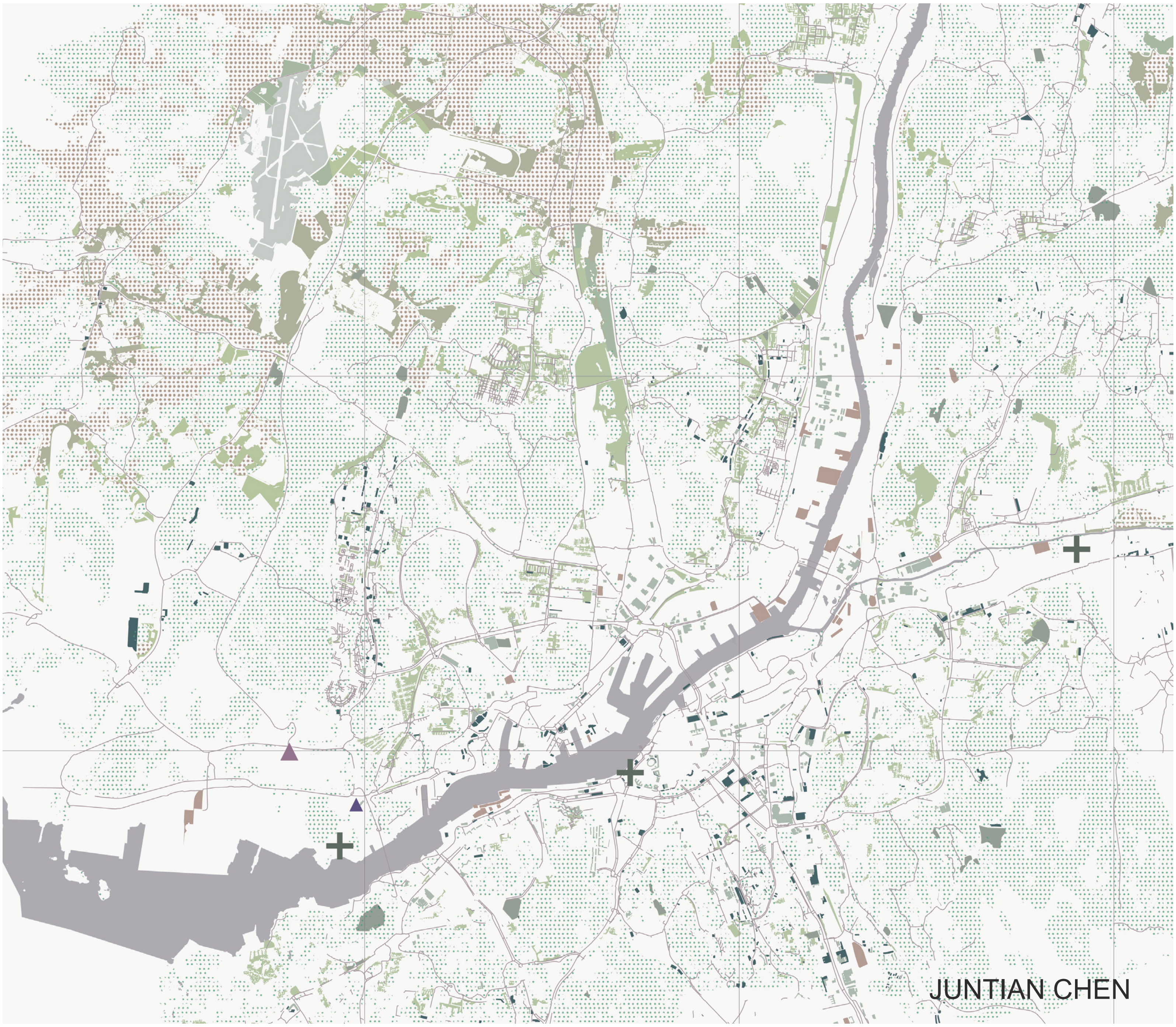
URBAN (CIRCULAR) FOOD SYSTEM

Facilitating circular food production model in Gothenburg



JUNTIAN CHEN

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Master Thesis 2021 - Social Ecological Urbanism

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Nigel Henderson - "Imagined Territory"

Neither is the landscape identical to nature, nor is it on the side of humanity against nature. As the familiar domain of our dwelling, it is with us, not against us, but it is no less real for that. And through living in it, ***the landscape becomes a part of us, just as we are a part of it.***

(Tim Ingnord 1993:153)

ABSTRACT

Nowadays, the global population is growing and the demand for food is expected to grow by up to 70% in the coming decades, that means the entire food system needs to be much more energy and resource efficient, while at the same time meet the increasing demand of food. In Sweden, food production is also an important issue related to the future's food security. How to design a new type of food system, which can balance the satisfaction of the food demand and negative effects,like GHG emission and surplus of phosphorus from food production, is an important topic. Circularity is an important approach to develop solutions that address the negative effects introduced above. Also, Urban planning can provide strategies for facilitating a circular food system spatially, and find methods to improve the system's efficiency and make it become a new type of public landscape.

The aim of this thesis is to investigate the methods of facilitating a circular food system in the city from the perspective of urban planning, and explore how the circular food system may change the urban landscape through design. In this thesis, Gothenburg will be chosen as a case city to test. The thesis is divided into 3 main parts, which are pre-research, speculation of circular concepts and scenario planning.

The first part of the thesis is the pre-research. Relevant exemplary projects will be reviewed and the current linear foodwatste recycling model in Gothenburg will be investigated, for supporting the concept design of a circular food system.
The second part of this thesis is to speculate the concepts of the future's circular food system at the urban and neighbourhood scale. The proposal of the new flow at the urban scale would be based on the investigation of how new actors may change the demand in the current food system, and the proposal of the new flow at the neighbourhood scale would be guided by the potential production model of 4 types of new actors. Meanwhile, criterias for locating four new actors and solutions of improving relevant infrastructures would be proposed, based on the circular food system concepts.

The final part of this thesis is to plan the scenario of the circular food system in the city and 3 zoom-in urban designs at the neighbourhood scale. The planning of the scenario on an urban scale is based on the criterias and solutions proposed in the second part. Then, in the zoom-in urban design, how circular food systems are implemented in urban and peri-urban areas will be presented.

The results of this thesis are a planning project and analysis methods of how a circular food system is facilitated in Gothenburg. Also, this thesis will offer different stakeholders guidelines of how to choose suitable locations and how to facilitate urban circular food systems at different scales.

KEY WORDS

Circular food system, food waste, local food production, flow, scenario,urban design

READING INSTRUCTIONS

This thesis is divided into 6 main parts, which are background, pre-research, speculation of circular concepts, scenario planning, bibliography and appendix.

A-Background: Why do we need a circular food system in Gothenburg? ***(Chapter I)***

In chapter I, the background of this thesis is analyzed from global to local scale and the reasons why Gothenburg needs an urban circular food production. Also,aims,guiding questions and the design-research framework of this thesis are explained.

B-Exemplary cases study: Approaches of designing circular food system ***(Chapter II)***

In chapter II, relevant exemplary projects in 3 different scales are analyzed and the general approaches are summarized and the starting point of the design was defined. Then in chapter III, the current food waste recycling system in Gothenburg and relevant actors are analyzed and mapped, for providing a platform for concepts design.

C-Design of circular food system concepts in Gothenburg at urban and neighbourhood scale ***(Chapter III and chapter IV)***

Chapter III is about the conceptual design of the circular food system in urban scale. In this chapter, methods and processes of how to design a circular flow at urban scale are presented. Chapter IV is about the design of a circular food system of new food production actors at neighbourhood scale. Process, methods of the design are presented. Also, the criterias of actor's location and relevant system for supporting circular food production are summarized.

D-Scenario planning and zoom-in urban design based on proposed system
(Chapter V and chapter VI)

Chapter V is about the scenario planning in urban scale. In this chapter, toolbox for GIS based site selection and supporting system analysis; process of analysing and final results of the scenario are presented. In chapter VI, 3 zoom-in urban areas which include typical food production models are selected to do zoom in urban design. In this chapter, how urban circular food systems can be integrated into concrete urban space are presented.

E-Discussion ***(Chapter VII)***

In the part of discussion, the conclusion of the project, limitation of the study and possible further works are discussed.

F-Bibliography and appendix

In this part, literature, data sources are listed. Meanwhile, detailed maps of the scenario planning are listed in the appendix.

Finally, in this thesis, keywords and key-sentences are in green colour.

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I.DESIGN OF THE THESIS

Brief of this chapter

In this chapter, the background of the food system from global to Gothenburg and the definition of circular economy will be introduced in order to answer why we need an urban circular food system in Gothenburg. Also, guiding questions, objectives and the design-research framework will be presented.

1.1.Global food system background

Food system is one of the most important sectors in the global economic system. It provides our human beings food and livelihood. Nowadays, according to reports,The food system as a whole (including refrigeration, food processing, packaging, and transport) accounts for around 25% of total greenhouse gas emissions in the world.
(https://ourworldindata.org/ghg-emissions-by-sector).

Agriculture accounts for 73.6% of total GHG emission of the food system itself (18.4% of total emission of the world) and the main contributors of agriculture's emission are enteric fermentation (5.8%) and the application of fertilizer for agriculture soil (4.1%) *.(source: the world resources institute (2020))*. At the same time, food production also leads to the high concentration of nutrients in the water body and have negative impacts on aquatic industry and water quality, which is resulted from the process of food production, especially intensive farming and fertilizer use.
(Source:https://www.eea.europa.eu/signals/signals-2015/articles/agriculture-and-climate-change).

Nowadays, the global population is growing and the global demand for food is expected to grow by up to 70% in the coming decades *(https://www.eea.europa.eu)* and that means more land and resource will be consumed by food production ,which would create additional pressures on earth. In conclusion, the entire food system will need to be much more resource efficient and reduce its negative impacts in the future's world.

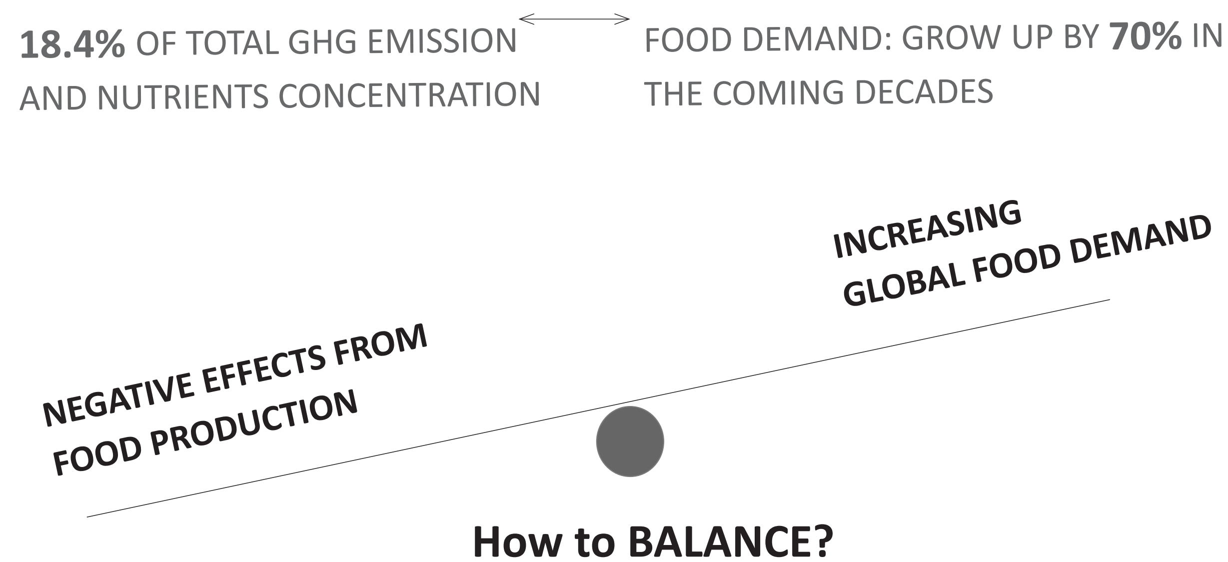

Figure1. How to balance the increasing demand of food and negative effects of food production?

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1.2.Background of food system in Europe and Sweden

Nowadays, Europe is one of the largest food producers in the world *(Source: Eurostat)* and accounts for a large amount of food supply in the world. In order to meet the growing demand of food in the world, more land and resources will be used for food production. However, suitable land and resources for food production is limited in Europe.

In Sweden, Food production is also an important issue which is related to social ecological sustainability and food security.The swedish agriculture can not be able to keep on running without fertilizer and fodder from other countries in the world if there is an uncertain disaster or crisis (like coronavirus) *(Eriksson et al 2016)*. Warmer temperatures and longer growing seasons can contribute to more suitable land for agricultural production which may compensate for the fragile and unsafe food system in Sweden nowadays in order to improve self sufficiency. However, how to design a new model of food production in Sweden which can balance the growing demand and reduce negative effects ---- for example: surplus of phosphorus in water-soil and loss of biodiversity in rural areas, is now an important topic *(Source:Potential for circularity in the agrifood system, Metabolic).*

In order to face the above issue, many solutions and policies in the EU and Sweden have been proposed nowadays for reducing GHG emission and the concentration of nutrients in food production, while at the same time improving production. For example: Local food production and markets, reduction of food waste; Efficient use of fertilizer and capturing manuel from livestocks, circularity in the food system *(Source: EEA, 2015, state and outlook 2015:Agriculture),* have contributed to the 24% reduction of emission in recent decades. Some of the above solutions are related to urban planning and design. Many relevant projects in different cities have attached importance to researching the metabolism process, food (or organic) waste recycling flows and public participation in the planning process.

1.3.Summary of the situation and trend in current food system

Based on the analysis above (see 1.1 and 1.2), From the whole world to Sweden, the demand for food is increasing due to the growth of population. In Sweden, besides the above reasons, self-efficiency is also an important factor when considering the food system. Meanwhile, to meet the growing demand of food, the current global food system model may contribute more negative effects like GHG emissions. In Sweden, concentration of nutrients in water and soil, loss of biodiversity in the rural area are caused by the current local food system.

To summarize, in order to address the contradiction between the demand of food and negative effects from meeting the demand of food, an alternative model of food system for the food system from global to Sweden is required, and the objectives of the new food system model may vary based on different local contexts.

1.4.Circularity as a goal for a sustainable food system in the future

1.4.1 Why circularity ?

According to a recent report from Ellen Macarthur Foundation, a circular economy is defined as an industrial system that is restorative or regenerative by intention and design. It replaced the “end of cycle” concept with restoration, shifts towards the use of renewable energy and eliminating the consumption of toxic chemical in the economic development, which aims for the elimination of waste by redesigning materials, products, systems and relevant business models *(Source: Towards the circular economy-economic and business rationale for an accelerated transition,2013).*

Nowadays, Food system is one of the most important sectors in the economic system and how to balance the growing demand and negative effects (see section 1.1) are important in the future, while the circular economy can become a systemic approach to develop the economy which include the food system, and at the same time this type of economic model can benefit businesses, society, and the environment by minimising the resource input and producing waste, also reduce GHG emissions, water and toxicity in the production process *(Source:https://www.ellenmacarthurfoundation.org/)*. Also, A shift towards a more circular economy is crucial to achieve a more sustainable and inclusive environment that meets future demands *(Remøy et al. 2019).*

To conclude, in order to transform the current economic system which includes the food system, the circular economy can become a possible model to develop the economy, reach future’s demand while at the same time benefit society and ecology through reusing waste and reducing negative effects.

1.4.2 How can circularity benefit the future's food system in Europe and Sweden ?

For the food system in Europe, biological nutrients from the current food system are now largely discarded in Europe and only limited amounts are re-collected to be composted, reused or digested. (*Source: Towards the circular economy-economic,2013,p51),* while in Sweden, although there are developed food waste recovery system in many cities, but there are still problems of nutrients surplus in soil for monoculture and water body (*Source:Potential for circularity in the agrifood system, Metabolic),* these problems would be more serious is the food system is developing based on current model.

Based on 1.4.1, the implementation of a circular economy model can be a possible approach to solve above problems, through transforming the system from current linear model (take-make-dispose) to a circular model by carefully managing the material flow of biological nutrients (for example: food waste and organic waste), The process of transformation can divert organics from the landfill to create more value in the waste cascading of the food system. Also, compared to the current model, the implementation of circularity can send valuable biological nutrients into truly circular paths by reducing and reusing (for example: 1.extraction of nutrients and soil through waste composting facilities and anaerobic digestion facilities; 2.extraction of energy through digestion and biogas facility.).

To summarize, The implementation of these circular strategies can help extract more value in the food system through reusing of waste nutrients and waste energy in the process of food production, while at the same time can help reducing the potential negative impacts, like the surplus of nutrition in water and soil, more cost of energy when increasing local food production, which is important when tackling current situation and trend of food system in both Europe and Sweden.

(*Source: Towards the circular economy-economic,2013,p22).*

Meanwhile, according to the summary in 1.3, self-sufficiency is an important issue for Sweden due to local climate conditions for farming and potential crisis, the implementation scale of the circular food system in Sweden from food production to the recovery of nutrients should be more local based.

Besides, nowadays many circular food production strategies have been developed in some European cities (For example: Food waste compost and recovery of nutrients like phosphorus) and in Sweden, these circular projects in city are able to be supported and funded by the local government and EU, that means the implementation of a urban circular food system becomes feasible.

