration sites: Current and new system simulation for the LYON and CATALONIA cases.

Related investigations took place in case studies in Lyon, France, Barcelona, Spain, Dolina, Italy and Lübeck, Germany (Fig. 1). While in Lyon and Dolina, mAD demonstration facilities were installed, Barcelona focused on information campaigns and Lübeck on high-quality BW collection.

Figure 1: DECISIVE demonstration and case study sites

Work package (WP) 7 of the DECISIVE assessed the eco-innovative part of the elements of the DECISIVE concept. This included the aspect, how the new elements can be turned into a business model to enter the market. Specifically, WP7.3 *Business outlooks*, led by SUEZ, assessed the business market opportunities with the following reports as results:

- Kroff (2020) D7.6: Influence of global and local constraints on the business market analysis.
- Kroff (2021) D7.7: "Road-to-the market" strategic business plan. DECISIVE deliverable D7.7

Figure 2 shows the specific tasks in the business model WP (see also D7.7). This report (D7.8) builds upon the previous works and examines business opportunities focused on a local context – the Lübeck region in Northern Germany. The presented work includes a compilation of possible business applications which may be implemented after the DECISIVE project ends. The compiled potential cases are evaluated in terms of rough time frame of potential implementation. The most promising business cases for quick implementation were selected based upon discussions with the local core stakeholder EBL.

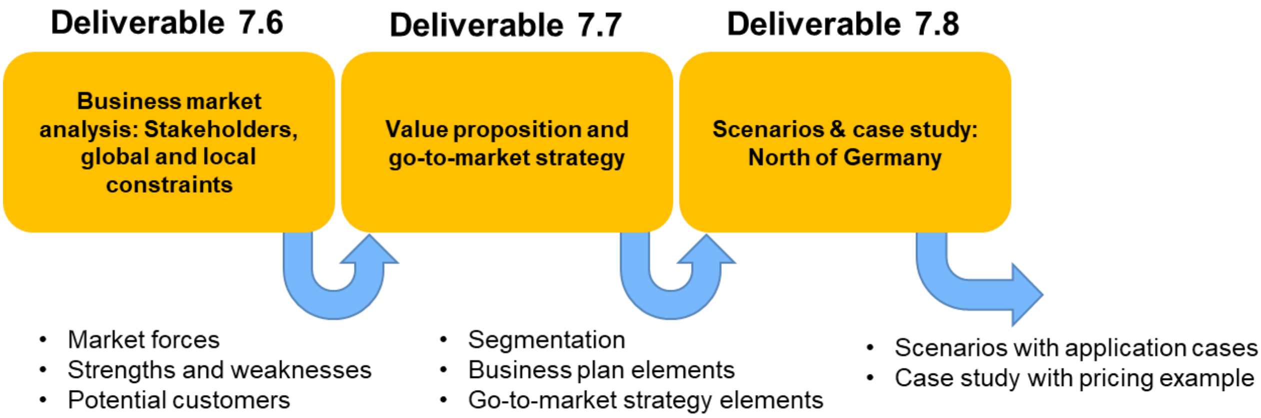

Figure 2: Concept of business outlook for DECISIVE results

1.2 Selection of case study frame

The city of Lübeck is situated in the study area of North Germany in the Federal State Schleswig-Holstein. It was selected as a case study area since the data basis and its availability is excellent as a starting point for concept development. Furthermore, excellent contacts with local stakeholders, such as the Lübeck waste management EBL, were built within the project period which also led to collaborations in other projects. This eased the development of the scenarios under consideration of feasibility aspects.
More information on waste management in Lübeck can be found in D3.6 (Schermuly et al. 2018) and D6.6 (Walk and Körner 2021).

As mandatory all over Germany, BW has to be collected source-separately. With the biobin (BWB) systems commonly used in Germany, an impurity level of mostly more than 2% is currently occurring, which applies also for the Lübeck average. The interfering substances in the source-separately collected BW are currently too high for a decentralised management in mAD units. However, also from a centralised management aspect, the share of impurities is seen as a problem from EBL. The company owns a treatment plant which is a combined anaerobic treatment in combination with the composting of the solid digestate. The impurities are an issue for the compost product marketing, which keeps potential customers from willing to pay higher prices for a high-quality product. Also, the impurities removal from the BW needs high-tech equipment and is therefore cost-intensive.

The focus regarding waste origin is laid on HHs and their kitchens, where most of the food waste (FW) is generated. The focus was laid so, firstly since EBL is responsible for collection of that type of BW in Lübeck, but not for FS BW. Secondly, FS BW was considered in D7.7. Furthermore, research was conducted by TUHH to improve the separate collection of FW in two test areas in Lübeck, Germany, with citizens from different socio-economic backgrounds. The results showed that with the tested novel collection method, plastic contamination of less than 0.1% and a total contaminant content of less than 0.5% is achievable in practice, which makes the system also usable for mAD units.

1.3 Methodology

In order to extract suitable business options for implementation after the project ends in the city of Lübeck firstly the situation background was elaborated both for a German context and a Lübeck context. Finally, the findings were in turn placed in a larger context. The methodology involved the following parts:

- The current status of BW treatment, the general objectives of improving BW management, the introduction to the framework for an improved BW management concept in the case study of Lübeck, as well as potential limitations and success factors (chapter 2).
- The establishment of three sub-concepts to improve BW management. The sub-concept proposition considers the specific background and goal, a detailed description and the tools for implementation. (Chapter 3).
- The identification and analysis of key stakeholders (chapters 4 and 5).
- Using business model analysis tools PESTLE, SWOT and market analysis to identify specific aspects for factors influencing the way to market of the proposed concepts (chapters 6, 7, 8)
- Presentation of the business model canvas and a financial overview for the implementation strategy of the proposed concept (chapter 9).
- Finally, conclusions and recommendations are made based on the findings from the previous chapters (chapter 10).

The overall methodology for the business model in WP7 is shown in Figure 3 (Kroff 2021).

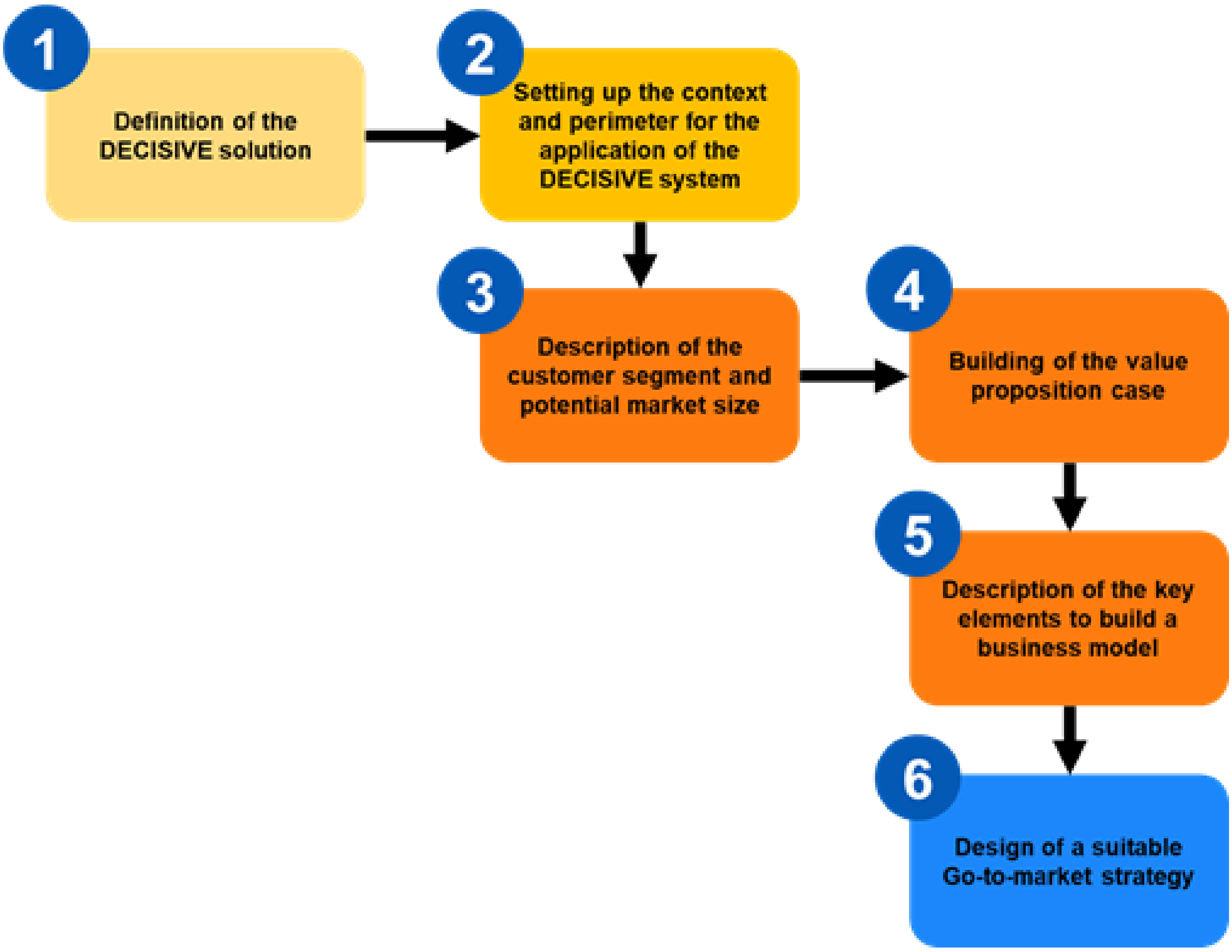

Figure 3: Methodology for the building of the DECISIVE business model

2. Definition of the case study framework

2.1 Status of household biowaste treatment

Germany: Currently, only relatively small quantities of domestic BW, namely HH FW, are collected separately throughout Germany, measured against the total potential, and this despite the fact that separate collection has been mandatory by law since 2015 (Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit 1998). Where a BWB is installed, the separate collection of green waste (GW) works well. However, the potential for a separate collection of FW is far from exhausted. On average, only between 20 - 30% of FW in Germany is currently collected separately. The largest share is disposed of in residual waste (RW) (Dornbusch et al. 2020). Dornbusch et al. (2020) also found that about 35% of the RWB consists of FW. These figures represent a Germany-wide average. Moreover, the impurities in compost produced from source-separated municipal BW are a concern at farmer’s level. Investigation in the SOILCOM-project (SOILCOM 2021) showed, that impurities are the major obstacle to compost acceptance by farmers as the main consumers of compost.

An improvement approach tested in some regions is the use of biodegradable plastic or paper bags for the collection of FW in the kitchen. However, this approach has several problems: 1) additional resource input for the bags; and especially for the biodegradable plastic bags, 2) complete degradability in the recycling plant is not necessarily achievable, 3) remaining residues are visually not distinguishable from fossil-based plastic fractions.

Lübeck: Area-specific differences can exist depending on the waste management concept and its implementation. However, the summarised findings can also be applied to the city of Lübeck. In particular, the municipal waste management company EBL has a large interest in reducing the proportion of improperly sorted materials, especially in source-separated BW. The share of FW, which is still disposed of in RW, is considered too high.
Furthermore, the quality of separately collected BW is poor. EBL sees it as a great challenge to get the separately collected BW free of unwanted substances such as plastic. Only a part of it can be removed during the recycling process with a high technical effort. Residues remain in the compost product and reduce its quality. With higher BW and therefore compost qualities, EBL expects that the compost marketing could be improved, also to sectors such as substrate production.

2.2 Objectives for improving biowaste management

Germany: Germany's sustainability policy requires the country to operate more sustainably. For sustainable development, it is also necessary to recycle BW much more efficiently. In the case of separately collected BW, it is thus possible to close the material cycle when the resulting compost is used as a soil conditioner in agriculture. Regionally, the practices currently used vary greatly.
Due to the German Landfill Ordinance (Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit 2009), municipal waste with BW fractions may no longer be landfilled without prior biological stabilisation such as fermentation or composting since 2005. Pre-treatment with landfilling of stabilised BW is also not promising for the future, as disposal via landfilling results in the loss of important resources and thus the material cycle cannot be closed.
A separate collection of BW has been mandatory since 2015 (Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit 1998). But even before that, many municipalities already provided a BWB in order to subsequently feed the BW at least to a composting plant, and increasingly also to an anaerobic digestion plant in combination with composting. These plants are mainly large central plants with throughputs of often several 10,000 Mg per year, with agriculture as most the important user of the product compost

(Bundesgütegemeinschaft Kompost e.V. 2020). Moreover, the German BW Ordinance (Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit 2021) demands since September 2021 that BW shall contain a maximum of 0.5% impurities or a maximum of 0.1% of plastics, before it is anaerobically digested or composted. If it is included in HH BW, a maximum of 1.0% impurities is permitted.

Lübeck: In Lübeck, EBL (EBL 2021d) treats the separately collected BW from the BWB first in an anaerobic digestion plant to produce biogas second into composted together with garden and park waste in a composting unit. This is done in the central plant at the Niemark waste management centre. RW, which still contains a lot of FW, is first pre-treated to remove a large share of non-biodegradable material and then stabilised anaerobically. The digestate is disposed at the own landfill site. Therefore, EBL is the core-stakeholder in BW management. The objectives to become better in BW management can be summarised as follows: 1) Decrease impurities in source-separated BW to decrease treatment costs and increase compost quality, 2) to shift BW from RW to lower management costs for RW and to increase the amount of the products from BW.

2.3 Concept of a decentralised biowaste management system

Although the German Biowaste Ordinance provides a framework for source-separated collection of BW, HH FW is currently only collected separately to a small extend. Furthermore, the amendment of the Biowaste Ordinance in 2021 demands more clean BW inputs to biogas and compost facilities. Since the suggestions currently provided for realisation are very vague, new solutions are being sought that enable better source-separation as precondition for successful circular management.

In front of this background, the concept for an improved BW management system focuses on the improvement of BW collection towards cleaner HH FW. This is also an obligatory element within the DECISIVE concept for decentral BW valorisation. Therefore, an improved HH FW collection is chosen as the starting element of the concept.
The specific starting point is always the place where the FW is generated. In the selected frame these are the kitchens in HHs. One element of the concept consists of a bucket system. Small and well-designed BW collection buckets are distributed to all the HHs in a neighbourhood. The volume of the buckets is adjusted to the HH's demands based on the FW potentials. Furthermore, the concept foresees structural measures at the current bin and container locations in or before the individual houses. The current BWBs will not be needed anymore, since in the second part of the concept, an e-cargo bicycle collects the BW from the buckets within the neighbourhood about 2-3 times per week. Optionally, the DECISIVE concept could also be fully implemented. In that case, the e-cargo-bicycle transports the waste directly to a mAD plant implemented in the neighbourhood. The concept could also be supplemented with additional elements from the DECISIVE concept (Kroff 2021), but they are not considered within this study.
The proposed solution is visualised in Figure 4. Basically, the concept for improved BW management consists of three parts:

- Sub-concept 1: Simplified food waste separation for residents
- Sub-concept 2: Proximity food waste collection by alternative transportation means
- Sub-concept 3: Food waste treatment by micro-anaerobic digestion technology

Their components are explained in detail in chapter 3. The implementation of the individual parts can lead to a slight adjustment of current practice but can also lead to a more comprehensive re-organisation of the waste collection and recovery system. The suggested concept for a decentralised BW collection is an add-on to the current centralised treatment practice of EBL. EBL's central BW treatment facilities will remain the core of Lübeck's waste management system. It could eventually be supplemented by mADs, if economically feasible. Otherwise, the option of mAD might be neglected (sub-concept 3), and the elements of alternative collection implemented solely (Sub-concept 1 and 2). In that case, the BW would be transported to underfloor containers established in the neighbourhood as interim storage. They would be established on places with roads easily accessible for waste trucks bringing the material to the centralised treatment.