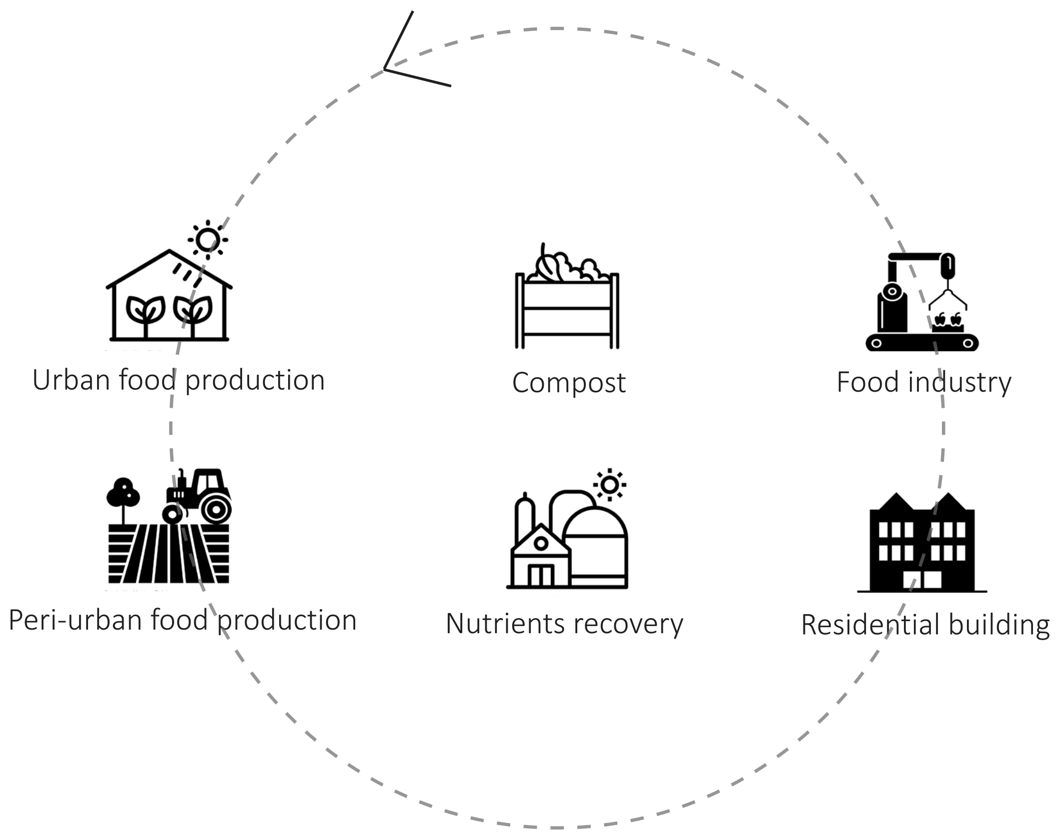

Figure2. Typical actors in the circular food system.

1.5.Opportunities for facilitating urban circular food system in Gothenburg

1.5.1.Why Gothenburg?

After the study of the food systems from global to Sweden and meaning of circularity in future's food system in Sweden , in this master thesis, Gothenburg will be chosen as a typical case city in Sweden to test the opportunities of facilitating an new type of urban circular food system, which can balance the satisfaction of growing demand of food and negative effects from food production through the perspectives and approaches of urban planning. At the same time, current situations and policies related to the food system in Gothenburg will be reviewed in this chapter.

Gothenburg is the second largest city in Sweden and the population is growing by 1.5% every year which means there is growing demand for resident's food and food security. However, most of the land suitable for farming in Peri urban area of Gothenburg is used for grazing and monoculture (cereal and potatoes), and are rented to raise horses due to economical benefit in land resource management (Wästfelt and Zhang, 2018) and the land for vegetable only accounts for around 10%, as a result, based on current land use, in order to supply food for local residents in the future, more food, especially vegetable products, still need to be imported, which means more fragile urban food security and more negative effect.

In order to compensate for the negative effect (like GHG emissions and concentration of nutrients in soil and water body) from the growing food demand and build up an efficient self sufficient food system of Gothenburg, there are still a lot of potential opportunities of developing an alternative urban circular food system because of the potential of land in the urban area and existing supporting policy framework regarding to the renovation of food system (from food production to food waste treatment).

1.5.2.Relevant policies for supporting an alternative urban circular food system

A lot of relevant planning projects and policies have been set up by the municipality of Gothenburg for supporting local food production in urban space and green start-up companies in rural areas of the municipality. For example: “STADLANDET” project, which is funded by “Europeiska regionala utvecklingsfonden” and “Mistra Urban Futures” (*https://goteborg.se/wps/portal/enhetssida/stadslandet-goteborg)* and the planning of the district greenhouse by using the existing parking lots. At the same time, the government of Gothenburg owns around 3000 ha of land that is suitable for farming, and plans to rent the land to green start-up companies for food production in the future. In conclusion, starting up different types of local food production in different locations, ranging from urban to rural areas, is all able to be supported by the Gothenburg municipality politically and financially.

Besides supporting policies and funds for sectors of local food production, there are now also planning projects for the food waste management of Gothenburg region in the coming decades. Food waste treatment is also an important sector in the whole food system and a better treatment process would have potential to contribute to the reduction of the negative effect of using imported fertilizer in food production (which is the main contributor of GHG emission in the whole food system) if the food waste is recycled to become local resources.

In 2030, Gothenburg plans to reduce the food-waste production by 50% per inhabitant, while 20% more food waste should be sent to nutrition recovery for biogas or other equivalent purposes, and that requires a new system, services and facilities.*(Waste management plan of Gothenburg region 2019),* that means the local food waste in Gothenburg would have potential

Figure3.Cover of sweden waste management plan and waste management plan of Gothenburg Region

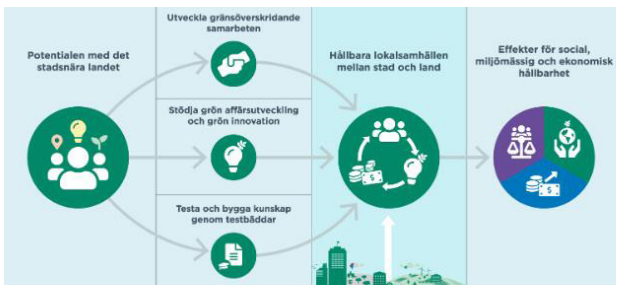

Figure4.Stadslandet project and the framwork of running the project(Source: Gothenburg municipality)

to become local resources in the future, which would also have opportunities to support local food production by replacing the imported nutrients (Especially Nitrogen and Phosphorus), and have potential to create a circular model for food production in Gothenburg.

1.5.3.Conclusion

In conclusion, based on the study of relevant supporting policies and projects in the food system of Gothenburg, it is feasible to plan a urban circular food system in Gothenburg since the main sectors (ranging from food production to food waste treatment) of the whole food system can be supported by the municipality.

The urban circular food production system itself can contribute to a more resilient and self-sufficient urban future which can meet the increasing demand for food (especially vegetables) while at the same time reducing the negative effect of the local food production, which is necessary for Gothenburg in the coming decades.

1.6.Guiding questions and objectives

1.6.1.Objectives and possible final outcome

1.6.1.1.The objective of this planning project is to plan a circular food (production) system in Gothenburg, which can realize self-sufficiency, at the same time avoid surplus nutrition and related resources through reusing the waste resource (food waste, organic waste, water etc.) in the food system.

1.6.1.2.The final outcome of this thesis would be a set of urban circular food system planning and guidelines in different scales, which can be used by both government and food-related stakeholders in Gothenburg to refer to and negotiate with each other.

1.6.2.Guiding questions

1.6.2.1.Exploring how to plan and design a circular food production system in urban areas through the approaches of urban planning and test how urban circular food production systems may transform urban landscape in different scales through the design process.

1.6.2.2.Also, since the projects are related to the planning of circularity in food systems in urban areas, the method of designing with flows in urban planning will also be experimented in the thesis.

Facilitating a urban circular food system in Gothenburg,which can improve self sufficiency but also reduce negative effects from food production.

↓

1.How to plan and design a circular food production system in urban space?

+

2.How to design with circular flow in the food system ?

Figure5. Objectives and guiding questions

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1.7. Aim and delimitation

1.7.1. Aim of this thesis

Based on the objectives and the guiding questions of this thesis, in order to realize the objectives and answer the guiding questions, the aim of this project is to plan an urban circular food production system in Gothenburg that can contribute to self sufficiency and create more value though reusing the surplus nutrients (phosphorus and nirtrogen）and relevant waste resources.

At the same time, in this thesis, Methodologies and the process of planning a circular food system in urban areas through the perspective of urban planning will be explored.

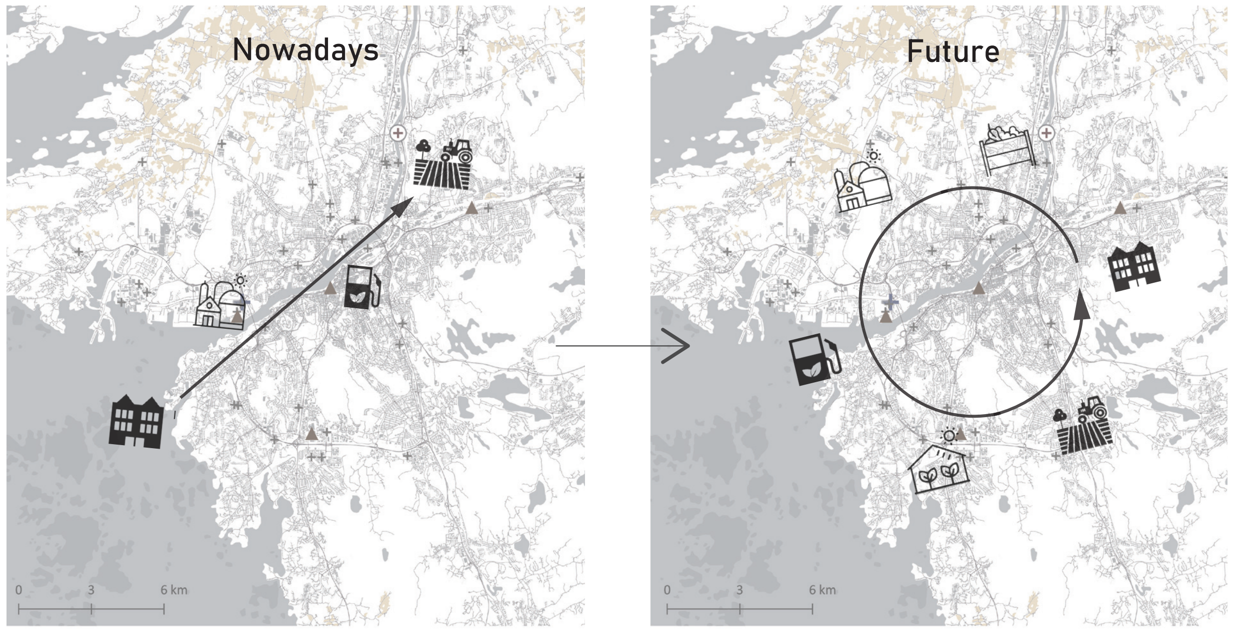


Figure6. Diagram of the aim - facilitating urban circular food system in Gothenburg

Aim

1.Planning an urban circular food system in Gothenburg, for self-sufficient and efficient use of resource.

2.Exploring the methodologies and the process of planning circular system from urban planning's perspective.

1.7.2. Delimitations

This project will focus on planning a circular food production system in urban areas and the model of “circular food production” is the focus. So that the designing of urban farming in detail (for example: plan of specific farming area, structure, vegetation) will not be a focus in this thesis.

For the circular food system, there are many approaches and strategies. Since this thesis will focus on the city of Gothenburg and the main goal of circularity is to reduce the surplus of nutrients and consumption of resource in urban food production, thus the recovery of nutrients (Phosphorus and Nitrogen) from food (or organic) waste and relevant resource (waste water and energy) would be the main circular model to be focused in this thesis, other types of circular models will not be focused.

Based on the analysis in 1.5.1, in Gothenburg, most of the land are for grazing and growing crops(90%) and land for vegetables only accounts for 10% , meanwhile, compared to land for crops and raising livestocks, there are much more demand of suitable land for growing vegetables but the land in the existing rural area is limited, that means in order to realize self-sufficiency, suitable land in both urban and peri-urban needs to be considered, also a specific circular model for vegetable production is required. In this thesis, the production of vegetables in the whole urban food system will be a focus while other food production will also be considered but will not be a focus.
Meanwhile, due to the Corona situation, it is very hard to do site visits to factories and interview relevant stakeholders. So that in this thesis, conceptual design of the planning and the methods of formulating the concept will be a focus, public participation in the planning will not be considered.

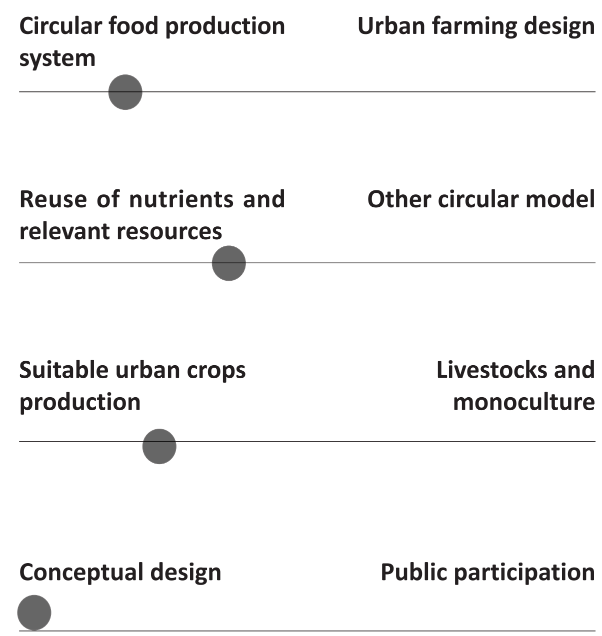


Figure7. Diagram of the aim - urban circular food system

1.8.Design-research framework

This thesis is divided into 3 main parts, which are pre-research, design of a circular food system (urban and neighbourhood) and scenario planning.

1.8.1. Pre research (Chapter I and chapter II)

The first step of the research is to analyze the background of the food system,from global to Gothenburg,in order to get an overview of the food system situation. Then, the importance of facilitating circularity in Gothenburg's food system is investigated.

After analyzing the importance of facilitating circularity in Gothenburg's food system, the second step of the research is to study relevant projects which also deal with circular food (or organic waste) systems. Exemplary projects in 3 scales (Urban, neighbourhood,building) will be reviewed and the main planning approaches will be summarized. The aim of this step is to learn the general process in facilitating a circular food system in a city, and help finding a starting point of the thesis project in Gothenburg.

1.8.2. Speculation of design concepts (Chapter III and Chapter IV)

The first step of the research is to investigate the current linear foodwatste recycling model in Gothenburg through the analysis of current actors, data of the flow and mapping of actor's locations. The analysis of current flow and the mapping will provide a platform for supporting the next step concept design of how to transform the flow from linear to circular.

The second step is to design the flow concepts at the urban scale. New actors and potential demand for food in 2030 based on the population and current land use for food production in Gothenburg will be defined. The result of this phase will decide whether it is necessary to expand food production in urban areas. If the answer is yes, then new actors will be added to the current linear food system in Gothenburg and how new actors will bring the gap of demand in between all actors will be investigated. The result of the demand investigation will guide the flow design of the circular food production system and balance strategy. The result of flow design design will guide the design of circular food production concepts of 4 main actors at the neighbourhood scale.

In the third step, the design of the circular food production model of four main types of new actors at neighbourhood scale will be based on literature study of potential circular food production models, and current policies of management set up regarding urban farming in Gothenburg. The potential circular food production model of 4 main types of actors will guide the flow concepts design on a local scale. The result of the design and the production model would be a base for proposing solutions for site selection of new actors, and solutions of supporting systems for circular food production.

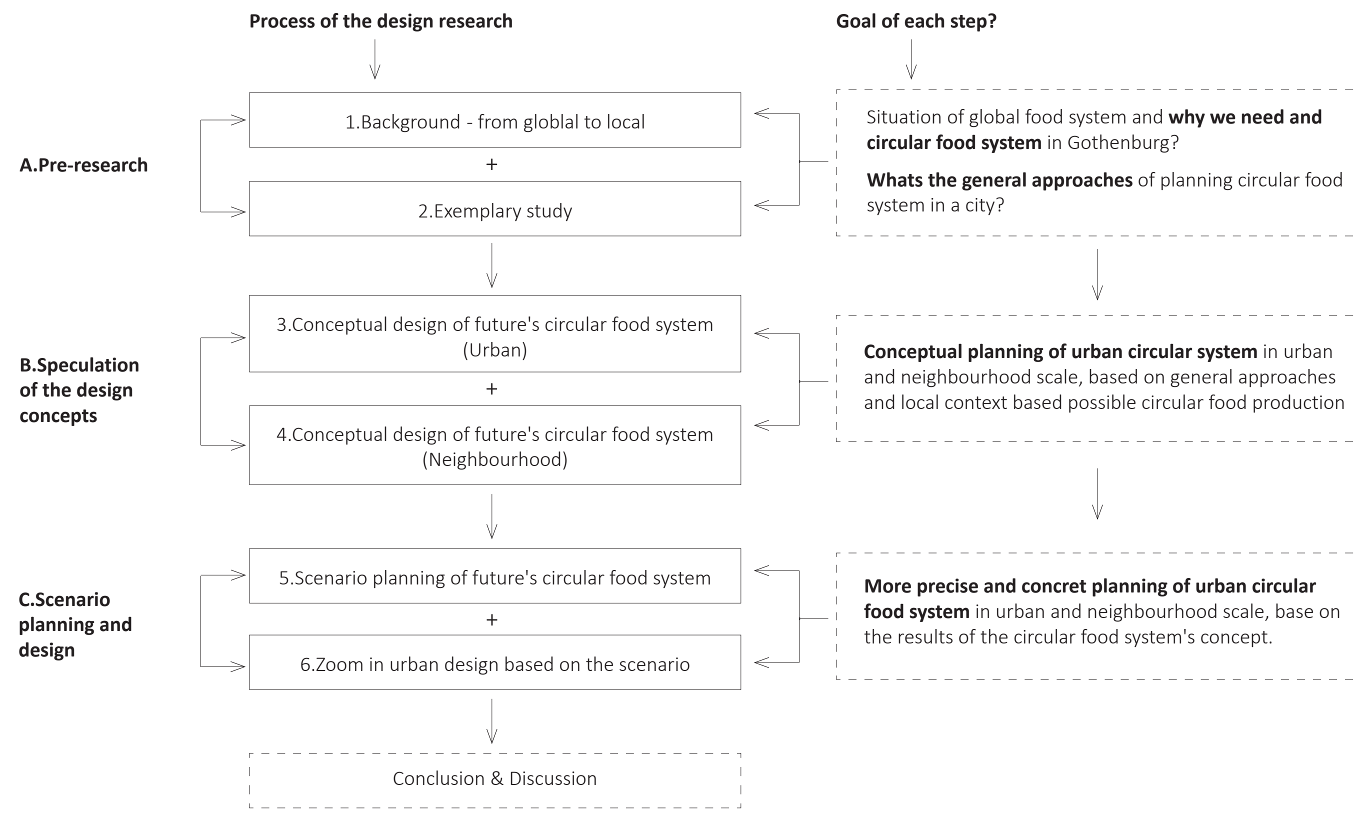
Based on the design results in the second step, criterias for locating 4 new actors and criterias of supporting system will be listed and categorized.

1.8.3. Scenario planning and zoom-in urban design (Chapter V and chapter VI)

The final part of this thesis is to plan the scenario of the circular food system in the city and 3 zoom-in urban designs at the neighbourhood scale.

The planning of the scenario at the urban scale is based on the criterias and solutions proposed in the second part, the methods for GIS analysis, data for calculation and parameters are listed according to four types of new actors. Then, in the zoom-in urban design, how circular food systems are implemented in urban and peri-urban areas will be presented.

Figure8. Diagram of the design-research framework



II.SURVEY OF EXEMPLARY PROJECTS

Brief of this chapter

In this chapter, relevant cases introduced above will be reviewed, in order to capture the approaches of framing design in facilitating circular economy in urban areas,especially when relating to the food system or food waste recycling flow. Then, in the end, common approaches and design methods that can be applied in different scales will be summarized in order to support the next step process of the project in Gothenburg.

2.1 Background of the exemplary projects study

After the analysis of the situation, trend and opportunities of the food system in Gothenburg, different exemplary cases will be chosen to study in order to learn the general process of planning an alternative circular food system in urban areas.

Nowadays, many realized relevant planning projects in regional scales, have already applied the geodesign (mainly about participation of stakeholders), flow research of circularity and the analysis of urban metabolism processes in different phases of planning an alternative flow and spatial solutions, for example: PULL Hamburg-Altona in Germany and Countryside of Pinneberg in Italy designed by REPAiR.

In the neighbourhood scale, there are also some built projects in facilitating a circular food system. For example: Hammarby and Augustenborg in Sweden, Noordhoek and Buiksloterham energy positive district in the Netherlands.The implementation of circular food systems in the above neighbourhood scale are mainly combined with other related systems, for example: purification and reusing of rainwater, waste treatment for nutrients recovery, distributed energy network, which can formulate an integrated circular food production system in the neighbourhood, and can bring the neighbourhood a self-sufficient lifestyle.

In the architectural scales, the food system related projects mainly focus on reusing the vacant land or facilitating "symbiosis farming" between greenhouse and the resource (water and energy) from industrial buildings. For example, there are some existing industrial building renovation projects in the Netherlands and Belgium which use the rooftop of large scale industrial buildings for setting up greenhouses which can provide industrialized food production by reusing the waste heat and rainwater, like Abattoir roof greenhouse and De Schilde. In Sweden, there are also some similar renovation projects which are on a smaller scale.

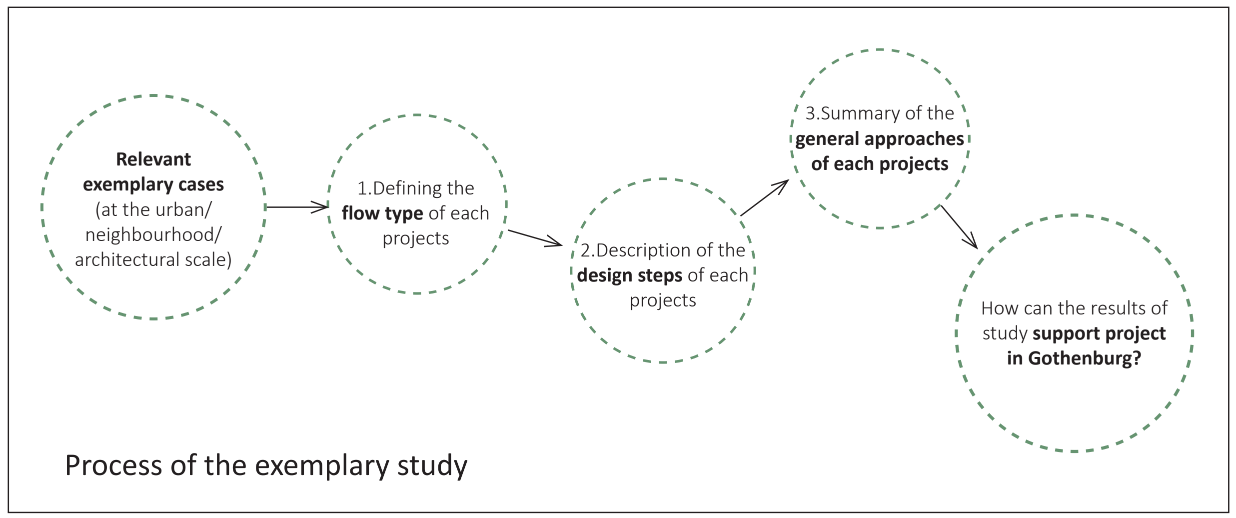


Figure9. Process of exemplary study

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2.2.EXEMPLARY CASES IN RELATION TO CIRCULAR FOOD SYSTEM

2.2.1. PULL Hamburg-Altona & County of Pinneberg (by REPAiR)

Flow type: Organic waste

Site: Hamburg-Altona & Pinneberg

Discription

This project focused on the renovation of organic waste recycling in the Urban scale of Hamburg. According to the project, most current empty spaces within the city already present an implementation plan, GIS mapping of actors, flow analysis, description of problems, discussing objectives and solutions with stakeholders are crucial in the process.

Finally, the circular solutions in Hamburg region are: 1- a quarter service centre (DHL, food sharing, repair-cafe) distributed in modules to optimize the accessibility and logistic. 2- decentralised composting plants and urban gardens and schools. 3- Planning waste management in designing buildings.

STEPS of design

Step1-
defining research zone
Step2-
Mapping of district scale urban infrastructures, built environment, natural conditions (terrain and hydrology) and waste scape. Then zoom in to the focus area, mapping urban infrastructures, building typologies, amount of food/organic waste and current companies related to food waste recycling.
Step3-
Defining problems in organic waste recycling
Step4 -
Defining objectives and solutions based on public participation.

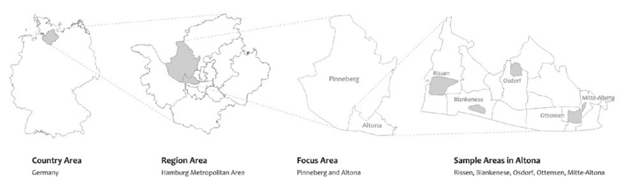


Figure10.Defining the research boundary in Hamburg

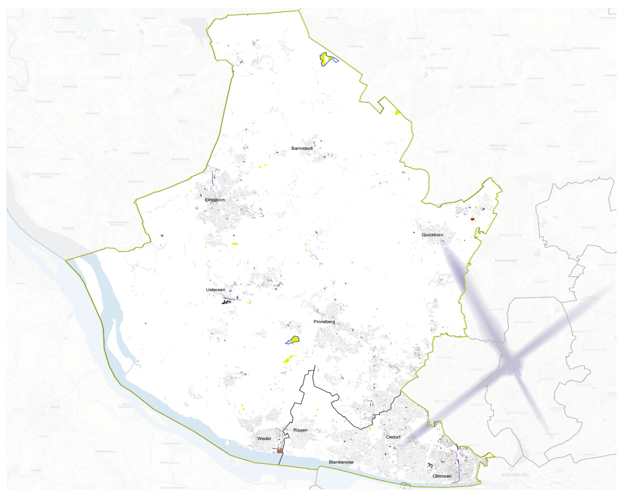


Figure11.Difining the wastescape in Hamburg region Hamburg as base for negotiation between stakeholders.

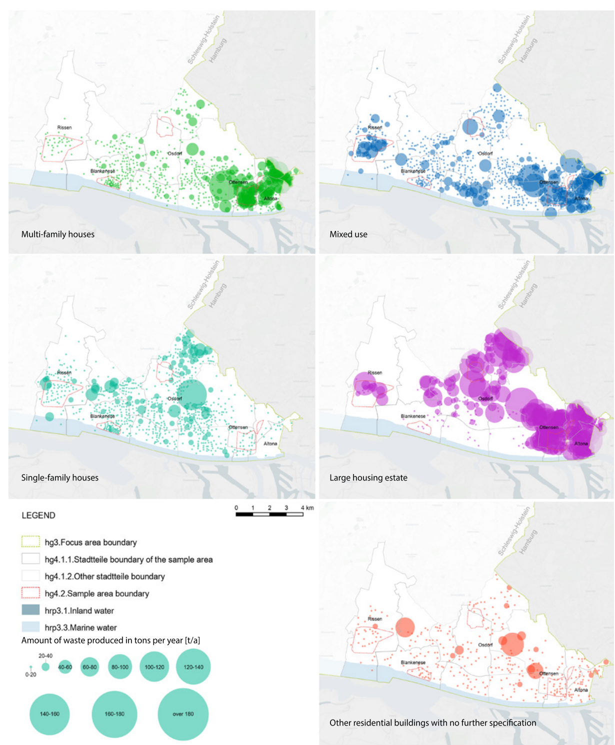


Figure12.Investigation of foodwaste resource in city

Summary of the planning approaches

(a). Phase of pre-researching
1. Mapping the situation of waste; 2. Defining priority zone; 3. Current flow research; 4. Analysing of spatial background (typology of building/Infrastructure/nature); 5. Social-economical background analysis; 6. actors analysis
(b).Phase of planning
1. Defining flow problems; 2 Defining design objectives; 3. Participation of stakeholders; 4. Defining new flows as solutions.

C.Design solutions(in spatial)
1. Improve accessibility to people; 2. Better accessibility to logistics; 3. Transforming suitable open public space.

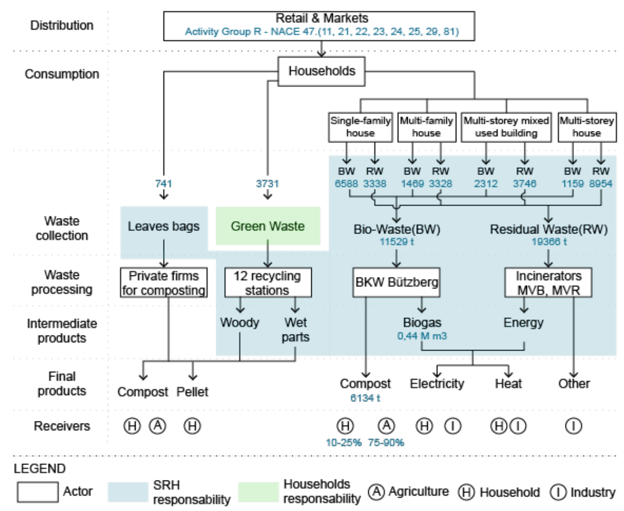


Figure13.Flow research of organicwaste flow types in Hamburg region

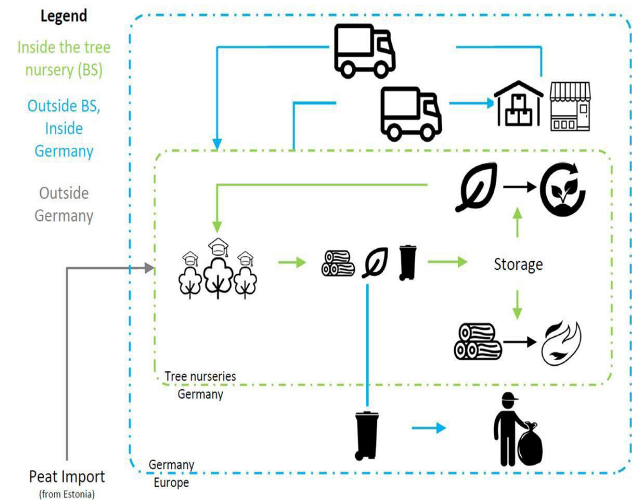


Figure14.Ecological innovation solutions in specific site based on analyis of problems in current organic waste flow

2.2.2. Re-Compost Land-Short supply chain of organic waste (By REPAiR)

Discription
Flow type: Organic waste
Site: Peri-urban area of Naples

According to a report of REPAiR Naples, more than 80% of organic waste is treated outside the region, but current factories are not able to handle such an amount of waste. This project focuses on planning a short supply chain by reusing vacant land and creating localized compost plants. The short supply chain allows collecting and treating organic waste for creating top soils for the new terrain and new fertile ground to recover the agricultural lands. (D5.3 Eco-Innovative Solutions Naples, REPAiR report). Also, after discussing with actors, the location of applying ecological innovation solutions had been decided (The final selection is mainly vacant land). The final ecological innovation solution is to localize medium compost plants in the selected location of each municipality to facilitate circularity.

Finally after another discussion with actors, land for local compost facilities (mostly wastescape and public space in Peri-urban area) can be decided.
STEPS of design
Step1-
defining research zone and actors involved in the project.
Step2-
Analysis of current waste recycling flow/data.
Step3-
Sketch of future's situation based on gaps and opportunities in current waste recycling flow.**Step4-**
Estimating the amount of compost facilities based on data analysis of population, surface of public space, surface of wastescape and production of organic waste.
Step5 -
Discussing with local stakeholders (PULL workshop) for deciding where to facilitate the recycling facilities

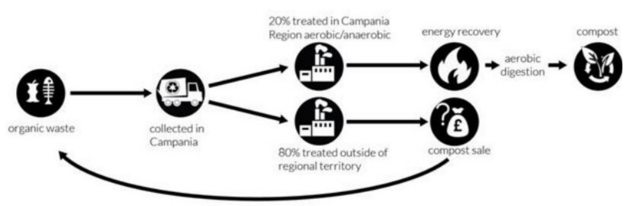


Figure15. Linear scheme of current situation (REPAiR report)

Figure17.ISystemic section of the Eco-Innovative Solution Re-Compost Land. (Source: REPAiR report UNINA Team, 2018)

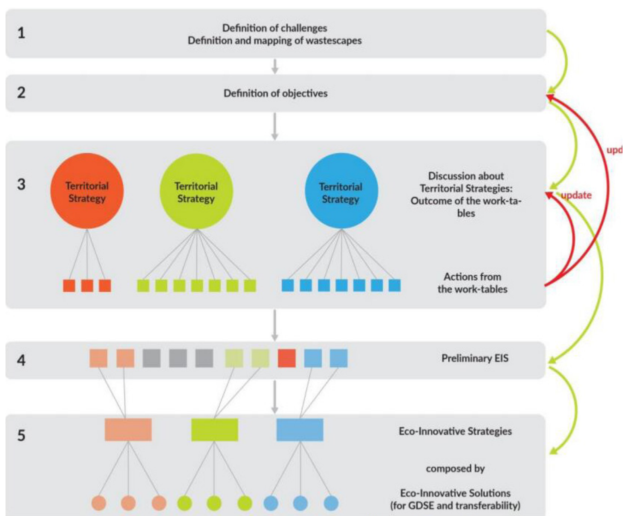


Figure16.Methodology for defining the EIS in the case study of Naples Source: REPAiR report,UNINA Team, 2018

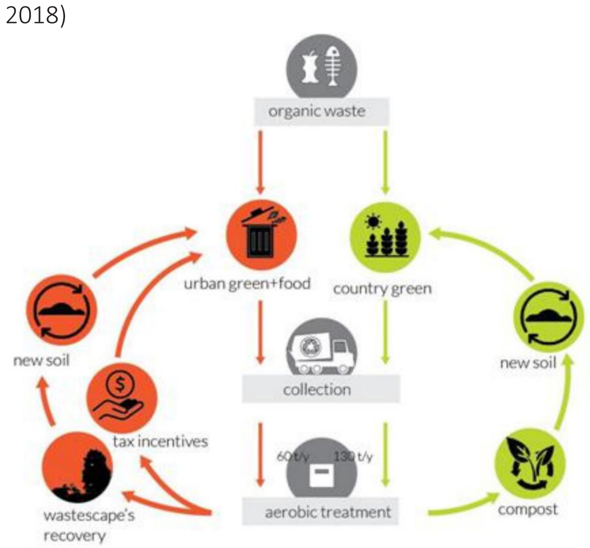


Figure18.Circular process scheme(Source: REPAiR report)

Summary of deisgn approaches of "On Organic waste"-Naples
(a).Phase of pre-researching
1.Analysising of spatial background(typology of building/Infrastructure/nature/wastescape);2.list of actors;3.Flow and data analysis of existing flow.

(b).Phase of planning
1.Data analysis of demand of actors related to organic waste(population, organic waste production, surface area of public space and wastescape). 1.Defining flow problems;2 Defining design objectives; 3.Participation of stakeholders;4.Implementing a new type of flow model for the food system;5.Dicussing negative effect of compost facilities

(c).Design solutions (in spatial)
1.Adding new decentralized recycling facilities (local compost).
2.Eco-innovation district;
3.Reuse of space(Public green, roof, vacant land and post industrial polluted land);
4 Using compost to benefit farmers; 5.Using compost to remediate surface-soil for urban landscape.

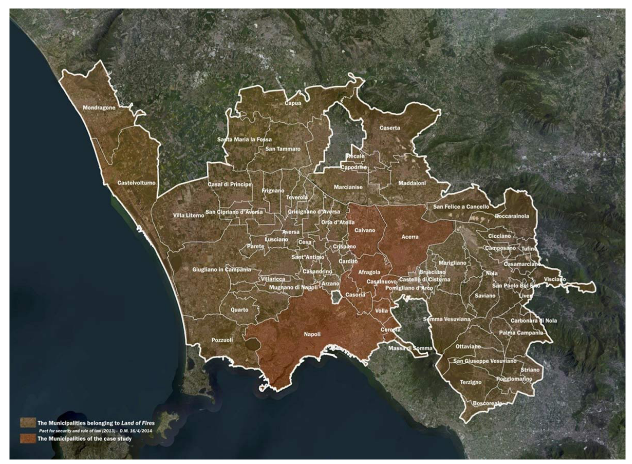


Figure19 .Defining the research boundary in Naples (Source: REPAiR website)

Figure20.Enabling contexts and hypothesis of Eco-district(Source: UNINA Team, 2018)

2.2.3 Neighbourhood scale projects

Brief of the selected projects

After reviewing two urban scale design-research projects of facilitating alternative organic waste recycling in the city, It is also necessary to choose smaller scale "pilot areas" in the city to test the application of the new circular flow..
Four relevant(about circular food system) neighbourhoods are selected to be reviewed in order to find how to facilitate circular concrpt in neighbourhood. order to find how circularity concepts(especially those related to food waste) can be applied to transform the built space and approaches of facilitating circularity.

Figure21.Hammarby (Site: Stockholm,Sweden)

Figure22.Hammarby (Site: Stockholm,Sweden)

Approaches
1.local facilities for digesting foodwaste and sewage for heating and biogas
2.Local biogas cooker
3.Purification and reuse of rainwater through urban green space.