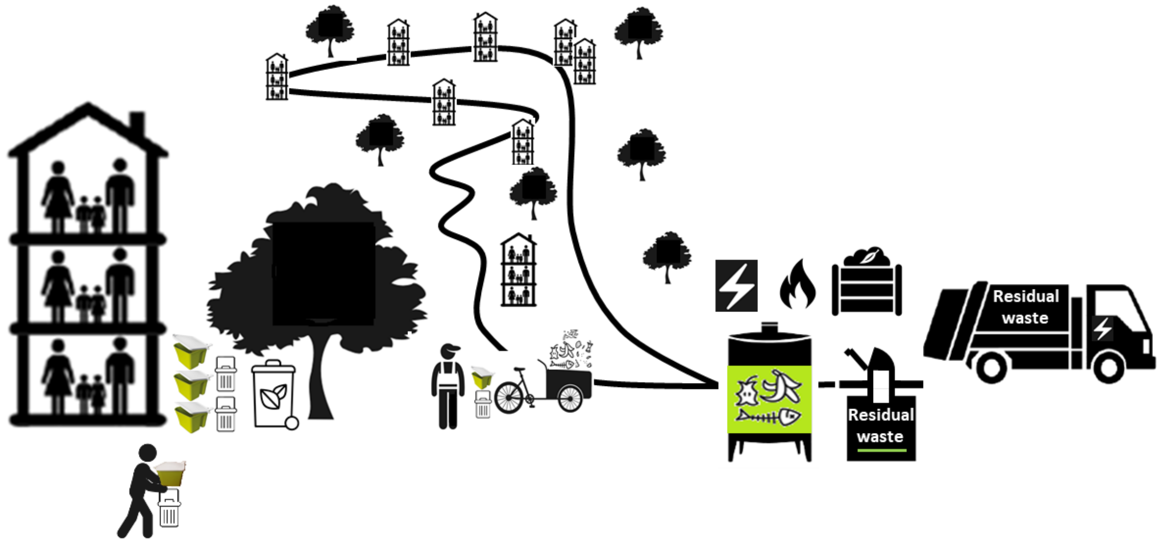

Figure 4: Schematic concept for circular decentralised biowaste management

2.4 Drivers for the implementation of decentralised elements

2.4.1 Limitations of current system

The current German BW collection system is based on BWB with sizes between 40L and 1100L, which are emptied area-dependent but usually biweekly. Collection is financed by waste fees, which differ between municipalities. As an example, not all municipalities have a separate fee for BW. The cost is then included in the RW fee. In general, the fees are commonly separated into a basic fee and a size-dependent bin fee. A demand and service-based fee such as a PAYT system is not very common in Germany, yet. The problems of the currently very rigid business model of BW collection relevant for the Lübeck case relate to:

- *The BWB location:* The technical implementation of area-covering BWB distribution currently cannot be adapted to site-specific construction issues. For example, some areas are declared as not connectable to a BWB because there is no space for large bins.
- *The joint collection of green waste and food waste:* It is a barrier to more comprehensive FW collection. GW can generally be stored longer and usually also develops fewer odours. While for GW the common biweekly collection frequency is sufficient, it is too long for FW, especially in the summer time. Due to odour development, FW is therefore often packed airtight in plastic bags and then disposed of with the RW or the BWB, leading to impurities there.
- *The fee system:* It is not oriented towards BW quality. Although it is adapted to local conditions, it does not favour good sorting due to a lack of monetary benefit. In Lübeck, the BWB is currently free of charge and is cross-subsidised by the fees for the residual waste bin (RWB). In multi-family buildings, the waste fees are not sent directly to the residents but rather to the housing associations. The fees are usually split evenly per HH. The consequence is a small individual incentive to improve personal waste sorting behaviour. Since these fees are then generally

displayed with other annual costs by the housing associations, many tenants do not even know their waste fees, which also does not favour correct sorting.

2.4.2 Potential success factors of a new system

The single elements of a decentralised concept can be generally adapted according to the demand in a specific region. The needs will be different from region to region and depend on the settlement structures. However, some general success factors for new systems can be named. They are also viable for Lübeck:

- *The logistics:* They can help to reduce transport costs and emissions due to shorter distances.
- *The proximity to citizens:* It can lead to higher visibility of waste management, which can give citizens a higher sense of responsibility for their own contribution to a successful circular bioeconomy, and therefore the collection performance can improve and result in a reduction of treatment costs.

2.5 Boundaries of this report

This report describes a business concept and scenarios for BW collection and valorisation as a case study for Lübeck, Germany. The local parameters and circumstances considered are very specific. Therefore, the scenarios and business models cannot be transferred directly to other regions or countries. For a more general business outlook, refer to (Kroff 2021).

In terms of costs and revenues of improved BW management, the boundaries are only expanded outside the concept for the collection part. For example, the overall waste collection fees and changes of those are considered. Collection costs with conventional trucks were estimated for sub-concept 1 for HH BW and HH RW, for sub-concept 2 for BW from underground container and HH RW and for sub-concept 3 for RW. Finally, an additional green waste collection is not considered either. Direct benefits due to the changes in terms of increased biogas production are estimated and included in all concepts. Financial benefits from high-quality compost are only included in sub-scenario 3 with the assumption, that compost is directly marketed to the residents. The current fee system in Lübeck is kept, which is based on RWB volume. However, waste fees were adjusted toe to the assumed better sorting performance resulting in less needed RWB volume.

In contrast, potential technological changes in the centralised treatment plant of EBL were not considered as well as potential savings in terms of less need for conventional trucks or the exchange of the original large BWBs with small buckets.

3. Business concepts for implementation of selected parts of the DECISIVE concept

3.1 Overview

There are various obstacles that make it difficult to put innovative and sustainable approaches into practice. However, there are some drivers, which can speed up such processes. The relevant for the Lübeck case were introduced in chapter 2.4. In any case, economical aspects are to be considered, if an eco-innovative solution should be put into practice. Therefore, this chapter focuses on the development of business concepts. The business concepts presented show various possibilities, which include low-cost but also cost-intensive adaptations. In the following chapters, the necessary equipment is discussed, the investment volumes estimated and logistical and technical adaptations to the existing system are considered. Based on this, business ideas are extracted and their possible integration into a future-oriented, sustainable BW management system described. They are based on scientific findings from the DECISIVE project.

The overall business concept described in this report is an improvement of BW collection and management. This business concept is divided into three sub-concepts that build on each other:

1. *Simplified waste separation for residents:* Considers the BW separation directly at the source, in HH kitchens by the citizens.
2. *Collection by municipal waste management responsible:* Considers the collection of that BW within a defined urban area by a neighbourhood waste manager with e-cargo bike to decentralised storage or treatment unit placed in that area.
3. *Food waste treatment by micro-anaerobic digestion technology:* Considers the valorisation of the source-separated and collected BW in a mAD unit placed in the respective neighbourhood is considered.

The frame of all concept parts is the decentralised approach, with all activities assigned to a specific, rather small urban area (neighbourhood). It can be defined as proximity management concept.

In the following, each business sub-concept is described regarding its specific background and goal, followed by a detailed description of the idea, the tools needed for implementation and the specific business concept elements such as stakeholders, tasks, and basic financing principles.

3.2 Sub-concept 1: Simplified waste separation for residents

3.2.1 Specific background

The most important actors in the separate collection of BW are those who generate the waste. In relation to the total FW amount generated, HHs account for the largest share (over 50%) and thus also have the greatest influence on the collected quantity and quality. The focus of this sub-concept is therefore set on HH FW, which is generated in citizen’s kitchens. The collection of this has the greatest potential for improvement within the municipal waste sector. The other HH BW type is GW. The collection of GW generally works already well and therefore is not specifically considered. One of the assumptions made is, that GW is collected by pick-up on demand. Furthermore, it is assumed, that the source of BW contamination is largely related to kitchen waste and not GW.

3.2.2 Specific Goal

The sub-concept aims to achieve a significant increase in the separate collection of FW while minimising contamination. The improvement should be tackled at the HH level. This can be achieved if less FW is disposed of in the RW and at the same time the separately collected FW remains free of plastic. The sub-concept proposes a solution that makes it easy for citizens to separate their BW by type in the kitchen. In particular, it includes the improvement of the user-friendliness of waste collection by a technical system provided for inside the HH accompanied by motivating measures.

3.2.3 Concept description

Figure 5 shows the scope of the sub-concept within the overall proximity BW management concept. The sub-concept aims exclusively to change the waste separation and collection in the HH to achieve a better separation of BW, specifically FW. The waste collection systems for non-BWs within the HH can also be improved within this context.
Many citizens do not separate their FW at all or do improper sorting with a large share of impurities. The approach and tools used to change this is an efficient and appealing design of waste collection features in the HH, specifically the kitchen. This concerns the sorting buckets for FW, but other waste fractions could equally be approached. The improvement is that the sorting buckets are user-friendly, aesthetically pleasing and designed to meet the demand. Furthermore, the same bucket type shall be provided to all HHs within the neighbourhood. Individual modifications are possible e.g., with respect to size in dependency of overall house size, individual HH size and consumption behaviour. The waste bucket system can be integrated into the kitchen as a complete system with all other waste fractions in a space-saving way. For the start of the transition, the distribution of FW buckets is considered solely. User-friendliness can be increased by bucket features such as odour-, leachate and fly-tightness, fitting dimensions, and easy to transport. Colour coding and pictograms can make it easy to sort the waste correctly without any language barriers. The distribution of the bucket is to be connected with the provision of information regarding sustainable waste management. The design of the features is taking into account the opinions of the citizens, specific improvements criteria and simplifications compared to the current situation.

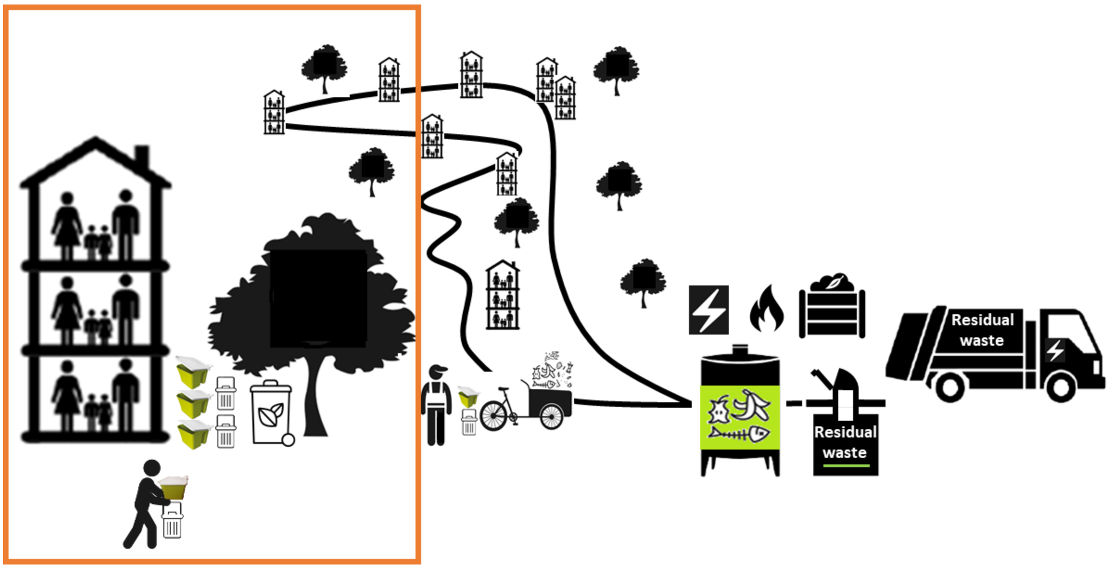

Figure 5: Overall concept and focus of sub-concept 1

Following, some major issues currently faced by citizens in terms of waste sorting are described. These are expected to be solved with the suggested sub-concept.

1) *Lack of or inconsistent instructions and colour codes*: Waste management in its detail is very inconsistent in Germany. This already starts with the colour selection of the waste bins. The BWB is often either green, black or brown. If one moves, this can lead to confusion, especially if waste management companies do not label the bins. Sometimes, they are labelled, however, in an unclear way. Sub-concept 1 includes the implementation of easy-to-understand instructions without language barriers. A uniform colour coding and symbolism using pictograms on buckets, bins, containers should facilitate separation.
2) *Missing space:* Most citizens collect their waste in the kitchen or surrounding space with very variable methods and tools. Often, when planning the kitchen, little or no space is foreseen for waste sorting. The common collection devices are not fitted and might have to be distributed all over the flat. Furthermore, they might be unfitting to the actual waste generation. Sub-concept 1 includes specially designated space for waste in the kitchen at appropriate locations, preferably provided already when planning a kitchen. A uniform bucket system, adaptable in its dimensions to the size of the HH and the volume demands for the different waste types, makes space saving waste collection possible. Sub-concept 1 includes measures for establishing uniform collection systems for the kitchens in multi-family housing with the involvement of the housing associations.
3) *Lack of equipment* or *equipment that is inconvenient to handle:* As mentioned before, the waste collection devices in the kitchen are often individual mixtures of vessels or bags that do not fit together and which often do not have a proper place. This often prevents the execution of a systematic and efficient routine for waste sorting. Especially for of FW, it is important that the devices are placed well and closes well to prevent from odours and liquids leaching. Furthermore, it needs to be easy to clean. The sub-concept 1 includes the consideration of such important criteria in the provision of suitable devices as important part of the FW collection.
4) *Poor service:* A particularly common shortcoming in the FW collection is the lack of service, especially in summer. The collection intervals by the waste managers are often still too long which leads to unpleasant nuisance and insect infestation at the waste storage. The sub-concept 1 includes proposals to improve the service. Measures are manifold and include the provision of collection devices in a suitable size, the option for a neighbourhood officer as a contact person and the increase of collection frequency of BW.
5) *No monetary incentives to separate well:* The fee structures in Germany offer little scope to save money with better separation. The systems are often based on a fixed minimum collection frequency for RW, additional BWBs can be chosen as option, and bin sizes can be determined by the house owner. Since RW should be minimised, often a price differentiation between RW and BW occurs. If the difference is strong, RW may end up in BWB, if too small the BW may not be separated at all. Sub-concept 1 considers this. Savings due to an extended collection frequency for RW or the shift to a smaller RWB are possible since FW was shifted to the separated fraction. Individual random controls of buckets may lead to fee increases in case of BW contaminations.

3.2.4 Tools for implementation

To implement a system as shown in Figure 5, technical devices have to be considered in cost calculations:

- Well-designed and distributed easy-to-use FW collection buckets
- Flexible choices from a standardised system regarding bucket sizes and specific features
- Optional: Specific kitchen sub-structures for waste collection places in cases of new houses. The time frame for this option is rather long-term for existing houses due to the need for adaption of the kitchen or can be included in the planning of new neighbourhood areas.