Figure23.Augustenborg (Site:Malmo,Sweden)

Figure24.Augustenborg (Site:Malmo,Sweden)

Approaches
1.Renovation of roof-garden
2.15Xwasterooms for community composting
3.Community allotment
4.Renovation of community green space for stormwater storage and purification
5.Using compost for supporting local

Summary of general design approaches

(a).Transformation of flow in the food system
1.Implementing a new type of flow model for the food system: Local circularity benefited by food waste and the treatment of local sewage water (Recycling food waste to fertilizer for surrounding farmland and biogas for bio-based fuel production)
2.Formulating a circular food loop system in the neighbourhood. (From growing to food waste treatment)

(b).New infrastructures for supporting the new food system
1.Distributed treatment facilities for food waste
2.Facilities for reusing and purifying the rainwater (sewage+rainwater collection) for irrigation

(c).Transformation of urban space
1.Improving accessibility of local food production and waste treatment facilities to both local(for residents) and city (for Logistic)

Figure25.Noorderhoek (Site:Sneek,the Netherland)

Figure26.Noorderhoek (Site:Sneek,the Netherland)

Approaches
1.Public utility building
2.Recycling foodwaste for energy production and fertilizer for surrounding urban green and allotment.
3.Decentralized energy facility.

Figure27. Buiksloterham energy positive district (Site:Amsterdam,the Netherland)

Figure28. Buiksloterham energy positive district

Approaches
1.Decentralized energy falicity (Solar and bio based)
2.Reusing polluted area and post industrial area
3.Public facilities for recycling foodwaste
4.Recycling foodwaste(also sewage) for energy and nutrients for growing
5.Rainwater storage and purification

2.2.4 Architecture scale projects

Brief of the selected projects

After the study of urban and neighbourhood scale circularity projects, there are currently also some architecture scale projects focusing on applying the circular flow(food waste and organic waste) and symbiosis with existing facilities like industrial, which shows how circular food system may transform a specific building and urban space.The site selection of this type of projects are mainly on the roof of existing large scale factories, food market and corner of urban street,which can benefit the realization of a short loop of food and the waste energy from the industrial building.

Also, vacant land in a community can also have potential to become a perfect site for people to implement a circular food system strategy and benefit the surrounding community.

4 architecture scale projects of integrating circular food systems, ranging from industrial symbiosis and renovation of vacant land will be reviewed for studying the design approaches.

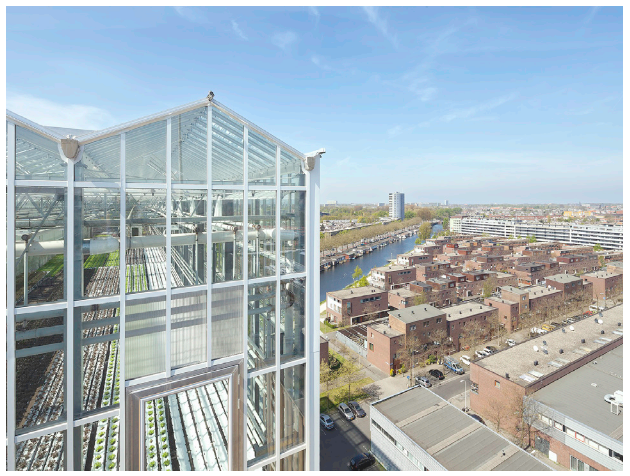
Figure29..Abattoir roof greenhouse (Source: https://salesguide.visit.brussels/en/musee/ferme-abattoir-bigh/)

Site: Brusell, Belgium

Approaches
1.Renovation of roof-garden
2.Using the wasteheat from meat market for heating the roof-greenhouse
3.Fish-vegetable symbiosis
4.Reusing organic waste
4.Greenhouse+Outdoor garden for public
5.Accessible to residents and foodmarket

Figure30.De Schilde (Source: http://www.spaceandmatter.nl/urbanfarmers)

Site: Den Haag, the Netherland



Approaches
1.Renovation of roof-garden
2.Using the wasteheat from meat market for heating the roof-greenhouse
3.Accessible to residents and foodmarket
4.Light structure

Summary of general design approaches

(a).Transformation of flow in the food system
1.Implementing a new type of flow model for the food system in the greenhouse based food production (fish-vegetable symbiosis)
2.Reuse of energy in the greenhouse based food production.

(b).New infrastructures for supporting the new food system
1.Facilities for reusing and purifying the rainwater (sewage+rainwater collection) for irrigation
2.Facilities for reusing waste heat from the building community to formulate a circular food loop system in the neighbourhood. (From growing to food waste treatment)

(c).Transformation of urban space
1.Reusing vacant artificial land,roof, or urban public space for food production
2.Flexible and low cost structure
3.Improving accessibility of local food production and waste treatment to both local(for residents) and city (for Logistic)
4.Better infrastructures for climate smart transportation (bike ,bus, etc.)
5.Providing infrastructure quality of becoming public landscape

Figure31.Kasvattamo Greenhouse(Source: ROOH studio/Archdaily)

Site: Helsinki,Finland

Approaches
1.Renovation of urban vacant public space
2.Community garden for food production
3.Flexible structure for growing food
4.Accessible to local residents

Figure34.R-urban(Source: https://www.change.org/p/yes-to-preserve-r-urban-in-colombes-no-to-the-temporary-car-park-that-is-planed-to-replace-it-

Site: Paris, France

Approaches
1.Renovation of urban parking lot
space
2.Community garden for food production
3.Flexible structure for growing food
4.Reuse of organic waste for local food production.
5.Public participation
6.Accessible to residents/local markets by environmental friendly transportation tools.

2.3.Summary of planning approaches from exemplary projects study

2.3.1.General approaches of planning circular (food) system in urban

After the study of the realized circular food system related planning projects in different scales, in order to get inspiration for starting the design-research of the projects in Gothenburg, general planning approaches of the above relevant cases are summarized below.

When tackling planning projects of urban scale circular food systems, generally there are three main phases in the design, which are pre-research, planning and proposing spatial strategies. In the first phase (pre-research), analysis of the existing flow in the food system and the analysis of actors are common methods which can help designers find the problems in the system. In the second phase (Planning), the first step is the demand analysis of different actors in the food system, then, the new flow of food waste recycling is sketched. Besides, public participation and geodesign platforms are also crucial in this phase. In the final phase (solutions), based on the previous step, different new facilities in the new circular food system are located.(For example: Decentralized food waste recycling facilities, reusing vacant land for food production)

The design methods of the neighbourhood and architecture scale projects can be described as how to implement circular food systems in specific urban areas. Similar to the projects in planning scale, there are always clear concepts of a new flow model of a circular food system, ranging from both social and ecological perspectives,based on different local contexts. Then, Symbiosis theory based food production model and new infrastructures of the model are implemented. The infrastructures themselves become public landscapes in the neighbourhood.

In conclusion, based on the summary of the realized relevant projects of different scales,it is common to start from design-research of a new flow and then investigate how the new flow can be implemented in the city, then the spatial solution can be proposed after the previous two steps. In all, flow research and systematic thinking are important in planning circularity in the food system.

2.3.2.How can the knowledge inspire the project in Gothenburg ?

The circular food system methods identified in the study of exemplary cases will guide the process of facilitating urban circular food systems in Gothenburg, from urbans scale to local (neighbourhood) scale. Based on the summary of the general approaches in the planning process at the urban scale in 2.3.1, Design research of the current flow of food waste recycling systems and relevant actors in the system would be a starting point in the design.

Scale of planning	Name of the project	Site	Type of circular flow	Problems of the existing system	What's the new circular system?	General planning approaches
Urban scale	PULL Hamburg-Altona & County of Pinneberg	Hamburg Germany	Treatment of organic waste and food waste	**1.**Organic waste are not treated well in specific areas of Hamburg **2.**Garden waste are not reused (Mainly in some plant nursery)	**1.**Using decentralised composting plants in buildings,school and urban space to compost food waste **2.**More community based station for food sharing and waste reuse	**1.** Mapping the situation of current local system; ; **2.** Current flow research; **3.** Social-economical background analysis and actors demand analysis; **4.**Defining flow problems and objectives; **5.**Defining new flows as solutions based on local problems and Participation of stakeholders
	Re-Compost Land-Short supply chain of organic waste	Naples Italy	Treatment of orgnanic waste and waste from soil remediation	**1.**80% of organic waste is treated outside the region, but current factories are not able to handle such an amount of waste.	**1.**Reusing vacant land and creating localized organic waste compost plants. **2.**Collecting organic waste for creating top soils for the new terrain and new fertile ground	**1.** Mapping the situation of current local waste; ; **2.** Current flow research; **3.** Social-economical background analysis and actors demand analysis; **4.**Defining flow problems and objectives through public participation **5.**Defining new flows as solutions based on local problems and Participation of stakeholders
Neighbourhood scale	Hammarby	Stockholm Sweden	Organic waste recovery and reuse of sewage	**1.**Lack of facilities for treating organic waste; **2.**Lack of facilities for reusing rainwater and sewage	**1.**New system for collecting organic water and sewage for local biogas production, **2.**Nature base circular rainwater system	**1.**Investigation of problems in current local system **2.**Design of the new flow based on local problems and background **3.**Planning new facilities for the new system
	Augustenborg	Malmo Sweden	Compost of food waste from the neighbourhood and reuse of rainwater	**1.**Lack of facilities for treating food waste; **2.**Flooding due to surplus rainwater **3.**Lack of facilities for treating surplus rainwater.	**1.**Transform food waste to fertilizer through neighbourhood collecting stations **2.**Nature based circular rainwater system	**1.**Investigation of problems in current local system **2.**Design of the new flow based on local problems and background **3.**Planning new facilities for the new system
	Noorderhoek	Sneek The Netherlands	Treatment of organic waste and sewage from the neighbourhood	**1.**Lack of facilities for treating organica waste and sewage	**1.**New system for collecting organic water and sewage for local biogas production and producing fertilizer for surrounding farmland.	**1.**Investigation of problems in current local system **2.**Design of the new flow based on local problems and background **3.**Planning new facilities for the new system
	Buiksloterham	Amsterdam The Netherlands	Treatment of food waste, organic waste and waste energy	**1.**Soil pollution, **2.**Fresh food are not accessible to local residents, **3.**Waste energy, sewage, rainwater are unused	**1.**New system for collecting organic water and sewage for local biogas production and producing fertilizer. **2.**Local food production supported by the waste	**1.**Investigation of problems in current local system **2.**Design of the new flow based on local problems and background **3.**Planning new facilities for the new system
Architectural scale	Abattoir roof greenhouse	Brussel Belgium	Reuse of waste nutrients from fish-farm and vegetable production	**1.**Surplus of nutrients from fish farm and vegrtable production **2.**Requirements of energy for heat	**1.**Using the symbiosis system to transform manure from fish farm to fertilizer for supporting local vegetable production **2.**Reusing waste heat of existing building	**1.**Design of the new flow based on focused food system and local context. **2.**Facilitating circular solutions and infrastructures based on different circular model **3.**Specific design based on the site condition.
	De Schilde	Den Haag The Netherlands	Reuse of waste nutrients from fish-farm and vegetable production	**1.**Surplus of nutrients from fish farm and vegrtable production **2.**Requirements of energy for heat	**1.**Using the symbiosis system to transform manure from fish farm to fertilizer for supporting local vegetable production **2.**Reusing waste heat of existing building	**1.**Design of the new flow based on focused food system and local context. **2.**Facilitating circular solutions and infrastructures based on different circular model **3.**Specific design based on the site condition.
	Kasvattamo Greenhouse	Helsinki Finland	Local food production	**1.**Fresh food are not accessible to local residents **2.**Land are unused	**1.**Local food production for residents live in the surrounding plots	**1.**Design of the new flow based on focused food system and local context. **2.**Facilitating circular solutions and infrastructures based on different circular model **3.**Specific design based on the site condition.
	R-urban	Paris Fance	Reuse of local organic waste for vegetables production	**1.**Fresh food are not accessible to local residents **2.**Requirements of nutrients **3.**Land are unused	**1.**Reusing vacant land for local vegetable production **2.**Collecting organic waste for producing fertilizer for local fertilizer production	**1.**Design of the new flow based on focused food system and local context. **2.**Facilitating circular solutions and infrastructures based on different circular model **3.**Specific design based on the site condition.

Table1. Summary of design apporaches from exemplary study

URBAN (CIRCULAR) FOOD SYSTEM

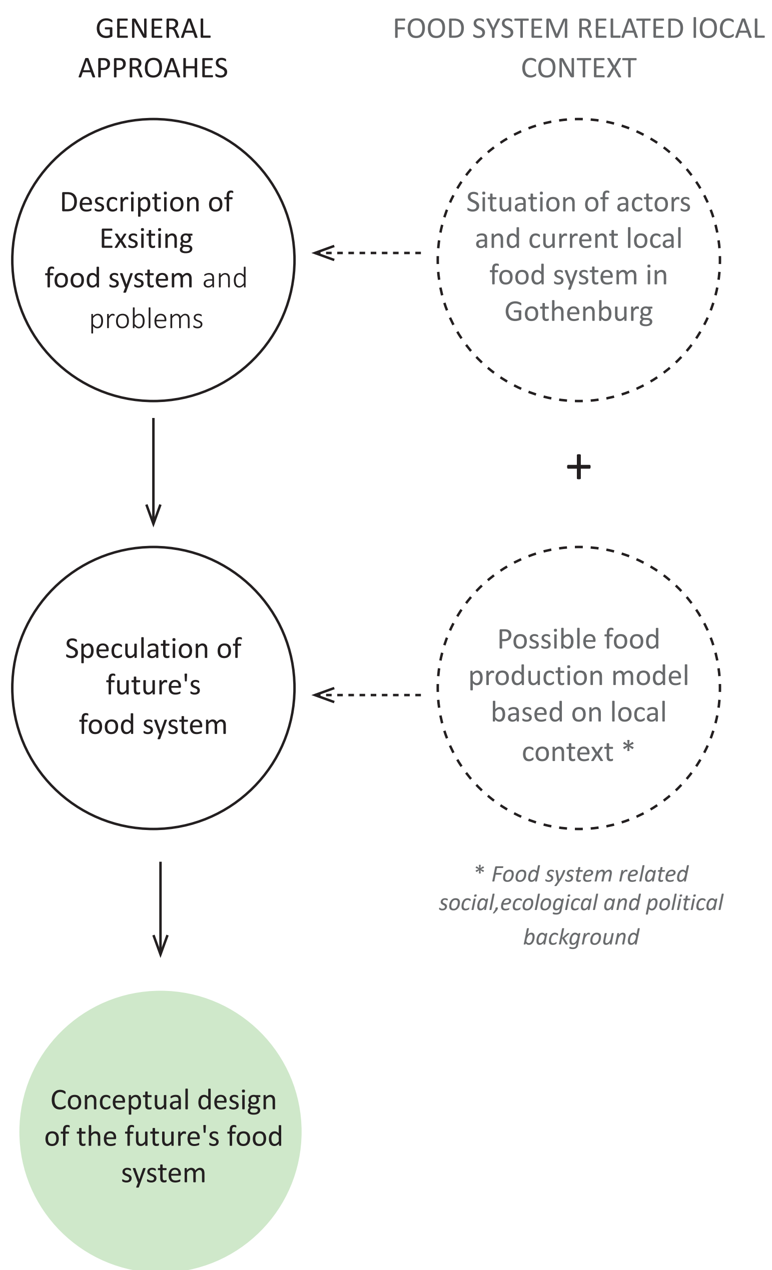


Figure 35. Summary of the exemplary study: Speculating new flow based on the local context (social,political and ecological background)

III.DESIGN OF CIRCULAR FOOD SYSTEM AT URBAN SCALE

Brief of this chapter

In this chapter, the concept of an urban circular food system in Gothenburg (at the urban scale) will be designed and speculated based on 3 main steps.

The first step is the analysis of the actors and model of the current food system in Gothenburg, in order to find whether the current food system in Gothenburg needs to be improved.

The second step is about the analysis of possible actors in the future's food system, and the demand of local food production. Also, how the new system may change the resources demand between actors in the future's system.

The final step is the conceptual design of the urban circular system, based on the future's food demand and demand of actors analyzed in the second step.

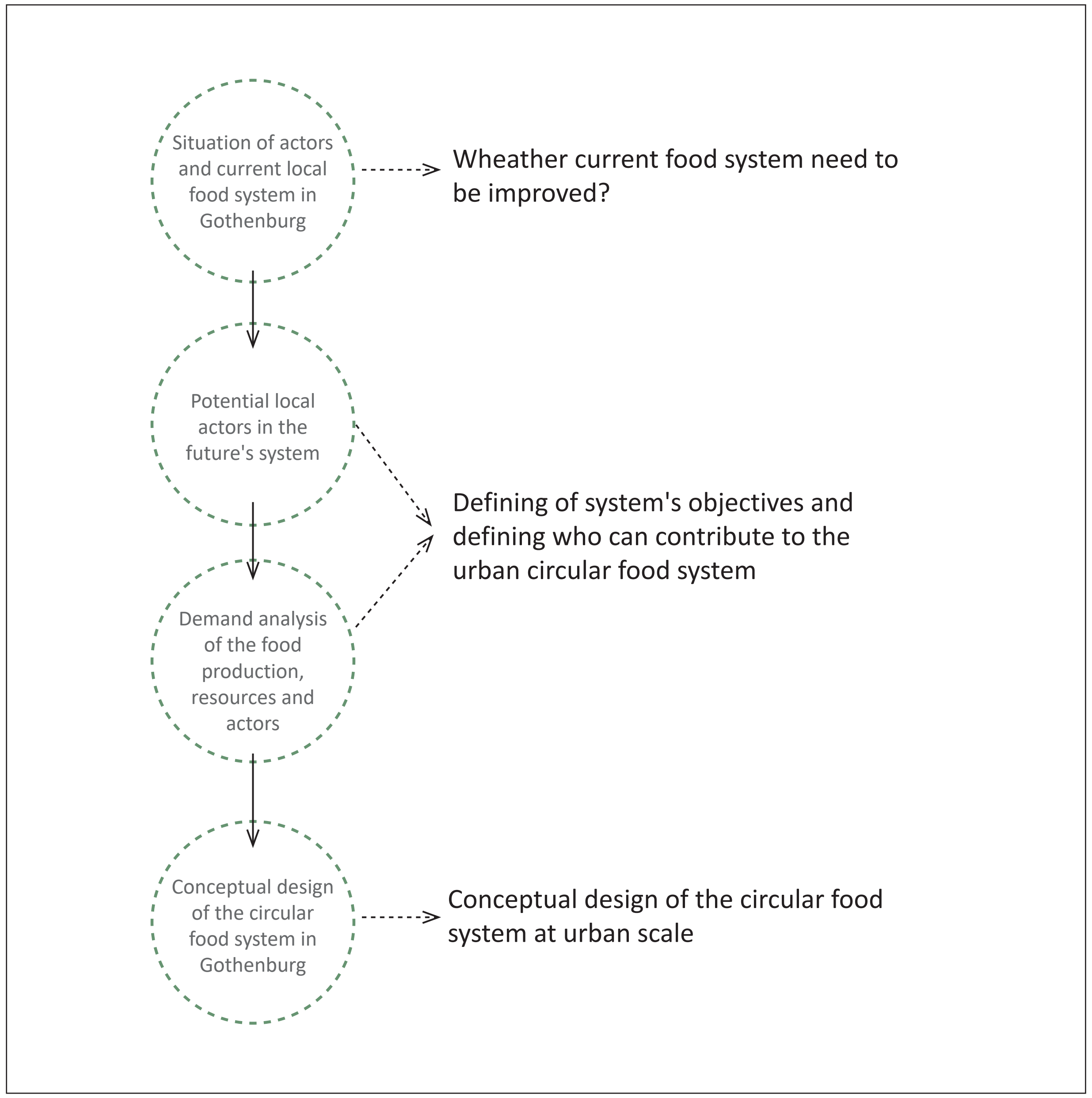


Figure 36. Process of conceptual design of the circular food system at urban scale

3.1.Situation of current food system in Gothenburg

In this section, the situation of the current food system in Gothenburg and the relationship between relevant actors will be analysed and mapped. Since this thesis will focus on circularity in urban food production and nutrients recovery, thus, actors in food production and food waste treatment will be focused in this section. The aim of the research in this chapter is to find how food production is linked to waste recovery based on Gothenburg's local context.

In the first step of the analysis, based on the resources from the municipality and relevant companies in the food system of Gothenburg, the actors and the data of material flow and relations between the actors (mainly food production and waste resources recovery) are mapped based on the reports introduced (see section 3.2).

Through the diagram of the current flow model below, the flow of the food system in Gothenburg can be divided into three phases from the perspective of circularity, which are (a) Resource (food waste and sewage) input, (b) Resource (food waste and sewage) processing and (c) Resource output (food production and energy recovery). The general way of food waste recycling in Gothenburg is to transport food waste from the neighbourhood to the centralized pre-treatment facilities (Marieholm pretreatment facility) for converting food waste into slurry. Then the slurry will be sent to the biorefinery plants and sewage plant (ST1 biorefinery and Gryaab) to produce biogas,fertilizer and energy from processing sludge at the same time. Finally, the CHP plants (Gothenburg energy will receive biogas from the 2nd step and produce biofuel and district heating;the other products,such as compost,are sent to the surrounding farmland as nutrients. In addition, in the suburb, foodwate and manuel are being composted to become fertilizer for soil,which is a kind of local circular recycling model.

To summarize, there are already developed food waste recycling systems and efficient centralized infrastructures in Gothenburg, which can transform the food waste into local resources for producing biogas, energy for heating and fertilizer for food production. In the next step, the role of actors in the current flow and data analysis of the resource flow in the current food system will be analyzed through diagrams and maps, in order to find whether the current food system needs to be improved.

URBAN (CIRCULAR) FOOD SYSTEM

3.2.Actor's role in the flow of current food system

3.2.1.Resource (food Waste) Input

According to the Swedish Environmental Protection Agency's calculations, approximately 78kg of food waste is produced per person annually in Swedish households. Local Residents of Gothenburg produce around 44460t food waste each year and 50% (22230t) are for bio treatment*(Avfallsplan för tretton kommuner till 2030)*, Local food industry produces 4080t waste and then sends them to ST1 biorefinery factory *(Etanolix 2.0 - Demonstration of Innovative Method for converting Industrial Waste to Ethanol in oil refinery for LIFE+)*. Farmland is also an important sector in the food system and in Gothenburg, most of the land is now for grazing so there is a large amount of food waste from animal like manuel, which would lead to GHG emission and additional nutrients if it is over supplied. *(https://www.metabolic.nl/publications/potential-for-circularity-in-the-agri-food-system/)*

3.2.2.Resource (food Waste) Processing

In the step of food waste processing,43618t for waste each year are sent to Marieholm pre-treatment facility *(Miljörapport Marieholm 2019)*and become slurry. Then the slurry are sent ro Gryaab factory, At Gryaab alone, there is approximately 55,000 tonnes of slurry each year from both food waste and sewage *(https://www.gryaab.se/vad-vi-gor/slam/)* and the factory can produce more than 70 Gwh biogas and 31100t left sludge are for agriculture *(Gothenburg annual report 2019)*. The biogas are then sent to Gothenburg energy for producing biofuel which can be used by 5000 passenger cars*(https://www.gryaab.se/vad-vi-gor/biogas/)*. The Gothenburg energy produces district heating when producing biofuel from biogas.
ST1 AB can process around 7200t waste product from the food industry per year, the factory produce 1699m3 biofuel for transportation with around 16000t stillage as animal food or biogas production *(Etanolix 2.0 - Demonstration of Innovative Method for converting Industrial Waste to Ethanol in oil refinery for LIFE+)*. Also,St1 Refinery AB was responsible for the delivery of approximately 16% of the total heat demand to Gothenburg's district heating network, which is 660GWh for 70000 families. *(EMAS RAPPORT)*.

3.2.3.Resource output (For food production and energy recovery)

Actors in the resource output will receive the products from the actors of the food waste processing. Farmland for grazing and crops around Gothenburg received the fertilizer from biorefinery plants (Gryaab and St1 AB), bio-fuel stations received the biofuel from Gothenburg energy (St1 refinery AB). At the same time, electrical power and district heating produced from food waste go back to residential houses and industrial buildings.

3.2.4.list of actors in the recycling flow

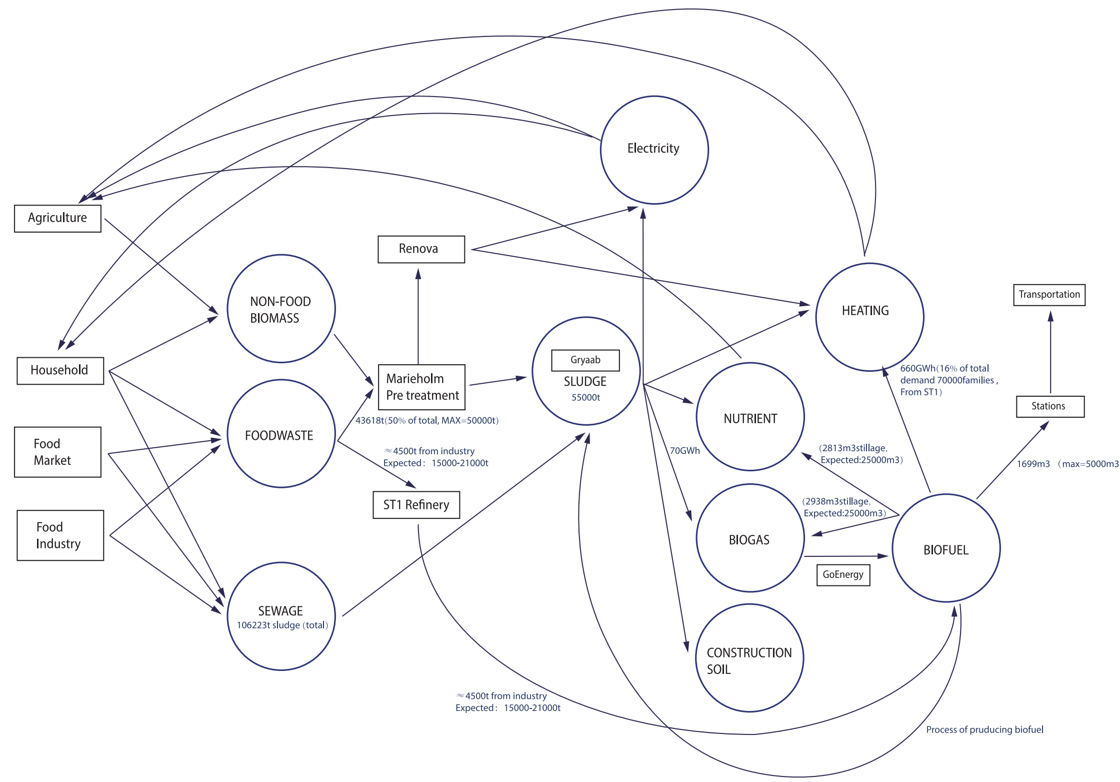


Figure 37.Current actors and material flow data in foodwaste recycling flow

Food waste Input	Foodwaste Processing	Resource Output
1.Household foodwaste 2.Peri-urban farmland 3.Food market 4.Food industry 5.Sewage system	1.Renova-Marieholm (*Pre treatment*) 2.Gryaab(*Slurry treatment and biogas production*) 3.ST1 Refinery(*Biorefinery*) 4.Gothenburg energy(*From biogas to biofuel*)	1.Gothenburg energy (*district heating*) 2.Renova CHP plant(heating and energy production) 3.Biofuel stations 4.Surrounding farmland

Table 2.List of current actors in different recycling steps

3.3.Flow mapping of the current food system in Gothenburg

3.3.1.Introduction of the flow mapping

In this part, Actors and flows in the current food system (see section 3.1 and 3.2) will be mapped and analyzed based on the 3 resource treatment phases introduced in 3.1. The mapping will show the current flow model of the food system in Gothenburg spatially and the maps can become a base for conceptual design of the circular food system in the next step.

Due to the differences between different groups of actors in the food system, besides the mapping of the whole food system, 4 types of resource flow (1.treatment of household food waste,2. treatment of industrial food waste, 3.recovery of sewage, 4. composting of manure from grazing) are mapped individually in order to show the flow between actors more clearly.

3.3.2.Methodological background of the flow mapping

In order to map the geo-locations of the actors in the food waste recycling system, QGIS is the main tool for mapping different layers of geo-information. Following the previous analysis of actors, in the phase of mapping, data of actors in 3 main steps of the recycling flow are collected in order to explore their spatial relationship between each other through mapping.

In the "Resource input", actors of the food waste input are mapped.The main data for mapping are the location of residents housing, food-related markets and local food industry and the area of food. The locations are point features and the "area "are presented by using polygon data.Data in the first step are all based on the open source from the spatial morphology group of Chalmers.

In the "Resource processing",since accurate addresses of each actor are not accessible,the plot data of each actor from spatial morphology groups were used to show the locations of all of the actors in the process step.(Marieholm pretreatment facility, ST1 biorefinery AB,Gryaab sewage plant,CHP plants).

The "Resource output" include the data of current arable land area and urban allotment area of Gothenburg.The data of arable land are from spatial morphology group, which is raster form.The data of allotment data are from open street map, which is polygon feature.In the mapping process, in order to calculate geometry,the raster feature of arable land are transformed into polygon feature for easier calculation.

Meanwhile, the mapping will be combined with diagrams of the current flow model and data in the recycling process in order to show the flow in both quantity and spatial perspective clearly.

A.Locations of current actors in the foodwaste recycling flow

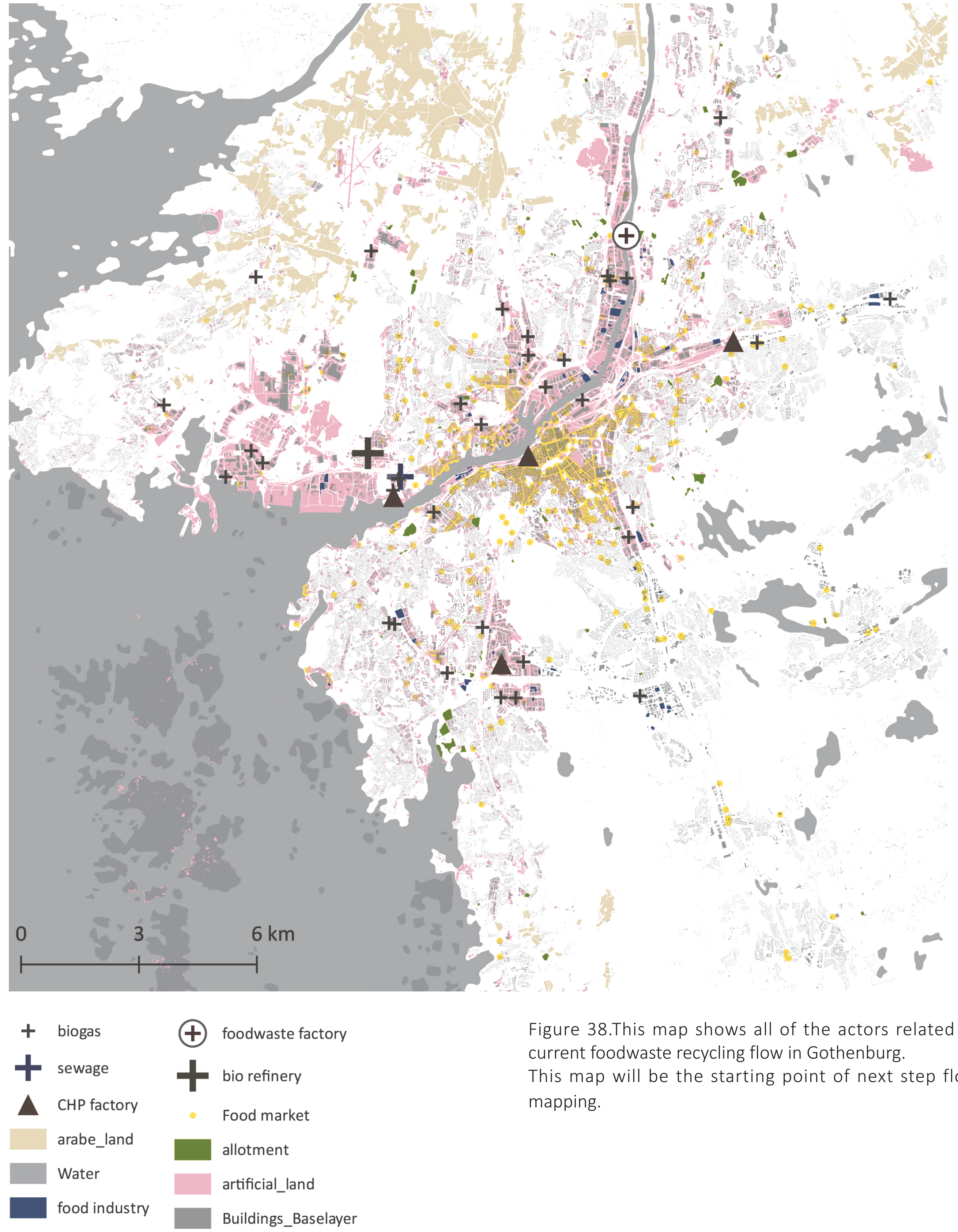


Figure 38.This map shows all of the actors related to current foodwaste recycling flow in Gothenburg.
This map will be the starting point of next step flow mapping.

URBAN (CIRCULAR) FOOD SYSTEM

B.The first type of linear food waste recycling flow (Food Waste recycling system of household & food markets)

Figure 39.Flow (from household foodwaste to energy and existing agriculture)

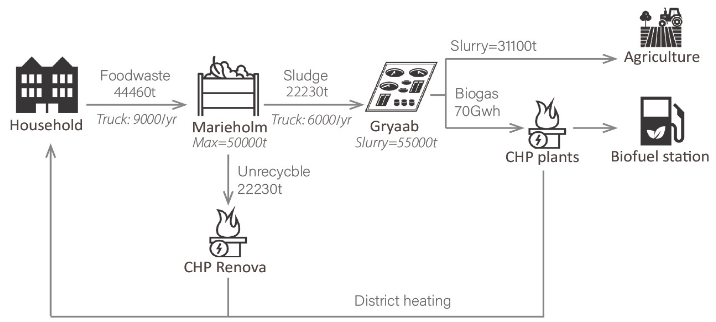


Figure40 Flow (from sewage slurry to energy and peri-urban agriculture)

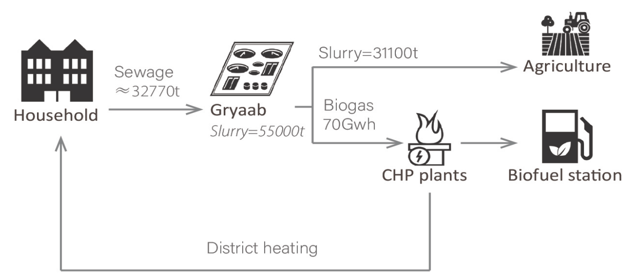


Figure.41 Mapping the circular steps in the household-foodwaste recycling system

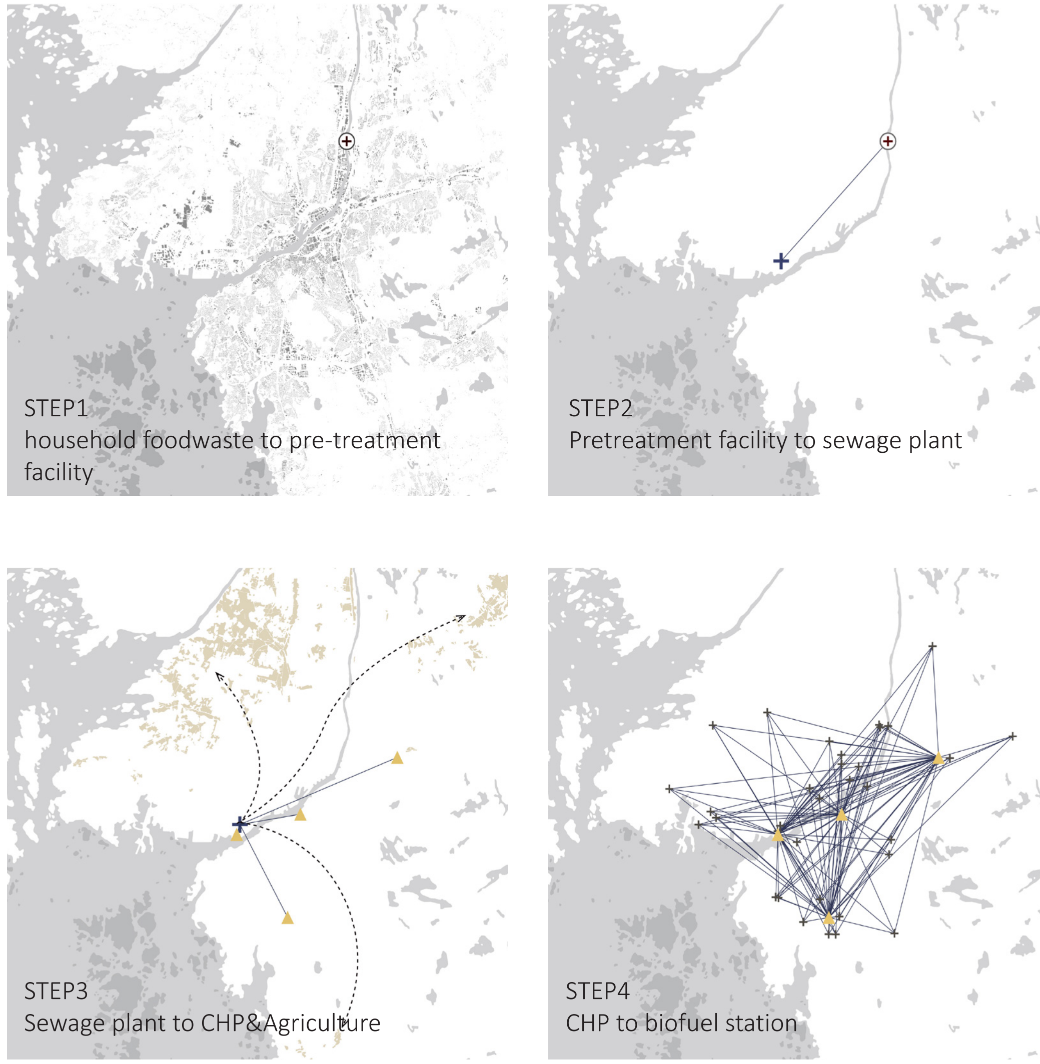


Figure 42.Actors in the household-foodwaste recycling system

Through mapping the procedure of household foodwaste recycling flow and locations of actors, It is obvious that main facilities in the current system of recycling is centralized and located near Gota river.
Also,nowadays sludge from sewage and food waste are mixed in Gryaab AB.