3.3 Sub-concept 2: Proximity food waste collection by alternative transportation means

3.3.1 Specific background

In conventional collection systems, three steps are relevant, when collecting waste from HHs and transporting it to unloading sites. First, the collection vehicle drives empty to the first collection point of the serviced urban site. The following collection phase is characterised by frequent stop-and-go of the collection vehicle, and by lifting and lowering of bins or containers by loading devices. The stop-and-go often causes traffic jams and increases air pollution in the living areas. After the last vessel of the collection tour is emptied, the vehicle transports the BW to the unloading site, which is often a treatment plant and many kilometres away from the serviced urban site. After unloading, the collection vehicle drives either to parking or to another urban site for service. The fuel consumption of a collection and transport tour is largely determined by the distance between service site and unloading station.

A comparison of the effects of collection and transport in different development structures was carried out by Larsen et al. (2009). Bassi et al. (2017) conducted a comparative study on the environmental impact of different waste recovery processes in seven European countries and found that waste collection was among the few processes with negative impact on the greenhouse effect. Another issue is the ban on reversing large waste collection vehicles. This is a particular problem in dead-end roads without turning possibilities.

Due to the many drawbacks of conventional systems, there is a need to design waste collection and transport in a future-proof manner. TUHH and EBL already planned for trials in Lübeck, supporting the sub-concept 2 vision. For this, an e-cargo-bike for the collection of FW has been developed together with a Hamburg-based manufacturer and is ready to start trials.

3.3.2 Specific goal

Since waste collection by large collection trucks is costly, resource demanding and dirty, sub-concept 2 presents an option for making the collection and transport phase climate-friendly. It is the continuation of sub-concept 1 including the decentralised approach. By an e-cargo bike, FW is to be collected from the HHs of the neighbourhood and unloaded at a specific service station in the proximity of the collection area. Aims of sub-concept 2 are therefore to reduce emissions from the collection, to ease the traffic situation, and also to enable a more demand-oriented collection service. The proximity collection in a small area shall also promote more acceptance and understanding of waste-related issues.

3.3.3 Concept description

Sub-concept 2 is a continuation of sub-concept 1. It starts with the collection of the FW provided by the citizens with the buckets, considers the transport to a discharge point, and ends with the discharge into intermediate storage. Figure 5 shows the scope of the sub-concept 2 within the overall DECISIVE concept.

The focus is on the collection of FW with high quality from the citizens of the neighbourhood. The buckets, which are brought by the citizens to the collection point inside or in front of the house. The small, individually adaptable sorting buckets proposed in sub-concept 1 are not emptied into the current BWB but are placed in an attractively designed collection place. The conventional BWB is then not needed anymore. The neighbourhood manager collects the bucket contents 2-3 times a week from the collection places. For this purpose, this person uses a small collection vehicle, e.g., an e-cargo-bike. Since the provided buckets are small and handy, the emptying of FW into the collection tank of the e-cargo-bike can be carried out without a mechanical lifting device. During this procedure, the neighbourhood manager can also carry out quality control by visual inspection. He drives back the loaded e-cargo bike to the service station of the neighbourhood area. There, the FW is to be emptied either into an underground storage container, or into the mAD. The first case would be valid if no mAD plant is implemented. The content of the underground container could be collected from regular trucks. If a mAD is available, the pathway of FW follows sub-concept 3.

Sub-concept 2 has many advantages, compared to conventional truck-based systems. It should improve the traffic situation and avoid environmental and health impact of exhaust gases. The logistics are more flexible and demand-based. The individualised waste collection in multi-family buildings is a further improvement. It is the basics for an individualised fee system as an incentive for good waste sorting. With individual collection, there is the option of determining the waste quantities per HH and thus carrying out fair billing. In particular, the creation of the new professional profile of a neighbourhood officer, who is among others responsible for the e-cargo-waste collection, is future-oriented. The neighbourhood officer could also be a contact person in the neighbourhood and help with problems. His presence can lead to increased motivation for waste separation.

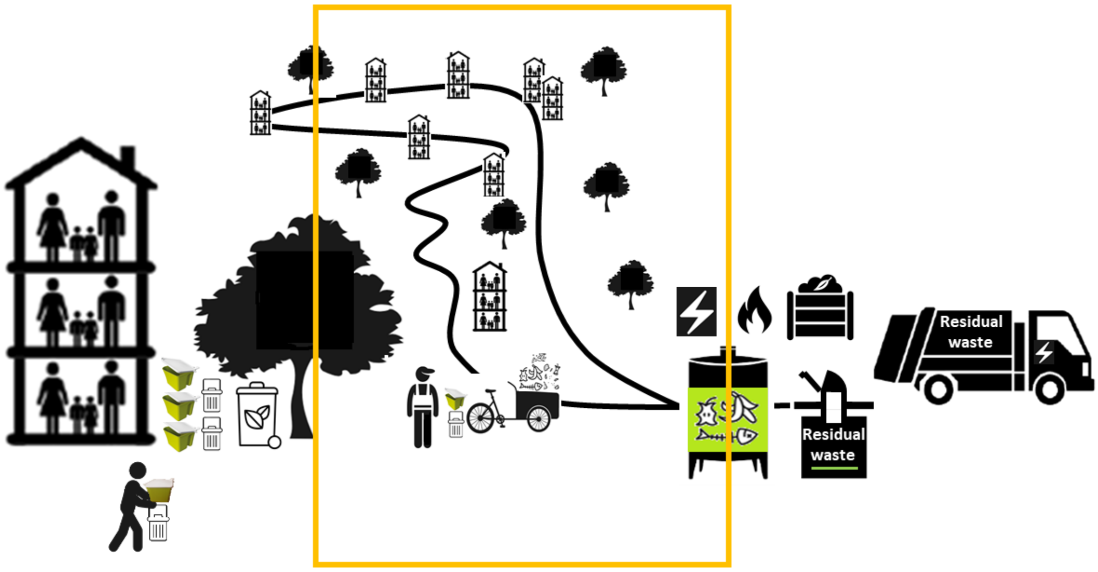

Figure 6: Overall concept and focus of sub-concept 2

In the following, current issues, which the citizens have related to waste sorting are presented. It is expected that sub-concept 2 can support to solve these.

1) *Lack of space and poor design of the waste bin site*: Expanding on sub-concept 1, there is often a lack of space not only in the kitchen but also at the waste bin sites of the house, especially in densely built-up areas. Due to a lack of space, there are currently no BWBs placed in many cases. Waste collection sites are often given no or low priority in building or site planning. Sub-concept 1 allows the placing of fewer or smaller RWBs. The frequent collection of the FW buckets in sub-concept 2 makes a BWB unnecessary, and the buckets need little space due to the frequent collection. However, storage space for buckets is needed before waste is collected directly from them. It shall be attractively designed and eventually lockable if it contributes to increased acceptance. Attractive design can not only enhance the visual presentation but also save space. Small, stackable buckets, can be lined up close together in a guide or shelf to make use of the height of the space. The compost produced from the waste could be used for planting around the collection point. This could be connected with demonstrations of quality differences between composts from well sorted and poorly sorted BW. The neighbourhood officer of sub-concept 2 can take care of such issues.

2) *No demand adjusted collection frequency:*
   Conventional waste collection is a rigid concept in terms of scheduling, which often does not allow a demand adjusted collection. Adjustments can usually only be done by selecting bin sizes. Low collection frequency bins are often quite empty, in others, they are overflowing or the materials are compacted. With a high collection frequency for the FW buckets as in sub-concept 2, this problem does not exist. The collection of FW from the intermediate storage site can also be carried out according to demand by means of level measurement. Thus, the collection from underfloor container by a large truck could take place with an automated filling level notice.

3) *Shared waste bins in multi-family buildings:* Especially in multi-family buildings, where many parties often empty into the specific bins together, problems with waste quality are common. The lack of motivation of a few can lead to all parties in the building losing the motivation to sort waste efficiently. With individualised waste collection, the concept contributes to each party being able to separate better under their own initiative, without being influenced by other parties. This also leads to the fact that point 5 from concept 1 becomes applicable.

4) *Poor visibility and service*: Complementary to points 1 and 4, sub-concept 2 can contribute to improved visibility and service through increased presence. The increased collection frequency up to several times per week also increases the presence. The service can be provided by the waste collector responsible for the neighbourhood. A positive image should be attached to this person, which is also given by an upgrading function designation, such as neighbourhood manager or recyclables manager. Recycling of BW should be given a positive image, which makes it easier for citizens to understand the importance of their own role.

5) *Odour nuisance from biowaste:* The collection frequency of BW is mostly bi-weekly but, that of RW often displays higher frequency. Many residents want to get rid of their odour-intensive waste as quickly as possible and thus dispose it of in the RWB, also because it can often be stored there well-packed in plastic bags to prevent odour. The concept of direct collection of the small waste bins necessarily requires increasing the collection frequency to several times a week. With a simultaneous lower collection frequency of RW, the best way to dispose it of is with BW. Moreover, the BW is then collected after two to three days. The emissions and conversion processes during the storage of BW were studied by Degueurce et al. (2020). An ideal maximum storage time for BW before treatment is therefore one week. The increased collection frequency of sub-concept 2 also ensures that less greenhouse gases are produced in summer, which are released unfiltered into the environment. At the transfer stations, airtight underfloor containers can increase the storage capacity of the BW. Thus, the waste retains a higher value-added potential for anaerobic digestion and/or composting.

6) *Precarious traffic situation:* Waste collection causes traffic congestion, especially during busy hours, and when roads are narrow. The sub-concept 2 solves this by collection in the neighbourhood's by E-cargo bikes. They are small, and can mostly move away from roads used by cars and thus solve this situation.

7) *Emissions from waste collection*: Conventional waste collection vehicles are fuelled by diesel or petrol, and therefore emit a lot of fossil-based exhaust gases. Electric-driven waste vehicles emit charged with electricity from renewable energies emits less than 20% to an equivalent diesel-fuelled truck considering production, energy provision and vehicle use (Designwerk Products 2021). The largest impact has the frequent stop-and-go at each of the numerous collection points. Electrically powered e-cargo bikes are considered to have even less emissions, and contribute

towards CO_2-neutrality, provided they are loaded with energy from renewable resources. The e-cargo bikes could be charged with the electricity produced in the neighbourhoods mAD (sub-concept 3).

8) *Safety and time:* Large waste collection trucks are a hazard, especially when turning or reversing. Accidents can happen with cyclists or pedestrians, but mostly with own employees as was stated by EBL. In addition, accidents, especially among waste collection staff are happening. A ban on reversing is supposed to counteract this. However, reversing is not always compliable. In addition, narrow dead-end streets without turning facilities can no longer be driven. Thus, waste collectors either have to push the bins over large distances to the collection vehicle, or residents have to bring the bin to the nearest roadside. In sub-concept 2, these problems are solved with the use of e-cargo bicycles in the collection phase. They have an improved operating radius and manoeuvrability compared to common trucks and the collection buckets are very handy. A decisive indicator for the safety increase is also the time saving that can be achieved through the improved system.

3.3.4 Tools for implementation

To implement a system as shown in Figure 6, technical devices have to be considered in cost calculations:

- E-cargo bike for transport between HHs and service station
- Facilities for e-cargo bike parking and equipment storage
- Optional: Underground container as intermediate storage

3.4 Sub-concept 3: Food waste treatment by micro-anaerobic digestion technology

3.4.1 Specific background

The sub-concept 3 built on sub-concepts 1 and 2, which are included in their entirety. With all 3 sub-parts together, the circular DECISIVE concept, with a decentralised mAD as a core element, can be implemented for a residential neighbourhood. This means that the neighbourhood's BW could be transformed into products such as electricity and heat from biogas in the immediate vicinity of where it is produced.
However, a large centralised biogas facility already exists in Lübeck. Additional decentralised placed mAD-units could be useful as add-on, e.g. if the collected BW amounts increase, and the capacity of the current centralised one is reached. However, mADs would also compete with an optional enlargement of the centralised biogas facility. A further reason for implementation of mADs would be the serving of neighbourhood's with large distance from the centralised one to eliminate transport-related problems. However, if it is implementable or not depends largely on the economy. For that reason, the business options for implementing decentralised mAD are discussed and compared to the centralised one. Implementing sub-concept 3 is not a necessity for implementing sub-concepts 1 and 2. If process economy is not promising under current conditions, sub-concept 2 finishes with an underground container for intermediate storage, instead of BW transfer to the mAD. However, also if economic viability is not given currently, it can change in the future, e.g., with new regulations regarding climate neutrality or increasing prices for fossil-fuel based energy. Therefore, it could also make sense in that case to implement at least one mAD unit to serve as a teaching object, to get experiences and to contribute to the citizens understanding of local circular economy and the possibilities of waste-valorisation.

3.4.2 Specific goal

The sub-concept aims to valorise the separated BW in the proximity of its generation. In addition, the transport distances are to be reduced, both on the waste and the product side of the value chain. The second collection phase of waste transport from intermediate storage to the central treatment plant (see chapter 3.3.1) is unnecessary. The aim is also to use the products as much as possible in the vicinity of the plant. This concerns mainly, electricity and heat generated from biogas and, but also compost produced from digestate. A further goal is to increase awareness of citizens awareness for their importance within a circular bioeconomy. The mAD operation in the neighbourhood, together with other elements for a circular concept (e.g. compost and food production) can work as an educational showcase. This allows citizens to experience the complexity of circular economy on local scale.

3.4.3 Concept description

Sub-concept 3 is a continuation of sub-concepts 1 and 2 (Figure 7). The core is a mAD plant, which is located in the neighbourhood to valorise the BW from the vicinity where it is produced. The mAD takes in the high-quality BW sorted in sub-concepts 1 by the citizens and collected in sub-concept 2 by the neighbourhood officer. A central task is the determination of the size of the mAD unit. The approach for size determination can be discussed from two points of view: a) defining first the neighbourhood area and estimating the amount of FW generated, or b) defining the size of the plant, e.g. on the basis of existing demonstration sites (Dolina, Lyon) and developing the catchment area based on this. Point a) is considered as a better solution in the long-term, since mAD technology might develop more flexible. However, since there is still a lot of research and development going on, there are mostly common mAD plant sizes on the market at the moment. Due to this reason, the amount of FW to be collected was fixed (see chapter 9).