C.The second type of linear food waste recycling flow
(Food Waste recycling system of industrial and Agriculture)

Figure 43.Flow (from industrial foodwaste to energy/peri-urban

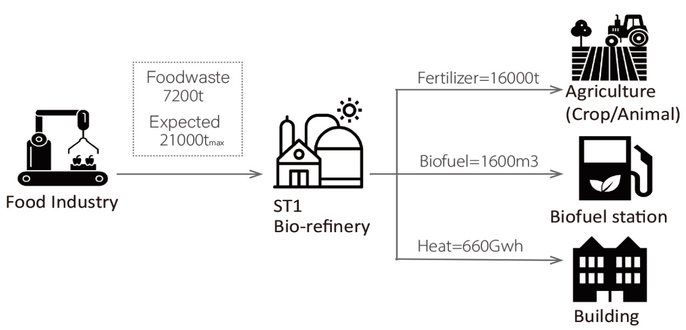


Figure 44.Flow (from grazing waste to peri-urban crop

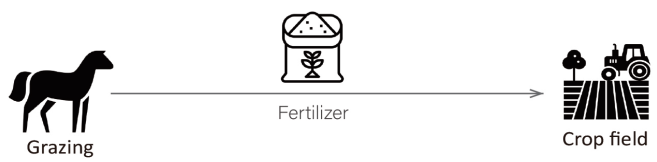


Figure 45. Mapping the steps in the food-industrial&agriculture waste recycling system

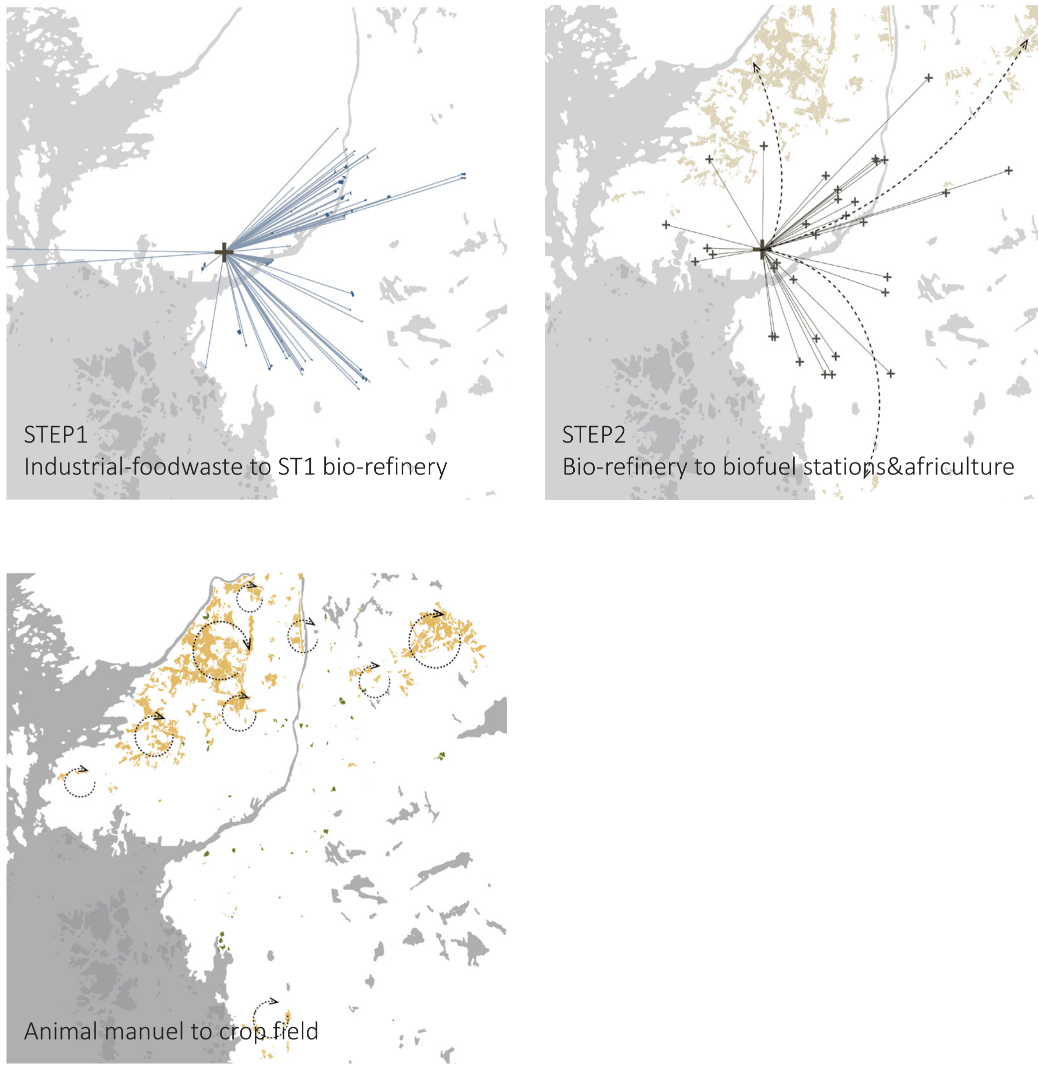


Figure 46.Flow (from household foodwaste to resource)

3.4.Summary of the analysis of current food system in Gothenburg

In conclusion, based on the above flow analysis of the current food system in Gothenburg, it is obvious that there are both circular models and linear models in the current food system.

Nowadays, although there are developed food waste recycling facilities in Gothenburg, there are still around 22230t food waste is not recovered. (see section 3.3.3.2) and from the industrial waste processing side, 21000t food waste is required, which is 13800t more than the supply of waste today (see section 3.3.3.3). which means the circularity in the section of household and industrial waste recovery can still be improved. For now, the recycling flow of food waste from peri urban farmland (mainly from the land for grazing) is circular currently due to the compost of organic waste and relevant facilities, however, according to 1.2 and 1.3, in the countryside of Gothenburg, there is still an imbalance of nutrition supply between grazing land and crops land, which have caused the concentration of nutrients in Baltic sea and soil, as a result, the nutrition recovery flow in the countryside can also be improved.

From the spatial perspective, the above maps show that current food waste treatment facilities in Gothenburg are all centralized and located in the suburb area (Marieholm) and in this treatment facility, all of the food waste in the city should be dealt with, which means in order to treat the food waste in Gothenburg, large amounts of transportation tools (For example: heavy trucks for transporting waste) are required for delivering food waste from collecting points to Marieholm.(5000 times /yr), and 4000 heavy trucks are required to transport slurry from Marieholm (see section 3.3.3.2).

In all, there is still potential to develop an alternative model of the circular food system in Gothenburg based on the study of current flow models and spatial distribution of food systems and relevant actors. The mapping above would be a useful base for the next step ------- Concepts design of the new model for the circular food system in Gothenburg. Before the starting of the conceptual design in Gothenburg in the next chapter, potential new actors for urban food production and recovery of waste resources in the future's food system should be analyzed and defined.

1.around **22230t** household food waste is not recovered. From the industrial waste processing side, **13800t** more waste nedd to be supplied for bio refinery.	2.Centralized facilities for nutrients recovery and sewage treatment, **9000** heavy trucks are required every year.	3.**Imbalance supply of nutrients** for soil in the countryside under different landuse.

Figure 47. Summary of current food system in Gothenburg: still need to be improved

1.Current system still have potential to be improved.

2.Who can join in the system to improve the urban circular food production?

Figure48.Urban Compost for farming in Hogsbo. http://1.bp.blogspot.com/_d1nHXXiTJDM/TALUXk0WfdI/

Figure 49. Delivery of foodwaste for community composting http://1.bp.blogspot.com/_d1nHXXiTJDM/

3.5. Potential actors of the food system in the future

3.5.1. Potential actors in the future

In order to formulate a new urban circular food system in Gothenburg, it is necessary to define the potential actors who can be added to the circular food system and can contribute to the self-sufficiency and better treatment of waste resources in the future.

The actors chosen below are all locally based and can show Gothenburg's way of managing local food production and how local residents manage the waste resource from food, according to the resources from the municipality and local association of urban farming.
(https://grow-here.com/en/discover/)

Nowadays there are two main categories of actors in Gothenburg, the first category is the urban actors, the second category is the peri-urban actors.
(https://goteborg.se/wps/portal/enhetssida/stadslandet-goteborg)

In this thesis, those actors who are located in the land belonging to the municipality or belonging to a public association will be a focus in the speculation process due to the complicated land property issues. Thus, some of the actors managed by private property, (for example: food production in private gardens and privately owned farmland) will not be included in the speculation process.

Meanwhile, due to the similarity of locations and scale between some of the potential actors, in this thesis, the actors are categorized into 4 types: 1.Community garden; 2.District greenhouse; 3,Roof-top fish farm; 4.Suitable land for peri urban start up companies. The defined actors will join the current food system in Gothenburg and the demand analysis of actors, experiment of the new flow, will be based on these new actors (mainly relevant to urban food production and treatment of waste resources.)

Table 3. a.Exisiting locations of actors in the future's flow

Foodwaste Input actors	Foodwaste Processing actors	Resource Output actors
1.Current recycling stations 2.Peri urban farmland 3.Food market 4.Food industry 5.Sewage system	1.Renova-Marieholm (*Urban treatment facility*) 2.Gryaab(*Slurry treatment and biogas production*) 3.ST1 Refinery(*Biorefinery*) 4.Gothenburg energy	1.Gothenburg energy (*district heating*) 2.Renova CHP plant(heating and energy production) 3.Biofuel stations 4.Surrounding farmland

Table 4. b.New locations of actors in the future's flow

New foodwaste Input actors	New Foodwaste Processing actor	New Resource Output actors
	2.New local (community/ neighbourhood) compost facility	1.Peri urban land rental for greenhouse 2.Peri urban land rental for small scale farming 3.Exsiting farms rental for food production 4.Community garden for organic farming 5.allotment 6.District green house 7.Industrial area based fish-vegetable farm and greenhouse 8.Food production in Private garden

Potential new peri-urban actors for circular food system

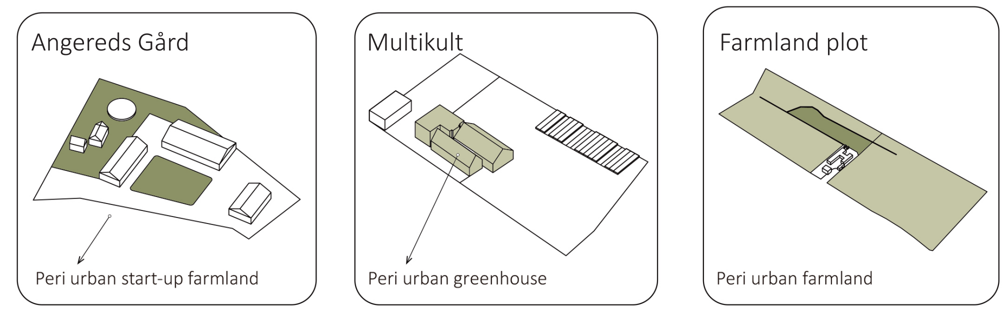


Figure 50.Potential actors in the future's flow (Peri-urban)

Potential new urban actors for circular food system

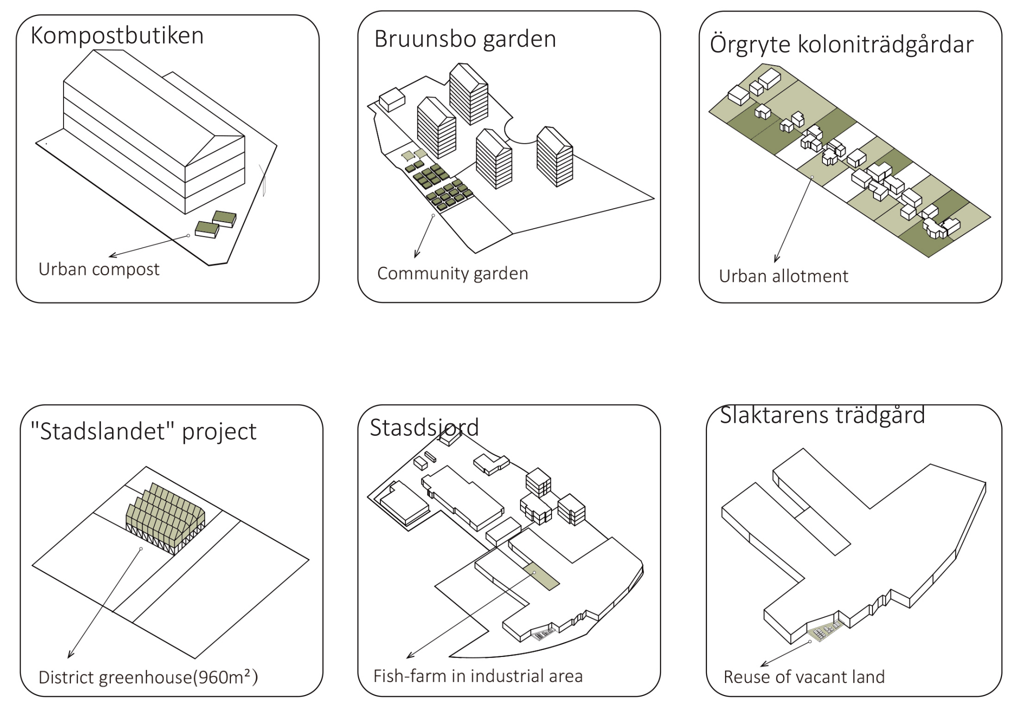


Figure 51.Potential actors in the future's flow (Urban)

3.6.Demand analysis of future’s urban circular food system in Gothenburg

3.6.1.Introduction of the demand analysis process

For any business to be competitive, there must be a demand for its products, and customers are behind this demand (Tiedemann,2020). After defining the potential actors in the future's circulatory system, the demand analysis of food production and actors is a key process in the flow design because it can show whether it is necessary to expand local food production, and how much resources are required by both existing actors and new actors in the whole process.

The demand analysis of actors includes two parts. The first part is to analyze the demand of food production and relevant resources in around 2030, which shows the demand of food for people and demand of relevant resources in the future. The result of the first part can help check whether current local farmland and resources related to food production meet the future's demand.,and can also help decide whether it is necessary to bring in new actors defined in 3.5 and whether it is necessary to expand land for food production.

Based on the results in the first part of demand analysis, The second part is to analyze the gap of demand between actors in the whole food system of Gothenburg in around 2030, which shows opportunities and threats the new flow can bring to actors in the system, after bringing in new food production actors, expanding land for food production and adopting new flow models. The result of the second part can help decide the balance strategies in the future’s circular flow in the food system.

After the demand analysis of local food production and demand of actors in the food system, the concept of urban circular food production system can be proposed.

3.6.2.Demand of the food production and relevant resources

3.6.2.1.Methodologies

In the first phase of analyzing the demand of the food, nowadays ,there are existing studies in Gothenburg about how to estimate the demand of land area and resources for food that can feed Gothenburg. The estimation is based on the yield and the amount of different types of food which would be consumed in 2030 *(Olsson et al.,2016)*. Then, the data of the land area for different types of food product will be used to estimate the total nutrients demand for each type of food, and the nutrients demand of food can be found through the database of the Swedish board of agriculture.

The step 1 of the first phase is analysis the consumption of each type of food (kg/yr/person) and area for food production based on the yield under 3 different ways of planting-----which is average, medium biointensive and low biointensive *(Olsson et al.,2016).* Step 2 is to summarize the land demand under three different ways of planting and compare it to the current land area for food. Then, step 3 is to calculate the demand of nutrients based on types of food, land area demand and types of fertilizer (N,P,K from manure and mineral). Finally, in the step4, the demand for nutrients (N,P,K) and land area are summarized together for proposing a raft strategy of how to meet the demand of food production in the future.