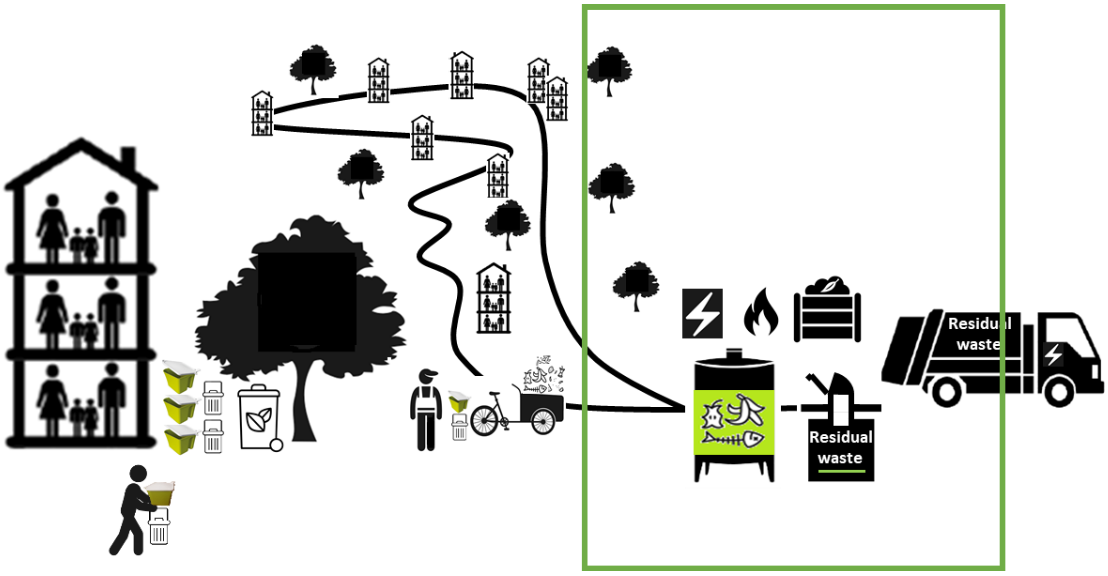

Figure 7: Overall concept and focus of sub-concept 3

The decentralised management concept within the neighbourhood is expected to improve the understanding with regard to BW so that it is perceived as valuable and not just dirty and annoying. The cycle between waste and food should be experienced in an easily understandable way through participatory concepts. As an example, the mAD can be integrated into a residential area together with an urban gardening project to contribute to community development. The resulting products, such as electricity, compost and food, can be used on-site directly. However, there are more indirect advantages of the mAD, but not considered in detail for the business concept.

3.4.4 Tools for implementation

To implement a system as shown in Figure 7, technical devices have to be considered in cost calculations:

- mAD-plant with accessories
- Composter for digestate treatment

4. Stakeholders

4.1 Stakeholder overview

The possible main stakeholders are listed in Table 1, Table 2, and Table 3 including their specific tasks. It has to be mentioned, that not necessarily all stakeholders are needed for implementation. Most actions could be carried out in principle by the waste management company. Their participation in all concepts is a precondition due to the general German waste management situation. However, certain tasks could be transferred to sub-contractors (Table 1, andTable 2), and some tasks have to be done in cooperation, e.g. the bucket production (Table 3). The following list gives a short description of the main stakeholders which might be involved in the implementation of the sub-concepts 1, 2, and 3.

- **Waste Management:** Main player in local waste management. In the example of Lübeck, this is EBL.
- **Regional public authority:** Describes local politics/government or city administration and urban planning. This can be parties, ministries and authorities. Set and implement policy frameworks.
- **Subcontractor (Waste management):** In contrast to the public waste management company, this item refers directly and exclusively to on-site waste management. Subcontractors can be companies specialised in additional waste sorting and management services.
- **Property management:** Includes housing association or cooperative and their property management. They manage or rent out apartments or houses either in third-party or private ownership.
- **Facility management:** Is often closely related to property management and describes persons who carry out work on site at the flats, e.g. caretakers. It can also be external service providers contracted by property management.
- **Supplier of components:** These can be manufacturers, e.g., of collection buckets, e-cargo bikes and mAD plants.
- **Waste producer:** Is either the owner or a tenant of the house. Benefits from services but is key for stakeholder for proper waste sorting.

The following stakeholders might also play an important role in the business models. However, they are seen as followers rather than drivers of the concepts. Nevertheless, their influence on the overall performance can be still high.

- **Designers, architects, city planners:** These stakeholders deal with the design of materials, products or buildings that are included in the concepts. These can refer, e.g., to the design of waste collection buckets, kitchens, e-cargo bikes, waste collection areas or mAD facilities.
- **Biogas plant operators:** Are closely linked to waste management. They might belong to the same entity, as it is the case in Lübeck. However, they can also be independent from the local waste management company.
- **Farmers:** Farmers are considered to be the main users of the products of BW management, e.g. compost.
- **Local food supplier:** Food suppliers are the link between farmers and consumers (in the list named waste producer).

- **Interest groups including NGOs:** Refers to organised interest groups in the field of BW management such as ECN, NABU or “Wir für Bio”. They are concerned, e.g., with policy making or communication strategies.
- **Higher education and research:** They refer to research institutions such as universities and specifically to research groups in the field of waste and resource management and agriculture.
- **Education/Training centres and schools:** Organisations which train in waste management and environmental professions, but also general schools.

4.2 Stakeholders involved in specific sub-concepts and their business opportunities

4.2.1 Sub-concept 1

The concept illustrated in Figure 5 offers business opportunities to different stakeholders as shown in Table 1.

Table 1: Stakeholders, business tasks and turnover generation in sub-concept 1

Potential business partners	Business task	Turnover generation
Manufacturers of buckets	Provision of specifically designed buckets	a) Bucket sale
Waste management companies	• Consultation for housing associations and landlords about incentive programs and technical devices • Catalogue of options to be provided to housing associations, landlords and individual citizens	b) Consultation service c) Basic waste fees d) Extra fees for further options e) Quality and quantity improvements for products from BW
Housing associations, landlords, tenants	Interface between manufacturers and waste companies, are rather mediators	f) Savings in waste fees

4.2.2 Sub-concept 2

The concept illustrated in Figure 6 offers business opportunities to different stakeholders as shown in Table 2.

Table 2: Stakeholders, business tasks and turnover generation in sub-concept 2

Potential business partners	Business tasks	Turnover generation
Waste management company	• Waste collection from HHs • Optional: Waste collection from intermediate storage • Optional: Provision of underground containers • Conceptual design of neighbourhood-based waste collection logistics	a) Consultation payments b) Waste fees (Implemented measures included in basic waste fees, with options for value-added extra fees) c) Revenues from products with improved quality and quantity d) Savings by lower transportation costs
Sub-contractor (e.g., property management)	• Waste collection and transport between HHs and underground container	e) Service payment for waste collection

4.2.3 Sub-concept 3

The concept illustrated in Figure 7 offers business opportunities to different stakeholders as shown in Table 3.

Table 3: Stakeholders, business tasks and turnover generation in sub-concept 3

Potential business partners	Business task	Turnover generation
Waste management company	• Decentralised FW treatment as combined biogas and compost production with mAD plant • Communication actions for improved BW sorting and collection	a) Waste fees (Implemented measures included in basic waste fees) b) Value of biogas considering specific compensation (e.g. EEG) c) Value of compost for selling in the mAD neighbourhood and other neighbourhoods d) Indirect: More biogas and compost by better separation of citizens
Sub-contractor (e.g., property management)	• Decentralised FW treatment as combined biogas and compost production with mAD plant • Maintenance of surrounding area where the mAD is implemented	e) Service payment for maintenance

5. Stakeholder analysis

The concept of a power-interest grid for stakeholder analysis, which was used in this report, is shown in Figure 8 (Mendelow 1981). It is based on identifying the power and the interest of related stakeholders and was applied to each of the suggested business model concepts. The results highlight the need for the intensity, stakeholders have to be managed by the project leader in order to successfully implement each concept.

The excel-based grid was filled by some of the indicated stakeholders, most importantly EBL, and DECISIVE consortium members.

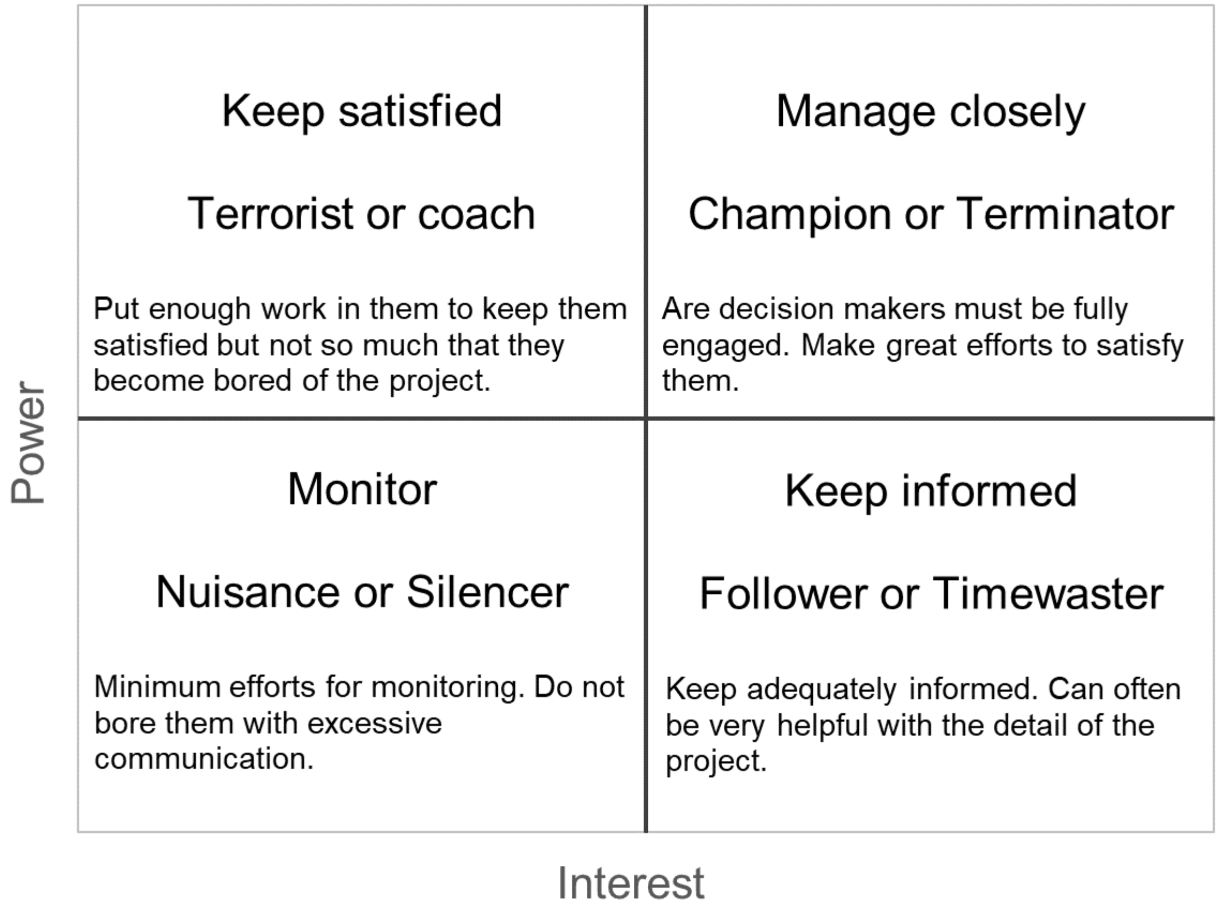

Figure 8: Concept of the stakeholder power-interest grid (adapted from Mindtools (2021))

Figure 9 shows the grid for sub-concept 1. It shows that important stakeholders such as the waste management, waste producers and property management have high power but also high interest in the concept. Furthermore, biogas plant operators and technology suppliers are important interest groups while designers and architects can have the power to implement new measures, e.g. for kitchen design in order to ease waste sorting.

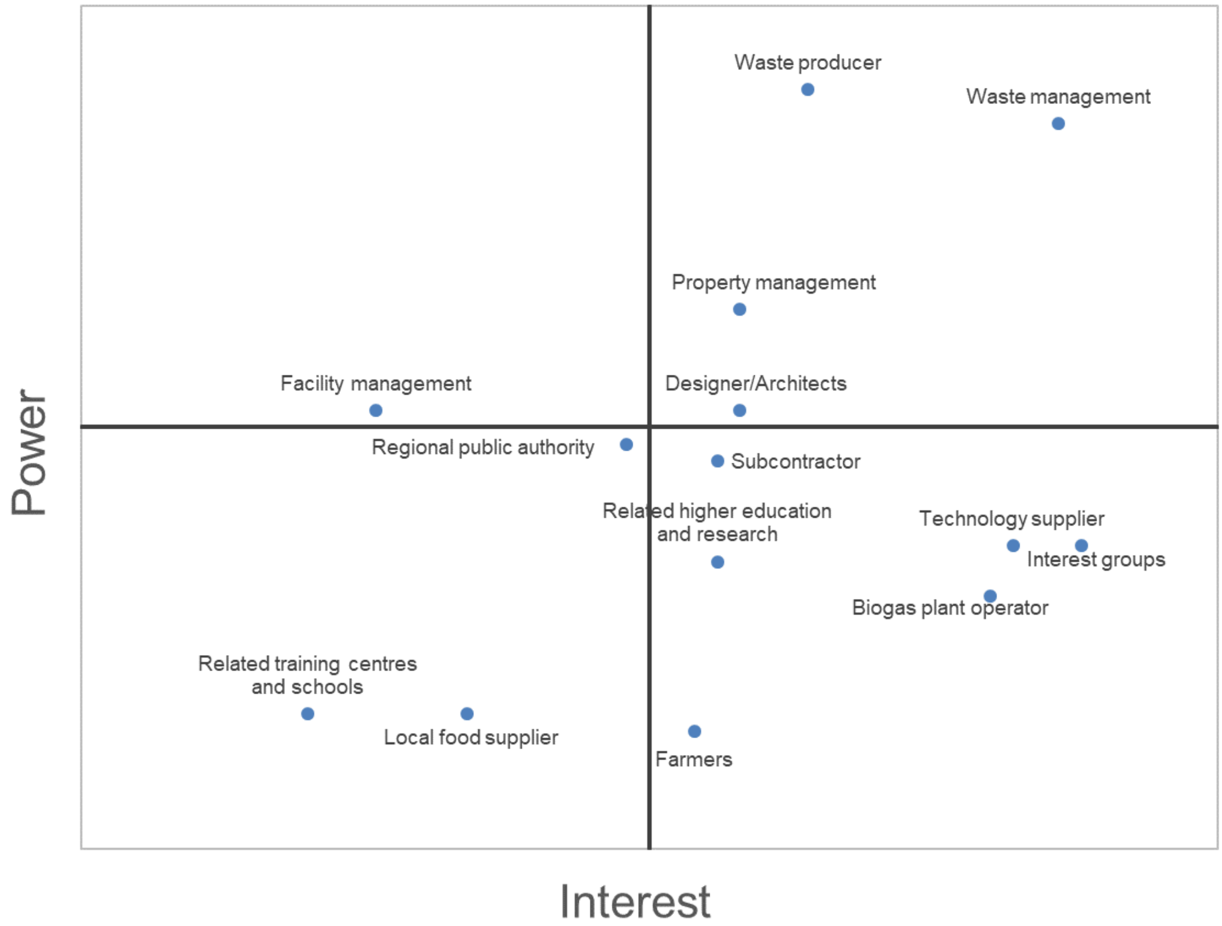

Figure 9: Power-interest grid for sub-concept 1

Figure 10 shows the grid for sub-concept 2. Similar to sub-concept one, waste management, waste producer and property management are among the groups with high power and high interest in the concept. Facility management and technology supplier have a higher level of power in comparison to sub-concept 1. In general, there are two main clusters with either high-power and high interest or low power and low interest for the concept. Five out of 14 stakeholders are within the cluster of high power and high interest.

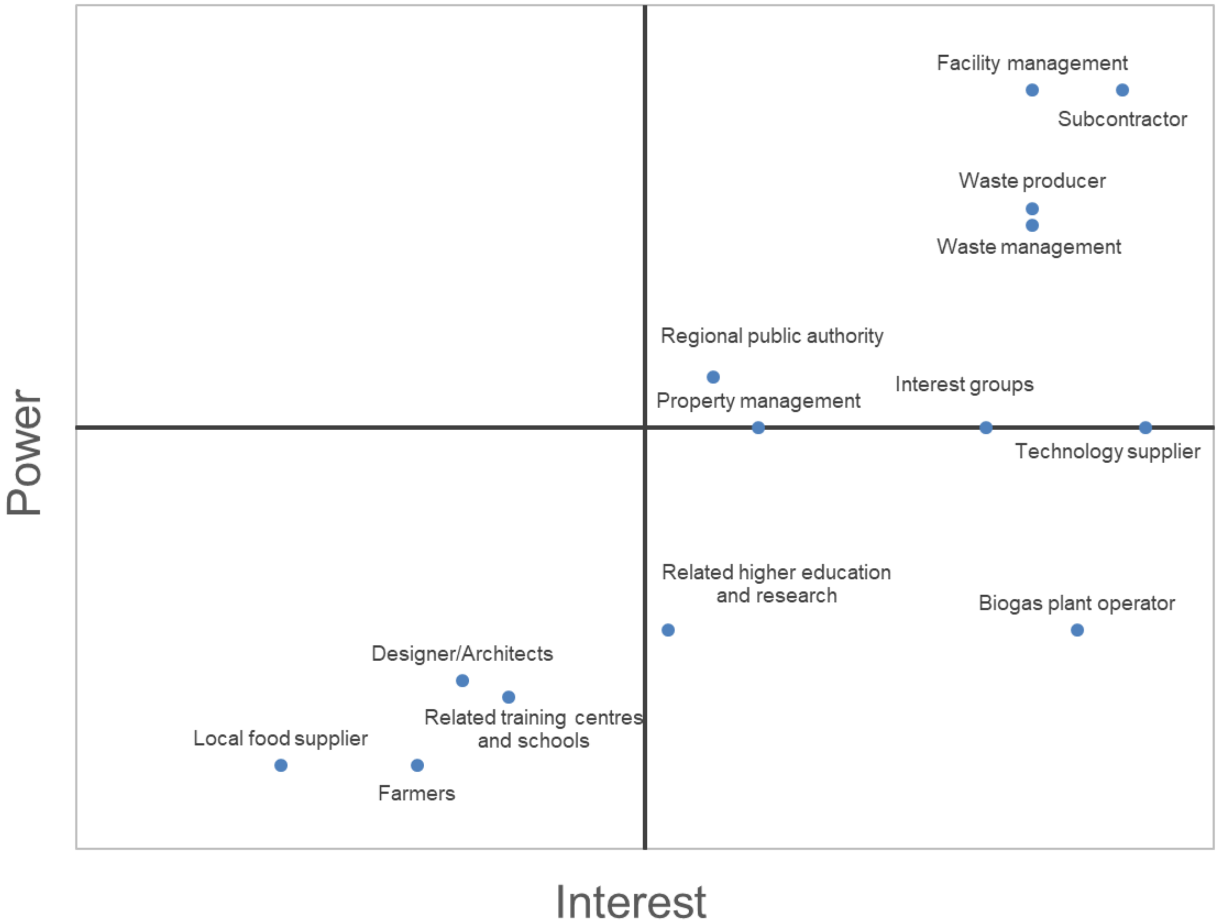

Figure 10: Power-interest grid for sub-concept 2

Figure 11 shows the grid for sub-concept 3. Eight out of 14 stakeholders are within the cluster of high power and high interest. The major change occurred for the waste management, which has high power but low interest in the concept. This is mainly due to their central approach for BW management. However, in contrast, regional public authorities might have high power and high interest in the concept of decentralised BW management. This could put pressure to waste companies in order to apply new concepts for waste management in general.

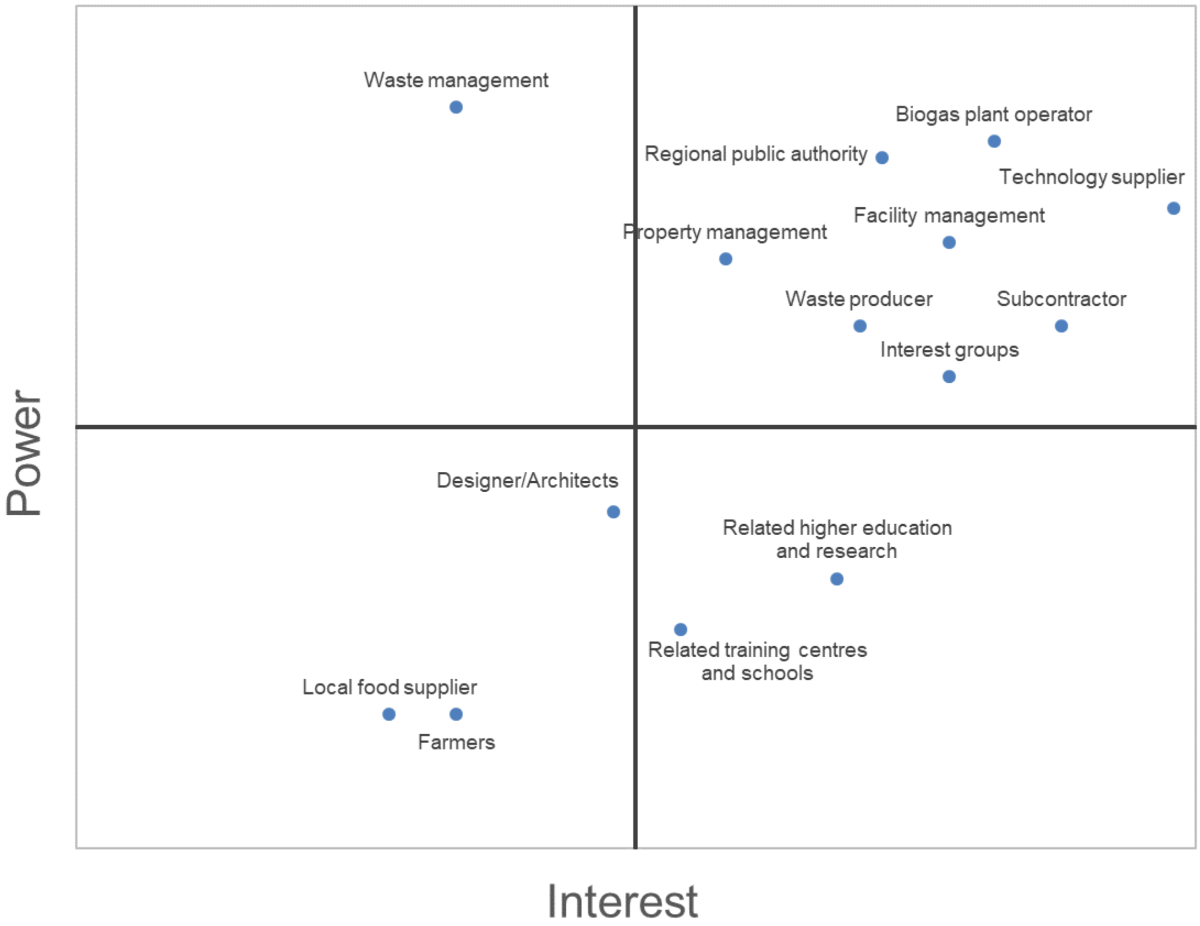

Figure 11: Power-interest grid for sub-concept 3

The estimation of the power of each stakeholder was a rather simple task compared to the interest. Interest can differ, e.g., between different property managements, while their power can be estimated objectively. However, most of the respondents for the stakeholder analysis answered in an acceptable range of ranking each of the involved stakeholder power and interest.

For a meaningful analysis, detailed knowledge on the local situation and potential stakeholders is key. For a future implementation strategy, a specific stakeholder survey needs to be developed in order to ask them for their interest in such business models. However, results for the key stakeholder, e.g., as EBL, regional public authority and interest groups were also confirmed with online research on related policy comments and plans.

6. PESTLE analysis

6.1 Method

A PESTLE analysis (Politics, Economic, Social, Technology, Environment) is an audit of six external influences on an organisation or business model in case of this report (CIPD 2020). These factors are important to consider for the road-map to implement the concepts. By analysing these factors, insights can be gained into external influences which may have an impact on business decisions. It allows decision makers to assess risks and use the knowledge to justify their decisions (CIPD 2020).

6.2 Politics

The EU's position on circular economy and bioeconomy

The current EU legal framework sets the context for many other policy instruments and legislation to be transposed into national legislation by the Member States. The general framework for waste management within the EU is provided by the waste framework directive (European Commission 2008). This directive

- establishes the waste hierarchy as key to making waste management decisions,
- contains the basic waste management definitions, e.g., it defines the end-of-waste status, and and under which circumstances a by-product is not considered as waste,
- requires from the member states to take measures to recover, re-use and recycle waste, which includes the separation of recyclable waste streams, where feasible,
- controls hazardous waste which is not allowed to be mixed with other hazardous waste

In 2015, the Commission published its Circular Economy Action Plan (European Commission 2020), which set the ambitious objective of treating waste as a resource by the year 2020 and turning the European economy into a circular economy. In setting the vision for 2050, it mentions a 'circular economy where nothing is wasted and where natural resources are managed sustainably'.

Germany's position on circular economy and bioeconomy

The German government's *Climate Protection Plan 2050* calls for a reduction of greenhouse gases to 65 % compared to 1990 levels by 2030 (UBA 2021). The share of electricity from renewable energies is to be increased to at least 80% by 2050 (Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit 2014). In 2020, it was 51.2 % (Destatis 2020). Bioenergy from BW is an essential element in achieving these goals. The importance of waste recovery is highlighted in the Recycling management act (Bundestag 2012) with the waste hierarchy: Prevention before material recovery before energy recovery before disposal. In the case of FW, the Federal Ministry of Energy and Agriculture's national strategy (Bundesministerium für Ernährung und Landwirtschaft 2019) follows the European Commission's bioeconomy strategy, which envisages a reduction of 50 % by 2030 (European Commission, Directorate-General for Research and Innovation 2018). The Biowaste Ordinance (BioAbfV, Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit 1998) regulates the basics of anaerobic digestion of BW and defines permissible BW. The ordinance regulates that BW must be collected separately since 2015.
This ordinance was updated in 2021 and requires a BW quality of no more than of 0.5% impurities or a maximum of 0.1% of plastics before it is anaerobically digested or composted. If the waste originates from the BWB, a maximum of 1.0% impurities is permitted (Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit 2021).

Lübeck’s position on circular economy and bioeconomy

Since 2010, the City of Lübeck has a climate protection plan: "Climate Protection in Lübeck - Integrated Framework Concept Project No.: 1 / 43874385" with the aim *"[...] to significantly reduce CO_2 emissions in Lübeck and at the same time to anchor climate protection as an integral part of future policy."* (Stadt Lübeck 10/29/2010). This stated CO_2 emission saving targets of 10% for Lübeck by 2015, but these were not implemented. The topic of climate protection only came into the focus of the city council in 2019, with citizen protests and the dissemination of current scientific findings. On 23.05.2019, the Lübeck city council declared a climate emergency (Dordowsky 2019) and the consequences were presented to the residents at a meeting on 24.06.2019 (Stadt Lübeck 6/24/2019). The annual saving of 5% CO_2 emissions is propagated for the next 20 years in three sectors - saving energy, increasing efficiency, using renewable energies. Furthermore, the protection plan names biomass as an energy source but only refers to the use of agricultural biomass, sewage sludge and sewage gas from wastewater and waste from the food industry. The valorisation of HH BW is not addressed (Stadt Lübeck 10/29/2010). The topic was also not addressed at the Climate Forum in 2020 (Engel 2020).

6.3 Economy

The gross domestic product (GDP) in Germany amounted to € 3,367 billion in 2020 and has thus more than doubled in the last 30 years (GDP 1991: € 1,586 billion, (Statista 2020a). The GDP per inhabitant in 2020 was 40,494 € (Statista 2020a). This makes Germany one of the richest countries in the world. In a comparison with the previous year, however, the GDP in 2020 dropped for the first time since the financial crisis in 2009 as a result of the Corona measures as is shown in (Figure 12, Statista 2020b).

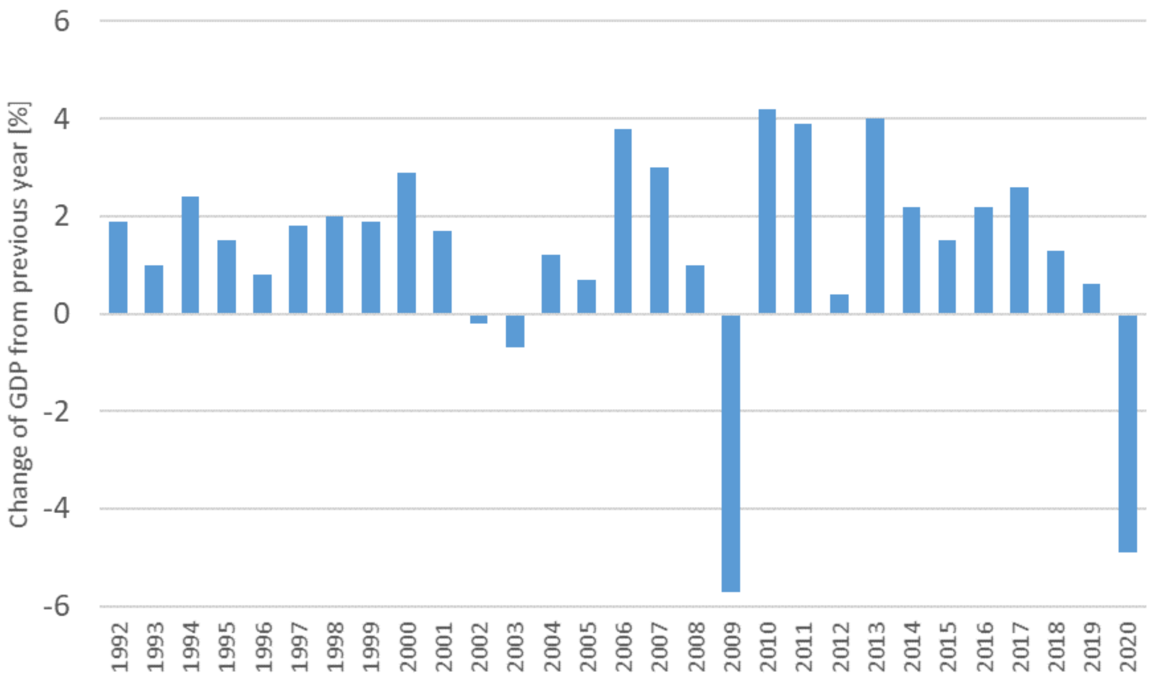

Figure 12: Change of the GDP compared to the previous year in Germany (Statista 2020b)

The city of Lübeck is located in one of Germany’s structurally weak regions as indicated in Figure 13 (Innovation Strukturwandel 2020), which are mostly located in former GDR states in eastern Germany. Most part of the Northern-German federal state of Schleswig-Holstein is structurally weak since it is mainly agricultural with low population density. The federal state has a GDP of 34,032 € per person and is therefore below the German average. However, the city of Lübeck is not structurally weak. It has a GDP of 45,098 € per person and is therefore above the German average (Statistikportal 2020).