1.
Estimation of food demand of Gothenburg in 2030+ Area for food production

Consumption of each types of crops	kg/person/year	Demand2030	yield,kg/ha	Area2030(average)	Area(low biointensive methods)	AreaMedium biointensive methods	Area(Current Situation)
Wheat flour	6.6	4365952.8	6080	718.0843421			183
Rye flour	0.1	66150.8	6510	10.16141321			
Oatmeal and other cereals	3.9	2579881.2	4960	520.1373387			216
Flour of mixtures of wheat and rye and flour of other cereals	0.3	198452.4	3384	58.64432624			3
Total flour and ground	17.4	11510239.2		**1307.02742**			**492**
potato	46.5	30760122	36200	**849.7271271**			**3**
Carrots	9.6	6350476.8	61300	103.5966852	88.54417535	51.79834258	
Cucumbers(green house)	6.2	4101349.6	443300	9.25186014	7.907572769	4.62593007	
onion	8.1	5358214.8	46300	115.7281814	98.91297558	57.86409071	
salad	14.7	9724167.6	19700	493.6125685	421.8910842	246.8062843	
Cabbage, red cabbage, Brussels sprouts, kale, broccoli	4.7	3109087.6	27400	113.4703504	96.98320544	56.73517518	
other kitchen plants	7.4	4895159.2	33700	145.2569496	124.1512389	72.62847478	
leek	0.8	529206.4	30200	17.52339073	14.97725703	8.761695364	
Cauliflower	1.5	992262	17300	57.35618497	49.02238032	28.67809249	
other root plants	1.6	1058412.8	34100	31.03849853	26.52863123	15.51924927	
tomato(greenhouse)	9	5953572	396500	15.015314	12.83360171	7.507656999	
Total vegetable	63.6	42071908.8		**1101.849983**	**941.7521226**	**550.9249917**	**≈30**

2.
Summary of land area demand based on demand of food and methods of growing

	LAND DEMAND(2030MAX)	LAND DEMAND(2030)	LAND DEMAND(2030MIN)	CURRENT AREA
FLOUR/CEREAL PRODUCT	1307ha	1307ha	1307ha	492ha
VEGETABLE PRODUCT	1101ha	942ha	551ha	≈30ha
POTATOES PRODUCT	849ha	849ha	849ha	3ha

3.
Estimation of nutrition demand based on land area, species and types of fertilizer

Crops Type （N)	Mineral fertilizers	Plant-available nitrogen(manual)	Total nitrogen(manuel)	demand(max)mineral/manuel	demand mineral/manuel	demand（min)mineral/manuel
cereals product	107	10	28	13070/36596kg	13070/36596kg	13070/36596kg
vegetables product	51	9	27	56151/29727kg	48042/25434kg	28101/14877kg
potatoes product	96	5	11	81504/9339kg	81504/9339kg	81504/9339kg
Crops Type （P)	Mineral		Manuel	demand(max)	demand	demand(min)
cereals product	12		7	15684/9149	15684/9149	15684/9149
vegetables product	10		7	11010/7707	9420/6594	5510/3857
potatoes product	38		3	32262/2547	32262/2547	32262/2547
Crops Type （K)	Mineral		Manuel	demand(max)	demand	demand(min)
cereals product	15		28	19605/36596	19605/36596	19605/36596
vegetables product	26		29	28626/31929	24492/27318	14326/15979
potatoes product	192		8	163008/6792	163008/6792	163008/6792

4.
Summary of nutrients demand and land area based on Gothenburg’s food demand

	AREA2030(mineral/manuel) max/kg	AREA2030(mineral/manuel)/kg	AREA2030(mineral/manuel)min/kg	CURRENT (mineral/manuel) /kg
N DEMAND(total)	150725/75662	142616/71369	122675/60812	54569/14647
P DEMAND(total)	58956/19403	57366/18290	53456/15553	6330/3670
K DEMAND(total)	211239/75317	207105/70706	196939/59367	8751/14698
AREA DEMAND FOR GROWING	3257ha	3098ha	2707ha	≈526ha

*Data source
The data for calculation here are collected from Swdish agriculture board and SCB.

Figure 52.Demand analysis of future's food demand for self efficiency and relevant resources demand

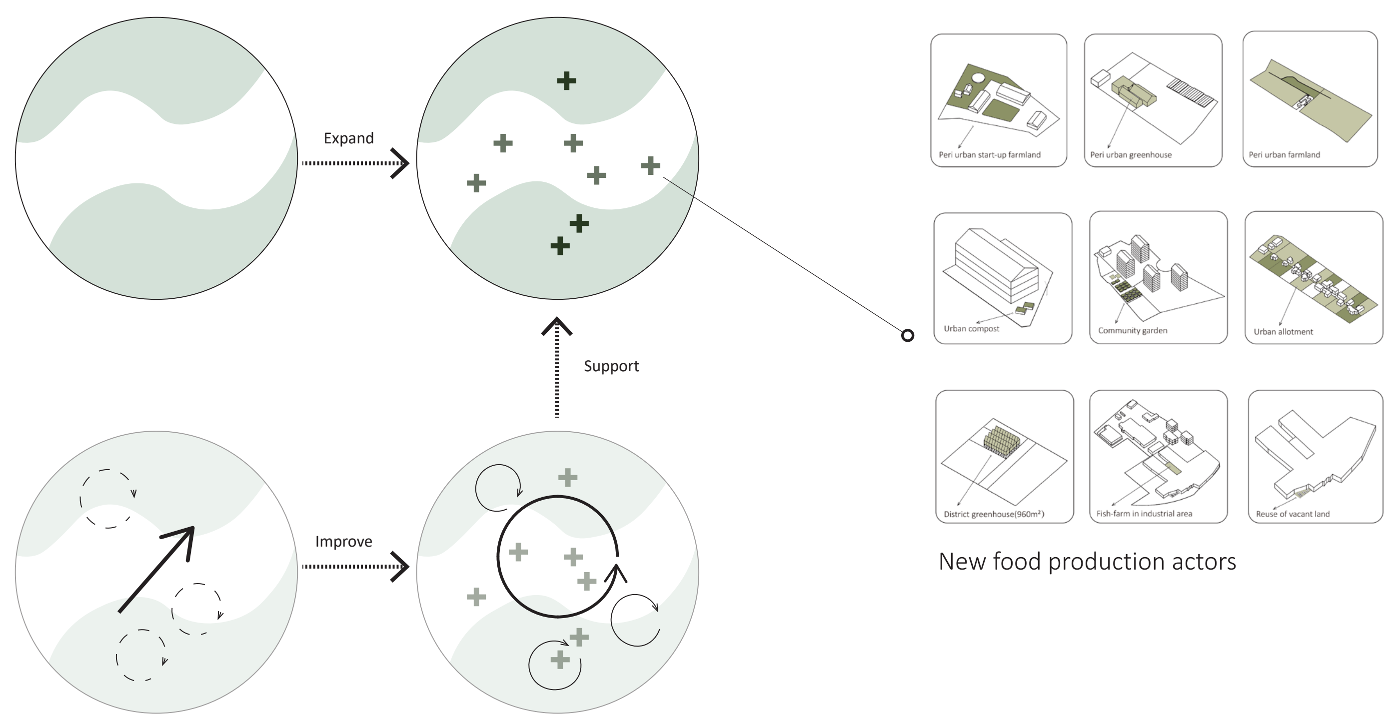


Figure 53. Strategies for improve the self efficienct and improcve circularity production

URBAN (CIRCULAR) FOOD SYSTEM

3.6.2.3.Summary of the analysis results

Based on the above analysis, 2181ha of the land should be added to current land for farming, and then the land area can meet the demand of local food production in Gothenburg. 815ha land should be added to current land for producing cereal and flours, 846ha land should be added to current land for potatoes, at least 520ha (based on medium intensive methods) land should be added to current land for growing fresh vegetables (30ha now). By the way, the demand for nutrients increases a lot in the above three main types of crops in Gothenburg if the food is produced locally.

Is it possible to grow food locally in Gothenburg? Based on the analysis in 3.6.2.2, Although Gothenburg municipality owns around 3000ha of land in peri urban area and the land area is enough for meeting the land demand for food (2707ha in total), but transforming the land use model of the rural land would not be feasible , because most of the land suitable for farming are used for grazing and are rent to raising horses due to economical benefit (Wästfelt and Zhang, 2018) and the other land are mainly for monoculture (mainly industrialized production of crops and potatoes). Meanwhile,the property of land is a complicated issue in transforming land use in the peri-urban area.

As a result, expanding land for farming in suitable urban space is necessary, where it can be integrated with current land for grazing and crop production in the peri-urban area. The expanded land in urban areas can be in different flexible forms based on different urban morphology (for example: intensive farming and agroforestry in the community garden, greenhouse,or rooftop farming) and vegetables can be suitable products in urban areas due to scale of land, economical benefits (Source: green growers) and current approaches of urban farming in Gothenburg, which can produce various types of fresh food for residents.

At the same time, according to the estimation of fertilizer demand based on the database of nutrients demand of crops from SCB (*Användning av kalium i mineral- och stallgödsel. Enskilda grödor 2018/19),* expanding the area of farming means additional resources for growing, which would bring negative effects to the existing model of the food system. As a result, a circular flow should be implemented to the expanded farming area.(for example:efficient use of local food waste,water and energy), that can help meet the demand of actors while reducing the negative effects of expanding food production.

However, the potential circular model would transform the whole food waste recycling system, which would bring both opportunities and threats to other actors in the system. So, in the next phase, the gap of demand between actors in the food waste recycling system will be analysed.

3.6.3. Gap of demand between actors in the food system

3.6.3.1. Methodologies

Followed by the previous phase, In the second phase of analyzing the gap of demand between actors in the whole food system, the whole flow in the food system is analysed in order to test how the change of resource input may affect demand of other actors in the system, after bringing the new food production actors and raft strategies summarized in the previous phase .

The first step of this second phase demand analysis is to divide the actors in three parts summarized in 3.1 (resource input,resource processing and resource output). Then in step 2, the data of the development goal of actors are mapped on the diagram, based on bringing the new actors and the strategies summarized in the previous phase. Finally, in step 3, the opportunities and threats in the future's system are summarized; the gap of demand in the future will be a focus for supporting the next step flow design.

3.6.3.2.Process of the analysis

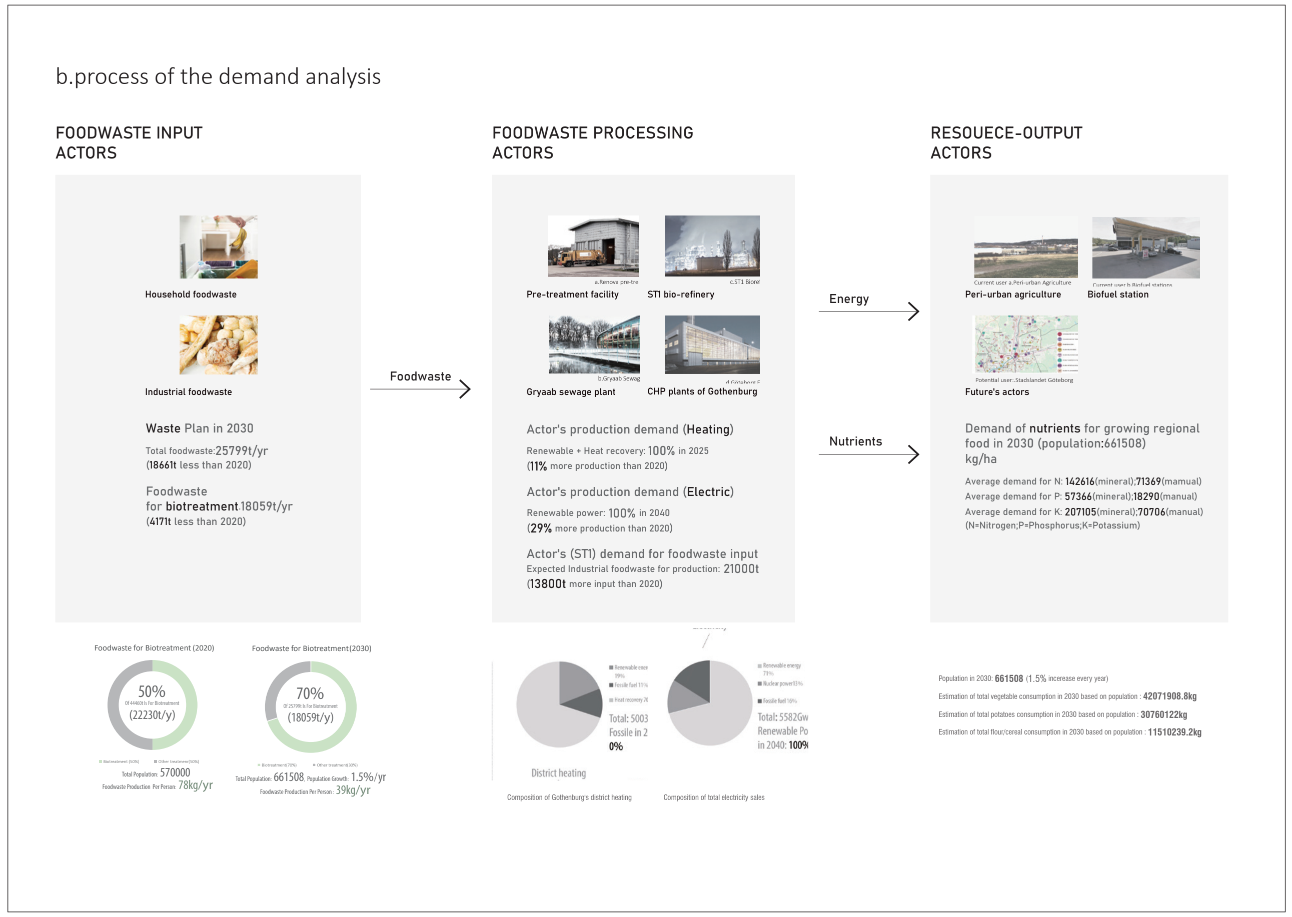


Figure 54.Gap of demand between actors after expanding food production (see appendix)

3.6.3.3.Summary of the analysis results

After the mapping of the development goal and the demand of actors in each step of the whole food waste recycling system in Gothenburg, the opportunities and threats brought by the new food production actors and the development goal of each actor are becoming clear.

The opportunities are mainly for the actors belonging to the part of "food waste input" and urban food production in the part of "resource output", because the goals and demands of themselves can benefit each other. The reason is because the goal of the food waste reduction is to reduce 18661t of the waste for burning in the next ten years *(source: Waste management plan of Gothenburg region 2030)*. If the food production area will be expanded in urban areas, more local food waste can be digested locally to become local resources, that means the food waste can be reduced locally while at the same time meet the demand of resources in future's local food production.

The threats are mainly for the actors belonging to the part of "food waste processing" due to the reduction of food waste input. If the actors in the "food waste input" can meet the goal of food waste reduction and the waste is digested locally, the actors in the "food waste" processing will receive less food waste for production. However, according to documents from companies like Gothenburg energi and St1 (*https://www.st1.se/om-st1/raffinaderiet/life-och-etanolix-20*), they have the plan of expanding production of renewable energy which is food waste based. *(source: Hållbarhetsredovisning års- och hållbarhetsredovisning 2018)*. As a result, there is a gap of demand between actors belonging to the "food waste input" and actors belonging to the "food waste processing". This gap will be a focus point in the next step flow design.

In addition, there are also threats for the peri urban farmland area belonging to "resource output". According to the email interview with an employee in the RENOVA, currently some part of the slurry produced from food waste is spread in the peri-urban area for farming, so that the reduction of food waste means the reduction of slurry input for peri-urban crops land. This gap will be the second focus in the next step flow design.

In conclusion, new actors and the expansion of farming in urban areas will bring the food waste recycling system both opportunities and threats. So that in the next step flow design, it is important to find a balance strategy, in order to compensate for the threats for actors belonging to the "food waste processing" and peri urban farmland.

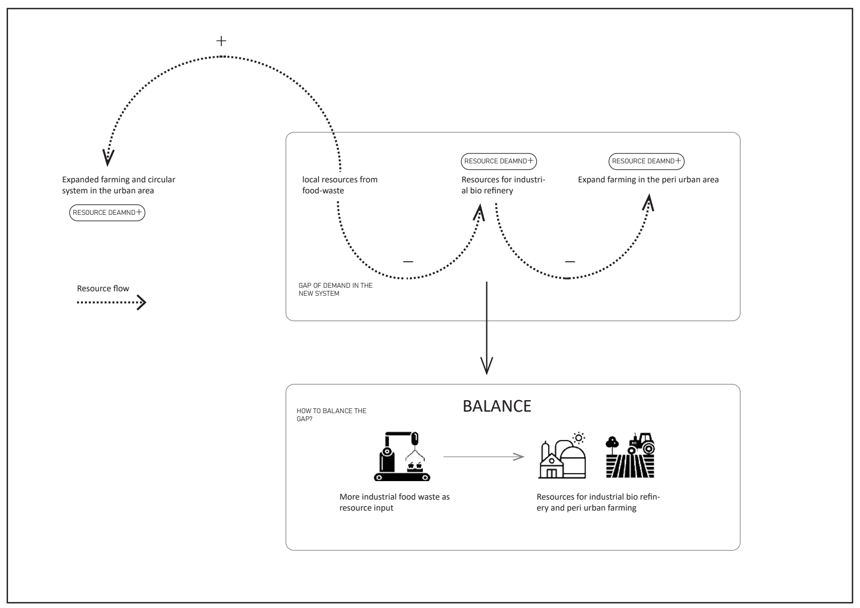


Figure55. Demand gap and balance strategy

3.7.Concept design of urban circular food system and balance strategies

3.7.1 Flow design of urban circular food system

After the previous analysis of new actors, demand of actors and proposed strategies, the flow design of the future's circular food system in Gothenburg will be tested here, which is based on the results of the current flow analysis and mapping in chapter III.

In this step, new actors and circular models will be added to the existing food waste recycling system, and the mapping below would show how the current flow would be transformed in both spatial perspective and quantitative perspective. The result of this step can help find leverage points for further planning.