Lübeck is also a university city with major companies in the fields of medical technology (Dräger, Euroimmung), food (Brüggen, Niederegger, Erasco/Continental Foods) and a seaport, which is a major hub especially for forest products and paper on the Baltic Sea. Another economic factor in Lübeck is tourism, with almost 2 million overnight stays per year.
The Sector Report 2020 states that "*The most employment-intensive sectors for Lübeck are the health industry (22,000 jobs), private services (15,000 jobs), business-related services (11,000 jobs), the food industry (8,500 jobs) and the logistics industry (6,800 jobs). These five sectors account for almost two-thirds (64%) of all jobs. In a nationwide comparison, the employment figures for these sectors in Lübeck are clearly above average*." (Wirtschaft in Lübeck 2020). The above-mentioned sectors are not only the most employment-intensive but also the sectors with the highest turnover.

The introduced collection and management concepts can help to boost the economy in the sector of BW treatment but also in the sector services by subcontractors. Jobs could be created in HH-related services, waste management and technology supply. If Lübeck is among the first municipalities to leave the German rigid common waste management concept, and as a showcase proves that alternative concepts can improve waste management tremendously, it could also call for start-ups related to resource management to be situated in Lübeck.

EBL has an annual turnover of around 100,000,000 € (EBL 2020b). The company has around 600 employees and personnel expenses of around 35,000,000 €. The company owns one of Germany's largest wet anaerobic digestion plants and is in the planning of increasing the capacity of the existing one.

Besides EBL, further companies dealing with waste management, amongst others the Buhck Group, Veolia, Dörner and Remondis, who can be competitors with EBL. Veolia, e.g., is responsible for the collection of recyclables in Lübeck. A surrounding company specified in composting is Gollan.

The company EBL sees the need for improvements in waste management as a chance for innovative solutions and also as necessity to be able to market their products for a valuable price in the future. Also due to the high annual turnover, EBL is open for testing innovative concepts on a small scale. The company is also willing to implement innovation since the awareness exists, that higher costs on the collection side will result in higher product quality and therefore increases in turnover are to be expected that can compensate the rising costs.

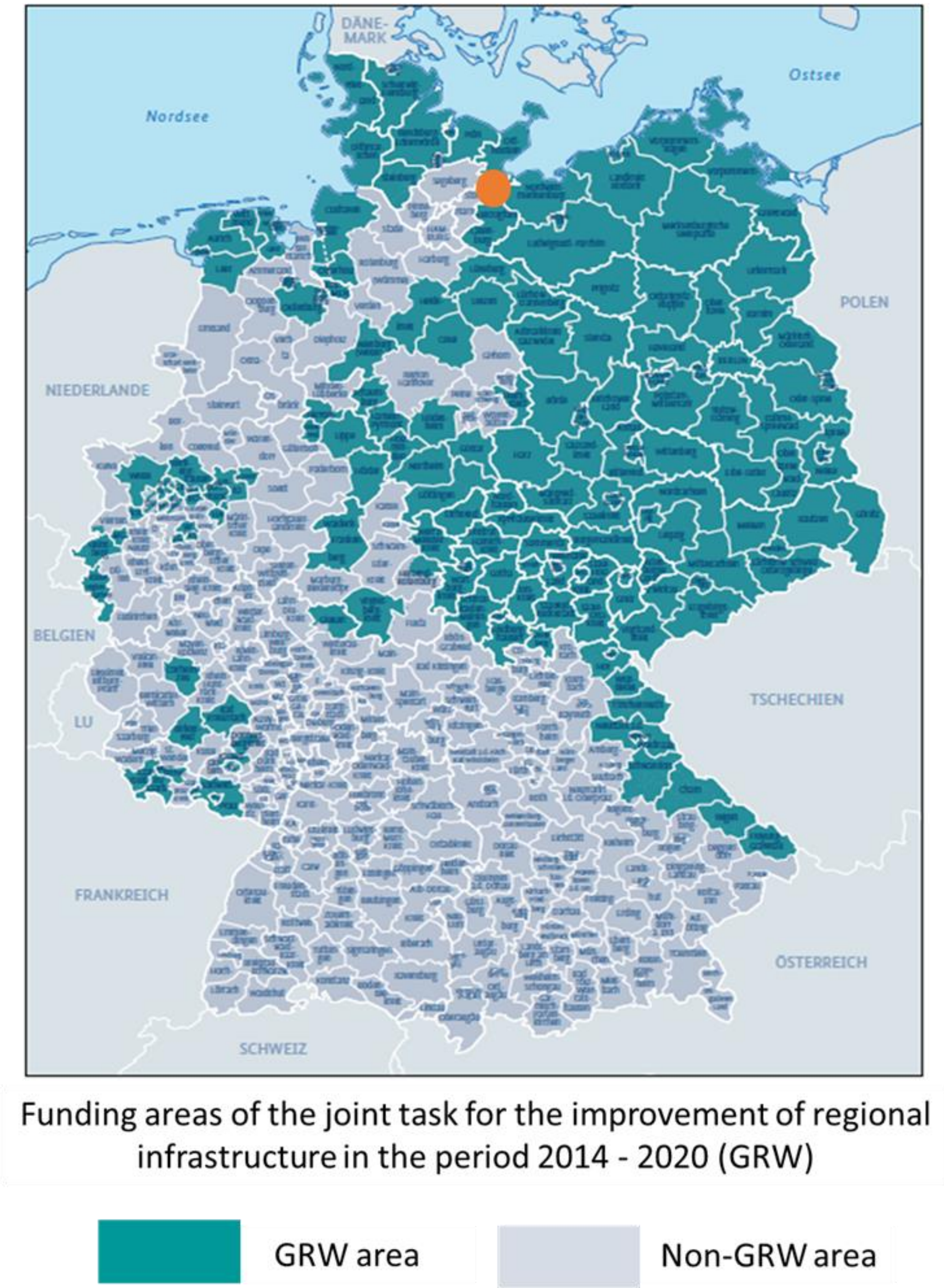

Figure 13: Map of structurally weak regions in Germany including Lübeck as GRW area (adapted from Innovation Strukturwandel (2020))

6.4 Social

With over 200,000 inhabitants, Lübeck is a smaller city according to the definition of the International Conference on Statistics and benefits from its proximity and good transport links to the metropolis of Hamburg (BBSR 2015). The population development is accordingly positive since 2010, as can be seen in Figure 14 (Stadt Lübeck 2019).

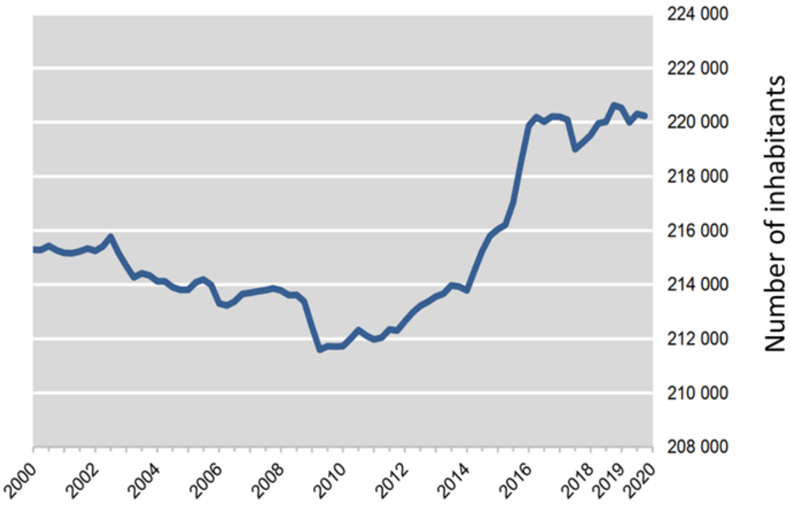

Figure 14: Lübeck's population trend

Lübeck has a mixed population in every respect and is younger than the national average (34% ≥ 65 years) with a proportion of 23% over 65 years (Statista 2013; Stadt Lübeck 2019). In addition, the proportion of foreigners is 11.5%.

Unemployment rates have fallen steadily from 2007 to 2019 and were below 7% at the end of 2019 (Stadt Lübeck 2019). However, the effects of the drastic measures (lockdown) to combat the Sars-cov2 pandemic remain to be seen. As Lübeck is very touristy, the restrictions will have a clear impact on the labour market. On 31.12.2019, approx. 25,000 people lived in communities in need (according to SGBII). The number of employees, subject to social insurance, contributions was 100,000 within Lübeck (Stadt Lübeck 2021a).

In higher education, Lübeck offers numerous courses of study in addition to medicine and health at the University of Lübeck. This includes Computer Science and Mathematics, Natural Sciences and Psychology as well as various technical specialisations. In total, 11,000 people study in Lübeck at the university and the technical colleges collectively (2020/2021) (Staatskanzlei Schleswig-Holstein 2021).

6.5 Technology

The main technologies relevant for this business model in the three sub-concepts are waste collection equipment such as small buckets and underground containers, transportation equipment such as e-cargo bikes and mAD plants.

Sub-concept 1: For the waste collection equipment, the market offers many options with different sizes. A list of producers of small collection buckets can be found in the appendix.

Sub-concept 2: The e-bike sector is growing for many years which also includes e-cargo solutions. The German government financially supports the purchase of e-cargo bikes (Bundesamt für Wirtschaft und Ausfuhrkontrolle 2021). There are many options for storage containers for the cargo bikes that can be used for the collection of waste. However, there is a growing market for cargo-bikes specifically designed for waste collection. A list of (e-)cargo bike producers can be found in the appendix. It is also indicated which bikes are specifically designed for waste collection.

Sub-concept 3: Moreover, the market of mAD plant suppliers is growing recently. Within the DECISIVE project, the two plants implemented in Lyon and Dolina were purchased from two different suppliers who were commissioned to specifically design the mADs for the project's requirements. For the Lyon case, Enwise (Enwise 2021), developed and built a mAD plant with the capacity to treat 50 Mg a^{-1}. For the Dolina case, SEAB (Seab 2021) developed and built a mAD plant with the capacity to treat around 200 Mg a^{-1}. Both providers have in common, that their solutions are built into ship-containers. This is important for easy transportation of the plant. In addition, the plant takes rather little space.

Regarding mAD technology, the DECISIVE project is proof, that there are already many high-quality solutions on the market. Besides the commissioned companies there are several more on the market with similar solutions, e.g., Impact Bioenergy (2021) and Puxintech (Puxintech 2021).

Biogas plants, in general, need to be designed according to specific safety regulations. Majorlaine (2020) describes the safety and risk aspects of a biogas plant. One critical factor of mAD plants, which are integrated in a decentralised management concept in urban areas, is the emission control and avoidance in order to increase acceptance by residents. In general, mAD plants currently have to fulfill the same technological requirements as large scale plants in terms of safety requirements.

In Lübeck, the current BW management is carried out by EBL, which owns a large central mechanic-biological treatment plant which treats source-separately collected BW and the biodegradable fraction of RW in two separate lines in order to produce biogas. Beforehand, there is an intense pre-treatment which removes a large share of non-biodegradable matter from both treatment lines. From compost, that is produced within the BW treatment line, residual particles of plastic and other impurities are removed during an intense post-treatment. The impurity removal in the BW line are necessary due to the high requirements for compost qualities (Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit 2021). Source-separatedly collected BW still contains high amounts of impurities in Lübeck. Currently, EBL is planning to expand their treatment plant in order to be able to treat more BW. It is also the goal, to switch the RW treatment line to a further BW treatment line. However, this implies a minimisation of biodegradable matter in RW. Further information on the technology applied by EBL can be found in D3.6 and D6.6 (Schermuly et al. 2018; Walk et al. 2020).

6.6 Legal

The following laws and ordinances are the most important ones for all sub-concepts:

- Circular economy act (Bundesministerium der Justiz und für Verbraucherschutz 2012)
- Biowaste ordinance (Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit 1998)
- Renewable energy law (Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit 2014)
- Federal Immission Control Act (Bundesministerium der Justiz und für Verbraucherschutz 1974)
- Clean vehicles procurement act (Bundesministerium der Justiz und für Verbraucherschutz 2021)

The *Circular Economy Act* regulates and promotes circular approach for the conservation of natural resources. It aims at achieving sustainable management of waste. It sets recycling rates to be achieved at a specific time in the future. For Germany, a recycling rate of 65% of all municipal waste was aimed until 2020. Officially, this goal was achieved in 2018, with a recycling rate of 67% (UBA 2020).
The *Biowaste Ordinance* regulates the proper management of BW. It defines the responsibilities in the management chain. One important part is the regulation of a maximum share of macro-impurities in source-separated BW. Treatment plant owners are also responsible for the review of collected waste. As indicated previously, the amendment of the *Biowaste ordinance* foresees a maximum share of impurities of 0.5% in source-separated BW. Furthermore, the plant owners have to assure that the product, usually compost, has a minimum share of plastics and other impurities. Those impurities are currently the main reason why farmers do not want to apply compost from BW on their land.
The *Renewable Energy Law* regulates the preferred injection of energy from renewable resources into the grid. This includes biogas from biomass which is HH BW and FS BW. Due to the low source-separation efficiency of HH FW, there is still a high potential to improve the sector of energy from biomass.

The *Federal Immission Control Act*, related to bioenergy, regulates the building permit and authorisation of a biogas plant. This includes all plants with a capacity to produce more than 1.2 Mio. m^3 of biogas per year. The *Clean Vehicles Procurement Act* regulates the minimum share of clean vehicles purchased by public entities. This share is 38.5% for the sector of light commercial vehicles. Until 2025 clean vehicles are defined by emitting no more than 50 g CO_2 km^{-1}. From 2026 on, clean vehicles are defined by emitting 0 g CO_2 km^{-1}. E-cargo bikes belong to the zero-emission category.

6.7 Environment

The federal state of Schleswig-Holstein is sparsely populated with 183 inhabitants per km^2. However, there are clusters with increased density areas such as the cities Lübeck, Kiel, Flensburg and Neumünster (Statistisches Amt für Hamburg und Schleswig-Holstein 2019). The countryside is dominated by agriculture, with a total of 651.000 ha of farmland and 9000 farms (Statistisches Amt für Hamburg und Schleswig-Holstein 2019).
As foreseen by the German *Climate Protection Act* greenhouse emissions have to be reduced by 65% until 2030 with the reference year of 1990 and to achieve climate neutrality until 2045. However, the action plan for Lübeck is more ambitious: Until 2030, greenhouse emissions have to be reduced by 50% but with the reference year of 2019 and not 1990 as the common German plan. Climate neutrality is to be achieved by 2040 (Stadt Lübeck 2021b). With the introduction of the *climate emergency*, this goal was further pushed.

On the other hand, Schleswig-Holstein has the issue of manure pollution and nitrate overload in the soil but also ground and fresh waters. Figure 15 shows the measurement points where nitrate concentration in ground water is above limitations (MELUND 2020; NMUEBK 2020; Bürgerschaft der Freien und Hansestadt Hamburg 2019). This calls for a better and proper biomass management in the federal state. The application of high-quality compost from BW can help to achieve improvements in this regard, since compost can help to store nitrogen in soil and provide it slowly to plants as a nutrient.

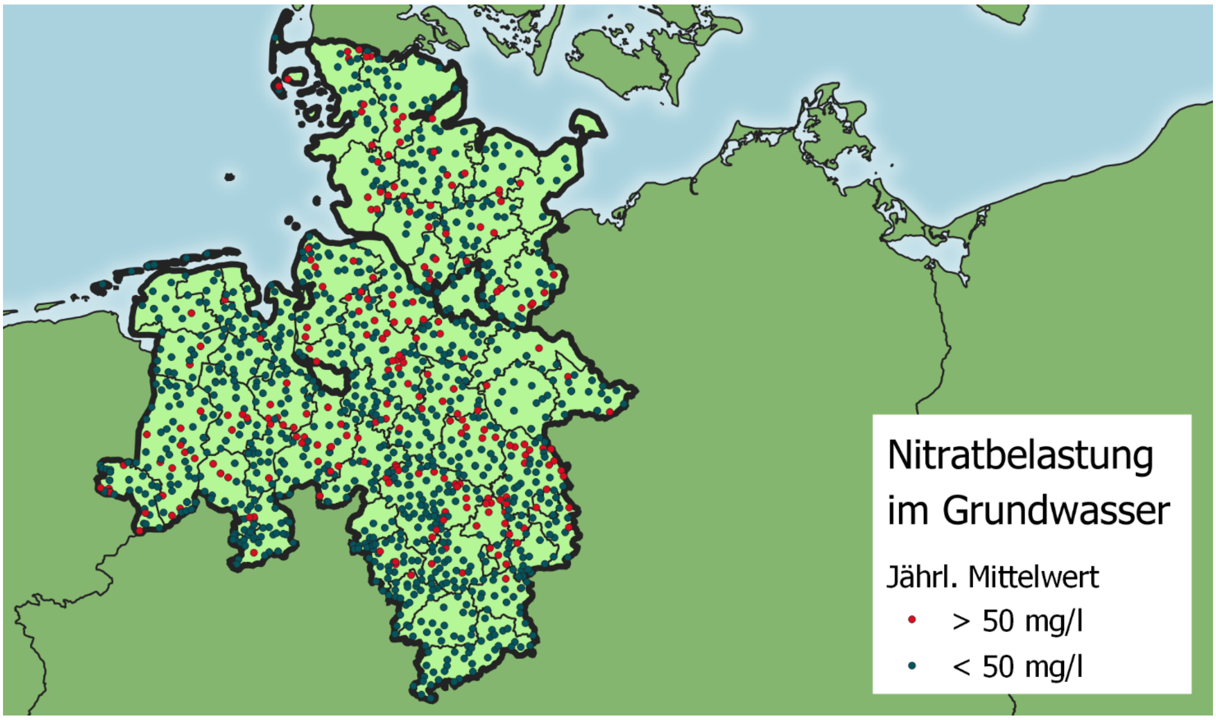

Figure 15: Nitrate measuring points indication nitrate concentrations and limits in Schleswig-Holstein, Hamburg and parts of Lower Saxony (Ortiz Cabrera 2020)

EBL is planning to extend their treatment plant in order to be able to treat more BW from the city of Lübeck but also other municipalities. This could lead to a higher amount of compost and therefore support a reduction of nitrate pollution. Furthermore, the company is open to expand their plant to a biorefinery, by including new products into their treatment concept. This could be a door-opener for other products investigated during the DECISIVE project, such as bio-based pesticides' products in a solid-state fermentation process (Cerda and Sánchez Ferrer 2017; Duval et al. 2019).

7. SWOT analysis

The SWOT analysis describes critical strengths, weaknesses opportunities and threats related to the described sub-concepts. In D7.6 (Kroff 2020) the basic concept of the SWOT analysis is explained. It basically describes how strengths can help to avoid threats, how weaknesses can expose those threats, how strengths can help to connect to opportunities and how weaknesses can avoid opportunities. Strengths and weaknesses correspond to internal characteristics of the sub-concepts while opportunities and threats are derived from the analysis of external factors. As indicated in D7.6 (Kroff 2021), they are highly based on the previous PESTLE analysis.

The most important strengths, weaknesses, opportunities and threats for the overall business concept but also for the sub-concepts are listed in Table 4.

Table 4: SWOT analysis of the business concept and its sub-concepts

Strength	Weakness

Overall concept
• Circular concepts
• Short distances and *hand in hand* workflow
• Various potential revenue sources: energy, heat, quality compost
• Larger valorisation potential of more and cleaner BW to biogas, higher quality compost and other value-added products
• Motivation for waste generators by incentive creation
• Visibility of the impact of one's actions related to waste sorting
• User friendly, more service-oriented
• Monetary incentives
• Eased quality checks for waste management
• Creation of new jobs
Sub-concept specifics
• Sub-concept 1: small logistical changes for waste generator, small investments for waste management, potential large overall benefits
• Sub-concept 2: Potential relief of traffic situation, higher collection frequency with more convenience for waste generators
• Sub-concept 3: Visualisation effects for the importance of circular bioeconomy on a small scale to increase overall acceptance of BW valorisation and its technology
	Overall concept
	• Dependence on waste generators
	• Macro-impurities in BW
	• Space constraints in in some areas
	• Lack of motivation by waste management to implement changes
	• Potential high investment costs, long-term return of investment
	• Potentially no improvement effect without benefits for better sorting by residents
	Sub-concept specifics
	• Sub-concept 1: Without accompanying intense communication activities, distribution of waste collection buckets might not have any effect
	• Sub-concept 2:
	    ○ Investment volume for vehicles and intermediate stations could additionally increase fees
	    ○ Increased collection and transportation time
	• Sub-concept 3: Implementation of a mAD plant requires higher personnel effort for mAD operation

Opportunities	Threats
Overall concept • Political will • Social will • Legal framework: new BW ordinance • Funding for demonstration sites • Increasing waste separation • Reduction of the ecological footprint of waste management Sub-concept specifics • Sub-concept 1: Increasing the motivation of citizens through a simple system • Sub-concept 2: Efforts towards traffic-calmed, low emission areas in residential quarters and space savings at the waste collection point • Sub-concept 3: Promoting local waste valorisation	Overall concept • Economic obstacles, e.g. constraint of fee system • Complex legal framework • Issue of locations • Inconsistency of regional waste management in Germany • Availability of centralised treatment plants • Waste avoidance efforts Sub-concept specifics • Sub-concept 1: Citizens still unmotivated and insufficient tools to increase motivation • Sub-concept 2: Space creation for intermediate stations and personnel required for collection • Sub-concept 3: Low cost-benefit of small decentralised plants and legal ambiguity about operation/operator

8. Market analysis

8.1 Potential markets

Waste management in Germany is a very regional and static market. Furthermore, profit margins are rather low in the business, besides technology. This is why especially for mAD plants, there could be a growing market, especially due to the plans of the EU, to support research in the sector of decentralised management schemes. The concept of mAD plants, e.g. also as a network, are not imagined as a competition to centralised biogas plants but as an add-on for certain situations. This includes new neighbourhoods that are planned to be energy self-sufficient, an increase of the capacity of the existing centralised plant or remote towns, where also decentralised wastewater management is in place. The use of e-cargo bikes can find its application as well in new neighbourhoods but also in very dense areas with narrow streets, such as old towns. Furthermore, an application in areas with multi-family houses, where BW separation is commonly not very efficient, could lead to better sorting behaviour in combination with an individualisation of BW collection and direct bucket collection.

8.2 Competitor analysis

EBL is legally required for BW management in Lübeck. The company is the only responsible for Lübeck's HH BW. Management of FS BW is an open competition also for private waste managers. In regard to the implementation of an alternative collection system (sub-concept 2) or a mAD plant (sub-concept 3), EBL has the option to operate it itself or sub-contract it. While a mAD could be run by externals, FW collection could still be managed by EBL or the opposite way. In regard to sub-concept 1, a competitor could be companies producing biodegradable bags which could be more favoured rather than buckets. For sub-concept 2 other collection concepts, especially larger trucks with innovative fuelling could prevent the implementation of small e-cargo bikes. Furthermore, potential sub-contractors could take over some part of the waste management instead of EBL dealing with it, e.g., the transport from HH to underground container. For sub-concept 3 owners of biogas plants could enter the market, especially since the use of energy plants is becoming less desirable. Those plants can still run but instead of the current input, BW could become favourable. The additional capacities could prevent the implementation of mAD concepts.

8.3 Customer analysis

Most important customer for all of the three sub-concepts is EBL who is responsible for HH BW management in Lübeck. The company benefits from the improved BW management by gaining higher profits from marketing biogas and potentially also compost. Furthermore, the company could benefit from image improvements by implementing a transition towards a sustainable circular bioeconomy which results in overall improvements on a social and environmental level.

9. Implementation strategy of business model

9.1 Business model canvas

The business model canvas (BMC), consisting of several elements, is used to define and to document a business model for the specific service or product to be marketed (Existenzgründungsportal 2021). The concept of the BMC is to bring together as many individual ideas as possible.
Those can be used as a building block to formulate the final business model. Table 5 shows the business model canvas for the overall concept and the aspects of each sub-concept.

Table 5: Business model canvas

<table>
<tr>
<td rowspan="2">Key Partners
All concepts:
• Lübeck waste management
• Property management
• Waste generators
• Public authorities

Sub-concept 1:
• Waste bucket provider
• Property management
• Designers/Architects

Sub-concept 2:
• Sub-contractors; “Last km” logistics, cleaning, maintenance
• City planners/Architects
• Underground container provider

Sub-concept 3
• mAD and composting technology provider
• Farmers / landscaping / gardening management</td>
<td>Key Activities
• All concepts: Providing solutions for improved biowaste collection
• Sub-concept 1: Providing food waste sorting equipment and intense communication activities
• Sub-concept 2: Improving transportation
• Sub-concept 3: Implementation of DECISIVE concept with mAD</td>
<td rowspan="2">Value Propositions
All concepts:
• High-quality biowaste
• High-quality customer services
• Strong social interactions and awareness raising due to customer proximity and high visibility including educational programs
• Reduction of municipal greenhouse gas emissions
• Reduction of municipal traffic, noise, risks, fossil-fuel demand
• Creation of „green“ jobs in a growing bioeconomy
• Improving visibility of circular economy concepts with more direct revenue streams including the integration of waste generators as important part of the circular system</td>
<td>Customer Relationships
• Direct consulting and communication
• Integration of different stakeholders into a streamline
• Billing via a fee system with flexible elements
• Neighborhood officers for close citizen contacts</td>
<td rowspan="2">Customer Segments
• Municipal waste management
• Subcontractors
• Households with revenue streams
• Companies and small start-ups developing services and technologies</td>
</tr>
<tr>
<td>Key Resources
• Technical feasibility of all sub-concept parts
• Proof of concept through scientific investigations and demonstrations</td>
<td>Channels
• Cooperation with housing associations, equipment producers and service providers
• Communication and education programs from politics, waste management, training centres, schools
• Educational workshops at the mAD site</td>
</tr>
<tr>
<td colspan="3">Cost Structure
• CAPEX: Equipment for different sub-concepts
• OPEX: Services, Staff, Maintenance
• Business model is value driven, intense interactions with all stakeholders in order to achieve high quality products
• Consideration of indirect costs via subventions by governmental environmental programmes</td>
<td colspan="2">Revenue Streams
• Waste fees
• Consulting service payments
• Educational event incomes
• Product marketing: Larger quantities but also higher qualities
• Free products for waste generators</td>
</tr>
</table>

9.2 Scenarios and their background data

The following describes the baseline as well as the different scenarios building on the sub-concepts described previously. Scenario 1 refers to sub-concept 1, scenario 2 refers to the combination of sub-concept 1 and 2 and scenario 3 refers to the combination of all sub-concepts. The baseline and all scenarios are based on potential sizes of mAD plants, also in order to make them comparable to each other. Therefore, study sizes of 50 Mg FW a^{-1} and 500 Mg FW a^{-1} were selected. While the smaller size reflects the mAD size of the demonstration site in Lyon, the larger one reflects a more commonly purchased size of mAD according to the producer Enwise (Enwise 2021). However, the large-scale scenario is not discussed in more detail but will be presented in a supplementary excel sheet. This is due to the fact, that most cost increase linearly, while only the investment cost reduces in relation to the plant size. The background data, used for the calculations in the different scenarios are summarised in Table 6.

The baseline considers the status-quo of source-separation efficiency in Lübeck including current management practice. In general, all inhabitants have access to a BWB. Scenario 1 considers the provision of waste collection buckets and accompanying communication activities. Scenario 2 considers scenario 1 plus FW collection with e-cargo bike and intermediate storage in an underground container. Scenario 3 considers scenario 2 without the underground storage plus FW treatment in a mAD plant.

Table 6: Background data for business scenarios

Parameter	Unit	Baseline scenario	Scenario 1: Sub-concept 1	Scenario 2: Sub-concept 1+2	Scenario 3: Sub-concept 1+2+3
Background data					
Total generated food waste[a]	kg HH.$^{-1}$ a^{-1}	130			
Source-separation efficiency	% of generated food waste	27	40	65	90
Selected scenario size					
Management of 50 Mg FW a^{-1}	No. of households	1450	1000	600	450
Management of 500 Mg FW a^{-1}	No. of households	14500	10000	6000	4500

[a]Average data for both investigated areas in all study phases

In order to build scenarios close to real conditions, data from a FW and RW collection test was used, however, was simplified for the scope of this report. The data is presented in D6.6 (Walk and Körner 2021). The test was carried out in two neighbourhoods in Lübeck. Based on this test, a FW generation of 78 kg inh^{-1} a^{-1} was found which reflects well the German average of around 75 kg inh^{-1} a^{-1} (Schmidt et al. 2019). Considering the average HH size of 1.66 residents found in the study, this results in a total FW generation of 130 kg HH^{-1} a^{-1} (Table 6).

The number of HHs necessary to collect the respective amount of FW was calculated based on the total generated FW and the respective source-separation efficiency of each sub-concept (Table 6). The higher

the source-separation efficiency, the less HHs are necessary to collect 50 Mg FW a^{-1} or 500 Mg FW a^{-1}, respectively. The number of HHs was rounded up.
The following summarises the findings from the collection trial used for the baseline and different scenarios:

- The source-separation efficiency of scenario 1 is the average ratio based on long-term performance results (Walk and Körner 2021). Inhabitants had pre-sorting buckets but had to empty them into the regular BWB. It was assumed that this source-separation efficiency could be achieved if the system set-up follows the description of sub-concept 1.
- For scenario 2, the average source-separation efficiency during the collection test was selected. The tested system offered much comfort and service for the inhabitants, such as a high collection frequency, which is also described in sub-concept 2.
- Only for scenario 3, an assumption of a potential source-separation efficiency was made. It is assumed that 90% source-separation efficiency is possible. If the full implementation of the DECISIVE concept with mAD is planned, further measures, such as intensified communication, quality controls and a high service should be carried out. This is assumed to have a high impact on the source-separation efficiency.
- The baseline scenario to which scenarios 1-3 are to be compared to includes Lübeck's current FW source-separation efficiency.

9.3 Financial indicators

In the following, the cost estimation for the different sub-concepts are demonstrated. A summary of the individual items is shown in Table 7. All calculations were based on investment (CAPEX), an interest rate of 3%, operational costs (OPEX) and revenues. It is only considered business as usual, e.g., an increase of waste fees was not included for simplicity. Net present value (NPV) was used as indicator in order to evaluate the profitability of each scenario. The return on investment (ROI) was calculated to evaluate the efficiency of the investment for each scenario. It is calculated by dividing the NPV by the overall investment. Finally, the payback period was considered which is defined as the years after which the investment was paid back by revenues.

CAPEX includes the purchase of equipment and single-time payments associated to it, e.g. customs. OPEX include all operations such as communication activities, collection cost including, e.g., staff and maintenance or supply. Revenues comprise waste fees, and biogas and compost marketing as well as further service charges by the housing association.

9.3.1 Overall costing

Overall costing for all scenarios was assumed for a total project time of 20 years. This includes additional investments after the ending of the lifetime of the items indicated in the CAPEX in Table 7. Services external of the ones from EBL, such as a caretaker were also accounted for, but it was assumed that those services were 100% compensated by HHs within the household service charge settlement monthly paid by inhabitants. However, an estimate can be found in the excel-based supplementary material. Furthermore, the supplementary material indicates in more detail the overall costing and background. In the following sub-chapters, the costing is explained.

Table 7: Cost, revenue and balance structure of sub-concepts for the public waste management

Unit size: 50 Mg FW a^{-1} Project lifetime: 20 years		Baseline scenario	Scenario 1: Sub-concept 1	Scenario 2: Sub-concept 1+2	Scenario 3: Sub-concept 1+2+3
Number of households		1450	1,000	600	450
	Estimated lifetime [a]	CAPEX [€]			
Waste collection buckets	5	-	3,200	1,920	1,440
E-cargo bike	8	-	-	4,080	4,080
Bike garage and storage	20	-	-	5,000	5,000
Underground container	8	-	-	4,500	-
mAD[a]	20	-	-	-	133,927
Stirling	10	-	-	-	5,000
Composter	10	-	-	-	5,000
Total CAPEX	-	**-**	**3,200**	**15,500**	**154,447**
	-	OPEX [€ a^{-1}]			
Collection	-	194,974	134,465	100,795	68,340
Centralised plant operation		36,454	25,140	15,084	11,313
Communication activities	-	-	4,000	3,000	5,000
mAD operation	-	-	-	-	28,494
Total OPEX	-	**231,428**	**205,245**	**144,080**	**132,047**
	-	Revenues [€ a^{-1}]			
Waste fees	-	323,976	223,431	110,160	70,362
Biogas	-	2,571	3,120	6,000	7,800
Compost	-	0	0	0	3,938
Total revenues	-	**326,547**	**226,551**	**116,160**	**82,100**
		Additional funding [€ a^{-1}]			
Public subsidies		**-**	**-**	**23,899**	**30,182**
Additional funding		**-**	**-**	**-**	**22,500**
	-	Balance (Revenues) [€ a^{-1}][b]			
Waste management (EBL)	**-**	**95,119**	**62,306**	**19,473**	**12,890**

[a]Including Transport, customs, installation
[b]CAPEX distributed to years of lifetime

9.3.1.1 CAPEX

CAPEX is based on real case data using references associated with the DECISIVE project and offer enquiries for producers of the respective equipment.

9.3.1.2 OPEX

The actual OPEX for the waste collection was estimated using an example given by bipro (2015). It was estimated a cost of 310 € Mg^{-1} collected BW. This cost was assumed to be the same for RW collection or separate GW collection assumed for scenarios 2 and 3. For the collection with by e-cargo bike, own assumptions were made in scenario 2 and 3. Total waste amounts to be collected based on the baseline scenario are 66.3 kg BW $inh.^{-1}$ a^{-1} and 195 kg RW $inh.^{-1}$ a^{-1} (EBL 2020a).
Salaries are based on inquiries to EBL (EBL 2021c) and literature review. The overall person-hours were estimated.
Annual maintenance, wear parts and further consumables were estimated from surveys with potential producers.
Annual maintenance & labour for the centralised plant was estimated with the original investment cost provided by EBL (EBL 2021b) and 7% of CAPEX based on Ascher et al. (2019), then distributed among the total number of households in Lübeck and finally multiplied by the number of households of each scenario.

9.3.1.3 Revenues

Waste fees are the largest revenue stream in waste management. For their assessment, the number of bins, their sizes and their collection frequencies are important. These data were evaluated for the current Lübeck situation with a dataset provided by EBL (EBL 2018). The fee system is based on the size and collection frequency of RWB. The fee system is a linear approach, e.g., a double sized with the same collection frequency costs also double the price. A collection frequency of once per week with the same bin size costs twice as much as a biweekly collection. Therefore, the fee is 1.836 € L^{-1} a^{-1} (EBL 2021a) for a biweekly collection frequency. Sizes range between 40L and 1100L and collection frequency ranges between once per month to five times per week. However, the most common collection frequency is biweekly. The most common size RWB is 120L followed by 80L.
For the calculation of the fee revenues in the different scenarios, the following assumptions were made:

- EBLs current practice of fee charge is kept in all scenarios (EBL 2021a). In the baseline, as well as scenario 1 and 2, only a charge for RW is made. In scenario 3, due to the large amount of FW collected, the standard fee for BWB is paid: EBL charges for a BWB only, if the bin size exceeds the one of RWB. The cost for every addition litre is 0.024 € a^{-1}, therefore, almost neglectable.
- The collection frequencies of RW were decreased with the estimated reduction of FW in the RWB for all scenarios. Also, collection frequency was decreased.

For the baseline, an average volume availability of 36.8 L HH^{-1} for BW and 121.7 L HH^{-1} was calculated for Lübeck residents. This assumption was based on a normalisation of each bin to be collected biweekly, although it was not in reality. This results in an average fee of 223.43 € HH^{-1} a^{-1} with the assumption, that only a fee for RWB was paid. With the indicated baseline bin sizes, an adaption of the bin sizes was estimated for the different scenarios which resulted in a decrease of waste fees to be paid. For scenario 1 the same bin sizes were used as for the baseline and therefore the same fee of 223.43 € HH^{-1} a^{-1} was assumed. For scenario 2 RWB size decrease, resulting in a fee of 183.60 € HH^{-1} a^{-1}. In scenario 3, RWB size decreased below BWB size, resulting in a fee of 156.36 € HH^{-1} a^{-1}.

Waste fees are not only used to finance the respective scenarios but also waste treatment and administration. However, the following was assumed:

- Waste fees and further revenues for biogas and compost were used to finance the system changes as well as the OPEX previously indicated.
- For scenario 2 and 3, for which decreased waste fees were assumed due to less RW and therefore smaller RWBs, it was assumed that public subsidies compensate the decreased fees to keep the baseline collection fees per household.
- For scenario 3, it was assumed an additional funding of 50€ HH^{-1} a^{-1} in order to finance the system and to gain revenues within the project lifetime. The origin of the funding is left open but a potential option are further public subsidies, financial reserves by EBL or a future environmental tax.

9.3.2 Results for financial indicators

The results for the financial analysis of the business scenarios (Table 6) is shown in Table 8. It includes NPV, ROI and the payback period.

Table 8: Summary of results of financial indicators

Project lifetime: 20 years	Unit	Scenario 1: Sub-concept 1	Scenario 2: Sub-concept 1+2	Scenario 3: Sub-concept 1+2+3
NPV	€	914,158	259,863	18,931
ROI	%	7,142	871	11
Payback time	years	<1	1-2	18-19

Scenarios 1 and 2 have high NPV and ROI. Scenario 2 only since an additional funding compensates the decreased waste fees. However, the payback time would be within the second year while scenario 1 has a payback time of only a few months due to the low initial investment costs. Scenario 3 also needs public subsidies to compensate the decreased waste fees but also additional funding. With this funding, the project can be profitable in the last two years.

However, one major item, the final disposal cost for RW, was not considered for the scenarios. Benefits would be generated by a reduction of RW and therefore reduce the disposal cost, e.g. for incineration. The current price for the disposal of RW is between 120 and 140 € Mg^{-1} (EBL 2021c). However, in the special case of Lübeck, this would mainly include the non-biodegradable fraction found in the RWB, since the biodegradable fraction is mechanically sorted and bio-stabilised through anaerobic digestion and aerobisation and then landfilled. This would lead to the assumption that a better sorting of BW would also lead to a better sorting of recyclables which further reduces the amount of BW.

10. Conclusion and outlook

A common reason for the currently insufficient performance of separate FW collection can be found, amongst others, in the lack of visibility of, and therefore knowledge on, its recycling pathways. Many citizens still do not know about what happens after they dispose of their waste into the bin. One reason for the lack of visibility is the treatment facilities being far outside of the city and furthermore their purpose being communicated insufficiently. These circumstances lead to a lack of awareness of one’s own responsibility within a potential successful circular bioeconomy concept. One’s own actions in relation to the value chain of FW, or BW in general, is rather unknown. The DECISIVE concept improves this through the decentralised proximity approach.

The implementation of the DECISIVE concept (scenario 3), does not only include the implementation of a mAD plant as core element. It also includes the demand for an improved FW sorting and collection. Therefore, all three concept elements, sub-concept 1 – 3 are needed to be implemented in order to increase the chance to become a successful concept. However, scenario 1 (sub-concept 1) and scenario 2 (sub-concept 1 and 2) can be implemented without the implementation of mAD technology.

The three elaborated scenarios of this report show, that under consideration of a set of assumptions, each of them can be financially viable. However, considering the specific regional background, this can be different in other regions. Scenario 2 and scenario 3 need additional funding, due to the high initial investment costs. Furthermore, waste fees decrease due to a better sorting performance and the better performance of biogas production (scenario 2 and 3) and compost production (scenario 3) cannot compensate for it. The subsidies could originate from regional programs or governmental programs for capacity building of climate friendly technologies. Furthermore, amongst others, potential changes in legislation, increasing energy prices, possible reward systems for carbon storage could lead to the viability of scenarios 2 and 3.

It is important to mention, that a better sorting behaviour of residents should not result in higher collection fees. However, fees for RW collection should increase, but need an additional effort for the supervision of the separated waste streams in order to avoid rebound effects such as disposal of RW in other bins to reduce costs.

The overall DECISIVE concept (scenario 3) includes all points presented in sub-concepts 1, 2 and 3. The proximity approach has the potential to increase not only the awareness and acceptance of residents being served by the system but also residents from all over Lübeck or the whole region. The concept of a circular bioeconomy could further include product application and food production on a local scale in order to visualise all important processes and stakeholders within a successful circular bioeconomy including the residents’ personal impact on the system. Therefore, the enrolled DECISIVE concept can also act as a teaching object and example for an efficient and successful circular bioeconomy. This aims at a higher motivation of residents to sort their FW correctly, reduce mis-sorting of impurities and eventually also a reduction of FW. The following implementation strategies are seen as the most promising ones:

- Implementation in a specific neighbourhood of a city to demonstrate the potentials of BW as a resource. Scenario 3 could be included in an educational centre for circularity.
- Implementation into a new and modern neighbourhood project which aims at being energetically self-sufficient including large green areas and gardening.

Scenarios 1 and 2 can be integrated into the regular municipal BW and FW management system. The investment cost is rather low but OPEX result in a small additional funding necessary for scenario 2. However, these small changes can have a major impact on improving FW sorting and collection. It is inevitable to accompany any changes in the system by an intense communication campaign. Both scenarios have the perspective to be implemented in short-term. Scenario 1 can be implemented for every household of the city. Scenario 2 is seen for the following situations:

- Areas with narrow streets, such as Lübeck’s old-town island, where waste collection including the navigation of large trucks is difficult or impossible,
- central areas with lack of space, e.g. where the placement of the current regular bins is challenging,
- newly built neighbourhoods which have the goal of being traffic-calmed and
- multi-family house areas where waste separation is an issue. The reason is usually the anonymity due to the sharing of large bin and therefore demotivating for all residents if some fail to sort correctly.

Besides financial benefits, a strong social and environmental impact can be achieved with the implementation of all scenarios. It can help raise awareness on the importance of one’s personal role in a successful circular bioeconomy. It requires intense communication actions by the municipal waste management and other involved stakeholders. This will inevitably lead to environmental benefits in the end, since BW is sorted more efficient and therefore treated more efficiently and nutrients can be returned to farmland where they support the growth of food. Furthermore, the setting of the scenarios will lead to the creation of new job profiles within a promising future bioeconomy.

Appendix

Appendix 1 : Supplier of waste collection buckets

Name	Provider/Producer	Single price [€]	Material
Indoor Bioeimer	naturalshop haentsch	19,90	
Bio-Komposteimer	Rotho	10,89	PP
Abfallbehälter	Engels	3,09	
Bioeimer	Garantia	9,99	PP
Mülli	SSI Schäfer	13,08	PE
MINIMAX square	mattiussiecologia		PP
URBA 7	sartori ambiente	ca 12	PP
Solid kitchen caddy	straight uk		
Avedore	plast team	8.75	REG

An offer for a larger quantity of buckets in a range between 5L and 20L by a German provider of equipment suggested a single price of 2.60€ (BIOLOGIC GmbH 2021). It was assumed that this price could be further decreased to 1.60€ with an official long-term agreement.

Appendix 2 : Supplier of collection bikes

Company	Origin	Source 1
CyClean	Italy	https://www.cyclean.it/en.index.html
Velove (Hersteller)	Sweden (Deutsche Ansprechpartner)	https://www.velove.se/
Radkutsche (Hersteller)	Germany	https://www.radkutsche.de/musketier/
RadPowerBikes	Utrecht, Niederlande	https://www.radpowerbikes.com/pages/commercial-radburro
XYZ CARGO	Germany	http://www.xyzcargo.com/de/raeder/
BAYK	Germany	https://bayk.ag/bring-cargobike/
Gleam	Germany	https://www.gleamproducts.com/
Cycles MAXIMUS	Germany	https://www.cyclesmaximus.com/cargotrike.htm
XCYC PICKUP	Germany	https://www.xcyc.de/de/pickup.html
Ecologia	Italy	
MaxPRO	Germany	https://www.pedicabshop.com/cargo-bikes/ecocargo-cargo-bike.html

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Image rights

Figure 4, 5, 6, 7

Household: https://thenounproject.com/search/?q=household&i=250948 (adapted)
Waste Bucket: https://thenounproject.com/search/?q=waste+bin&i=2796767 (adapted)
Bin: https://thenounproject.com/search/?q=green+waste&i=951597
Tree: https://thenounproject.com/search/?q=tree&i=2933816
Cargo bike: https://thenounproject.com/search/?q=cargo+bike&i=846640
Food waste: https://thenounproject.com/search/?q=food+waste&i=915312
Food waste: https://thenounproject.com/search/?q=food+waste&i=2130816
Food waste: https://thenounproject.com/search/?q=food+waste&i=2130853
Fermenter: https://thenounproject.com/search/?q=fermenter&i=612513
Compost: https://thenounproject.com/search/?q=compost&i=957870
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Fire: https://thenounproject.com/search/?q=fire&i=1519956
Waste truck: https://thenounproject.com/search/?q=garbage+truck&i=84573