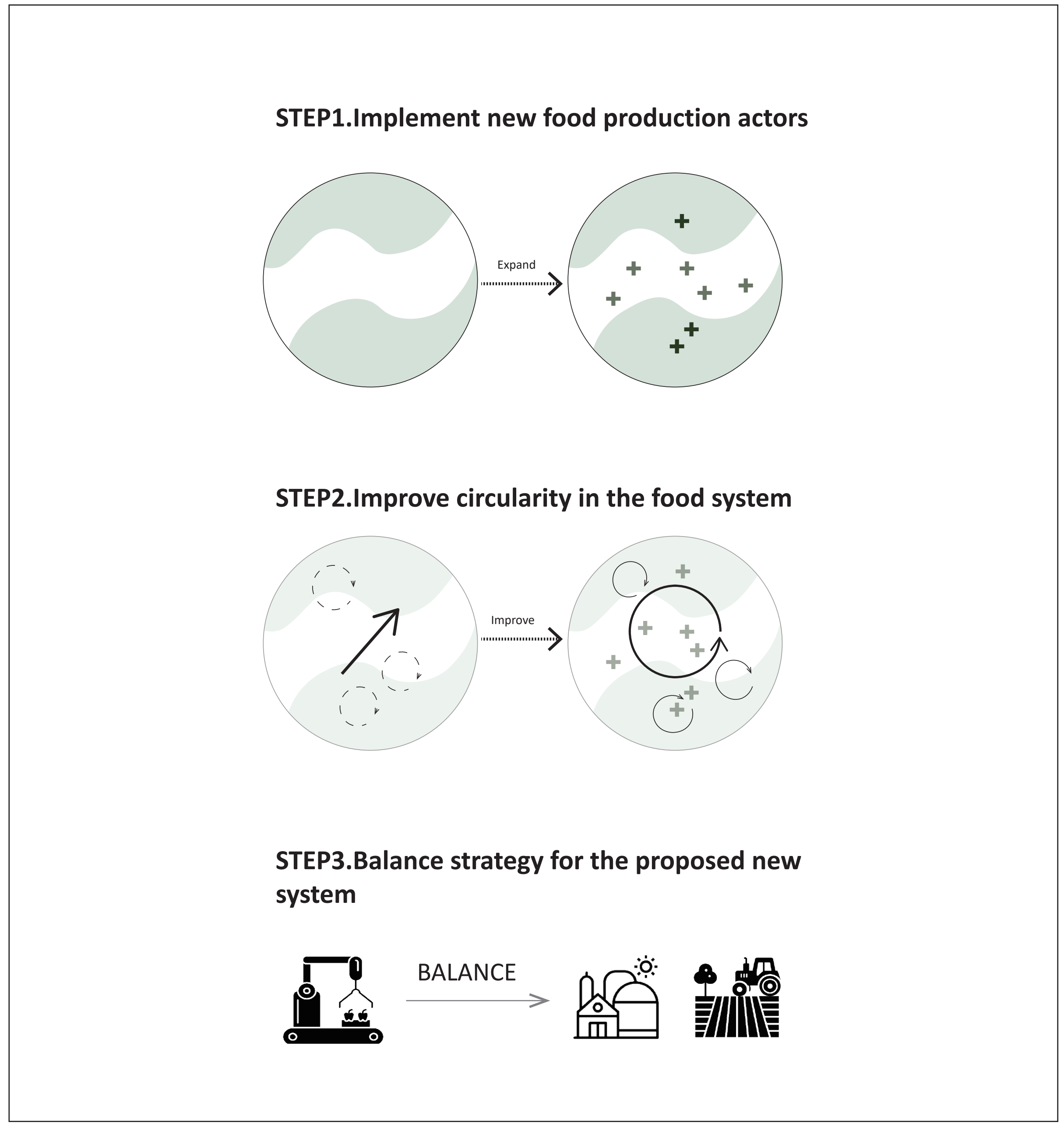


Figure56. Process of designing circular food production model at urban scale based on previous research

URBAN (CIRCULAR) FOOD SYSTEM

3.7.Design of urban circular food system at urban scale

Figure 57.The first type of circular low (from household food waste to urban/peri-urban food production)

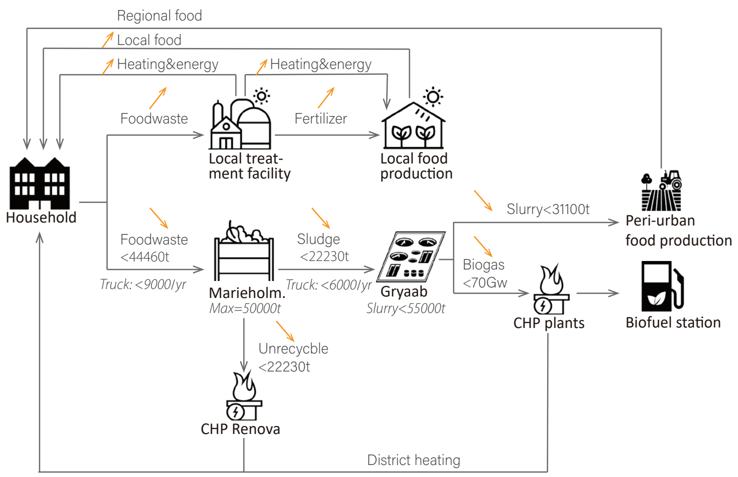


Figure 58.The second type of circular flow (from sewage to urban/peri urban food production)

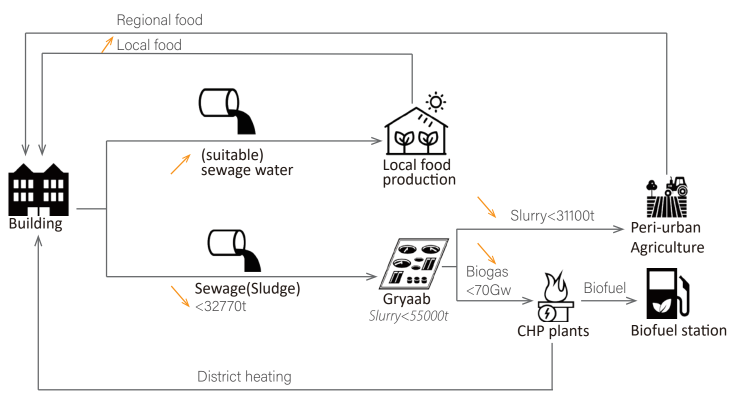


Figure 59.Mapping the circular steps in the food-industrial&agriculture waste recycling

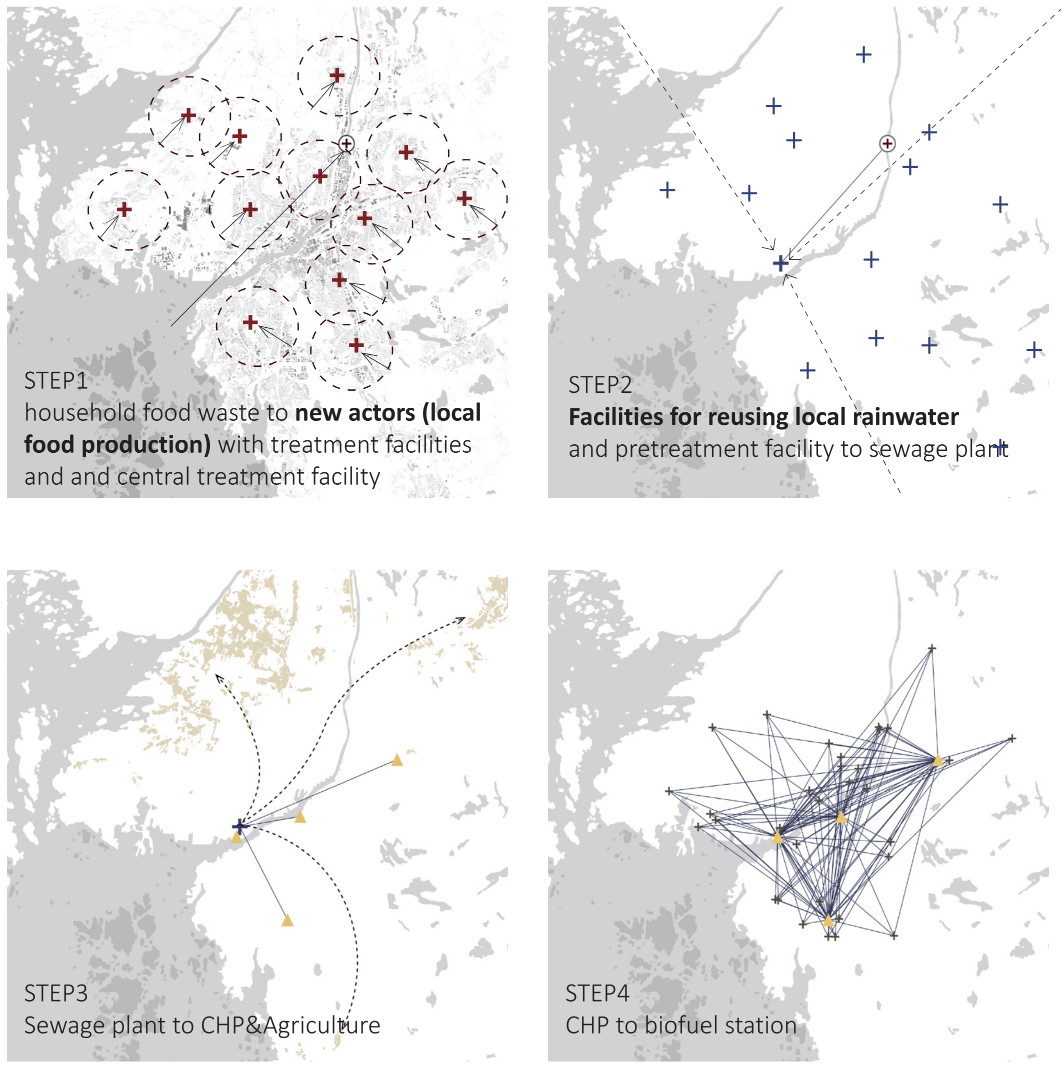


Figure 60.Flow (from household food waste to resource)

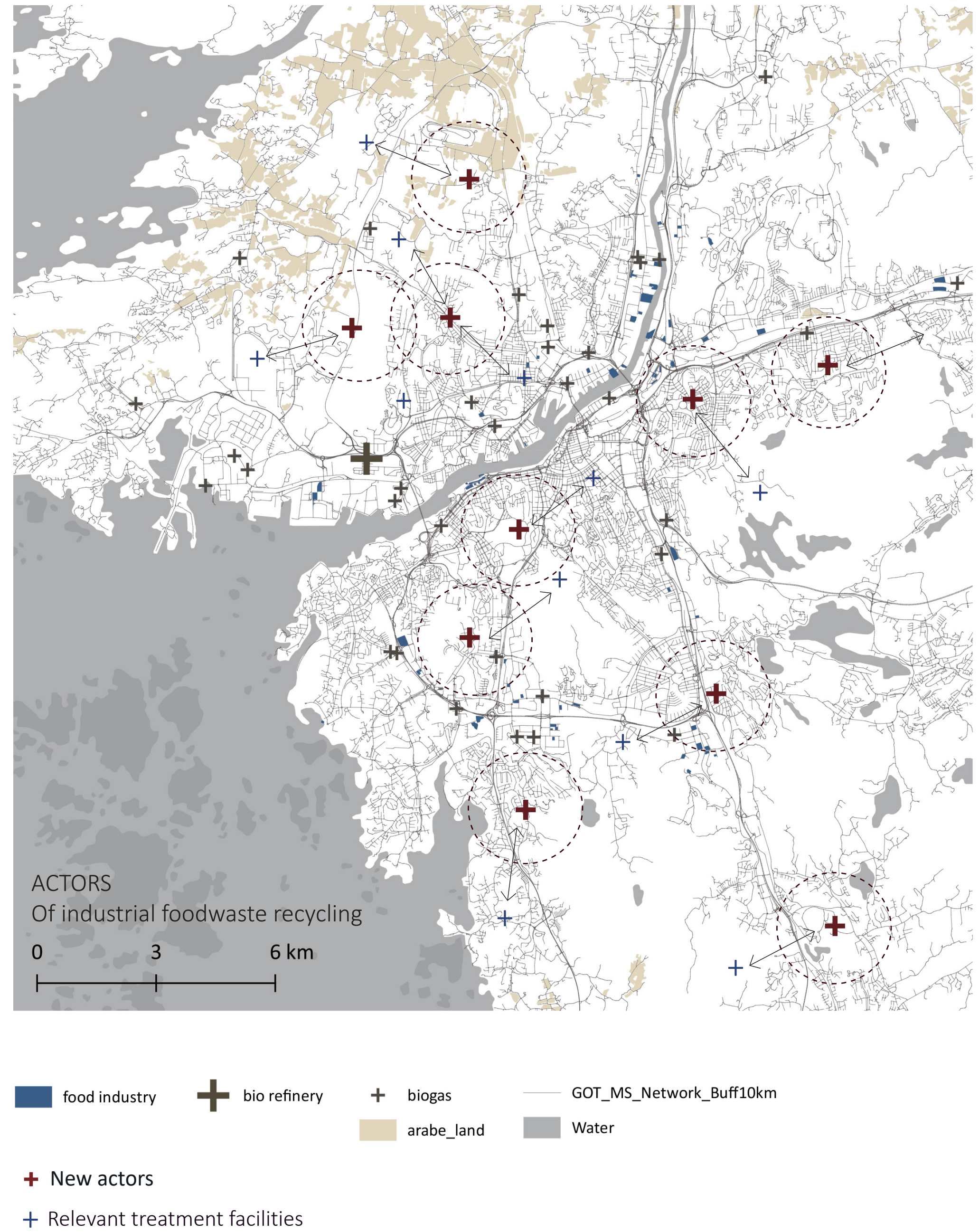


Figure 61..The third type of circular flow (from food industry and food markets to local/peri-urban agriculture and energy)

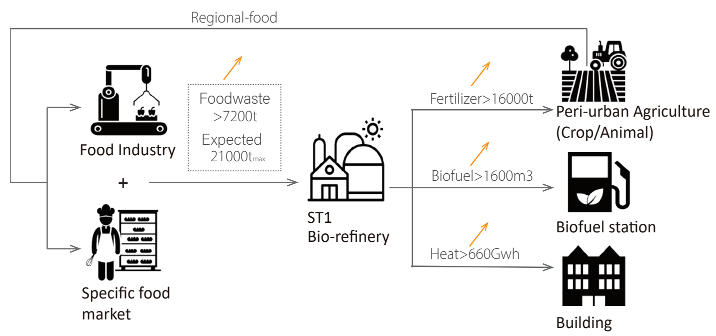


Figure 62.The fourth type of circular flow (from residual/grazing waste to local nutrients and energy)

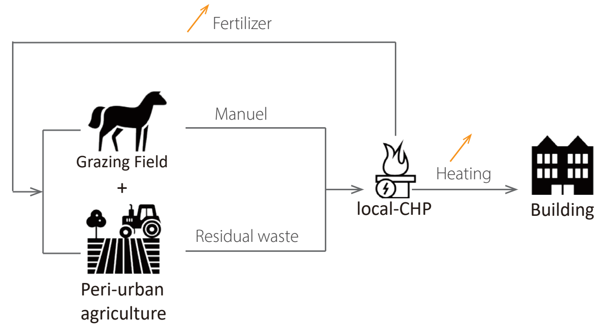


Figure 63.Mapping the steps in the food-industrial&agriculture waste recycling

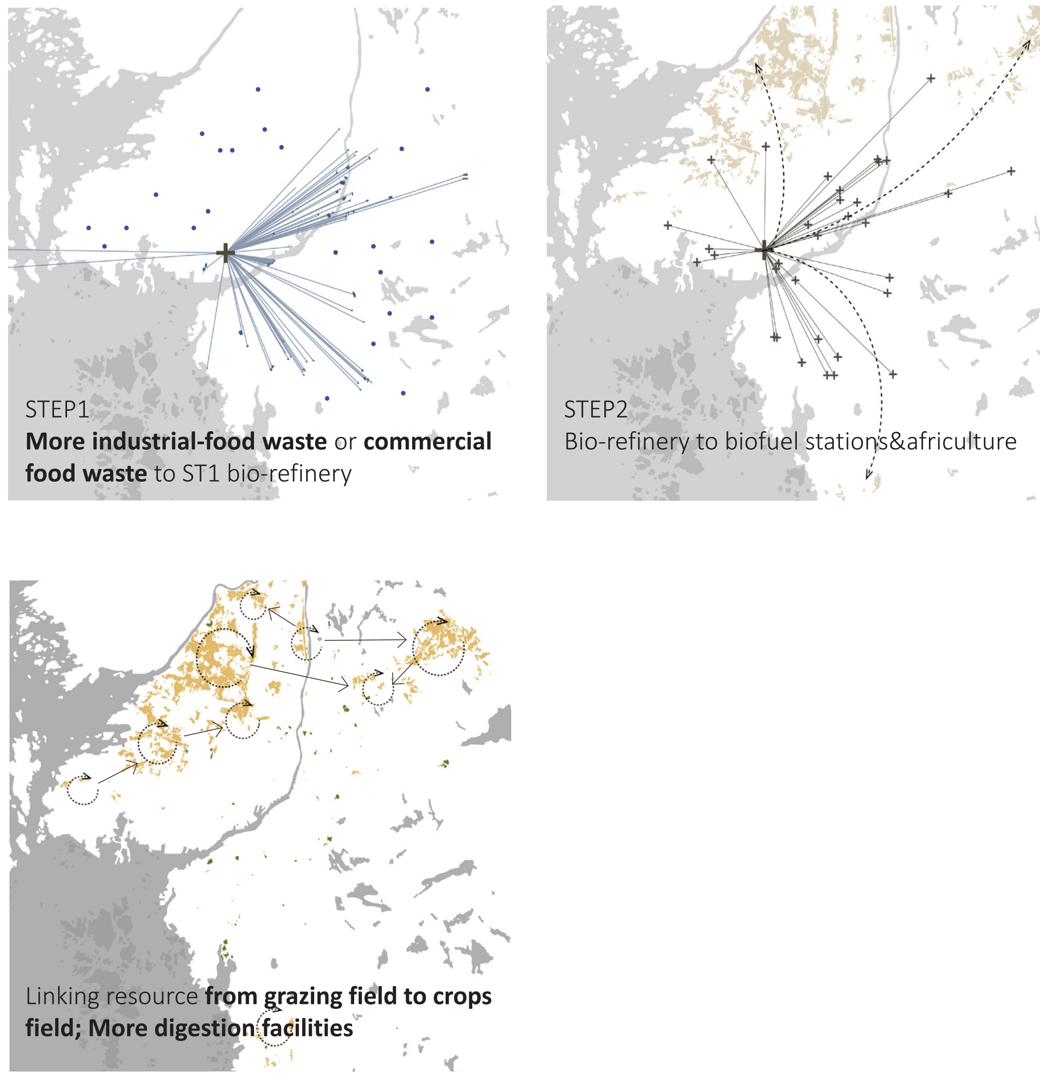


Figure 64.Flow (from household foodwaste to resource)

3.7.2. Balance strategies in the urban circular food system

For bridging the gap of demand actors in the "food waste processing", it is necessary to find a way of balancing the gap. According to the annual report of st1 refinery, more waste from industry should be collected in order to meet the demand of renewable energy production because nowadays, the collection of food waste from the food industry today is not enough for renewable energy production.
(source: *https://www.st1.se/om-st1/raffinaderiet/life-och-etanolix-20*). In conclusion, there should be alternative ways of collecting more industrial food waste (For instance: better logistic and separation facilities), which can be a balance strategy for bridging the gap of demand for food waste processing.

For bridging the gap of demand in the peri urban area, it is possible to link the land which is over supplied of nutrients to the land which is under supplied with nutrients *(Metabolic,2020,p25-31)*, also in order to reduce the demand of imported nutrients required for crops, More anaerobic Digestion facilities can be built in the current peri-urban farmland because the digestion process can reduce N2O emission through the treatment of manure and make the nutrients more easily accessible for the crops *(Hellsten,Dalgaard,et al.2018,p9)*. Also for today, the implementation of anaerobic digestion facilities is possible to be labelled in Sweden *(ISSN 1103-4092, November 2012)*.

To summarize, Finding alternative ways of collecting more industrial food waste can be considered as one balance strategy for bridging the demand gap of actors in the "food waste processing'. Linking land for grazing to the land for food production through anaerobic facilities can be considered as another balance strategy for bridging the demand gap of peri urban farmland in the "resource output"

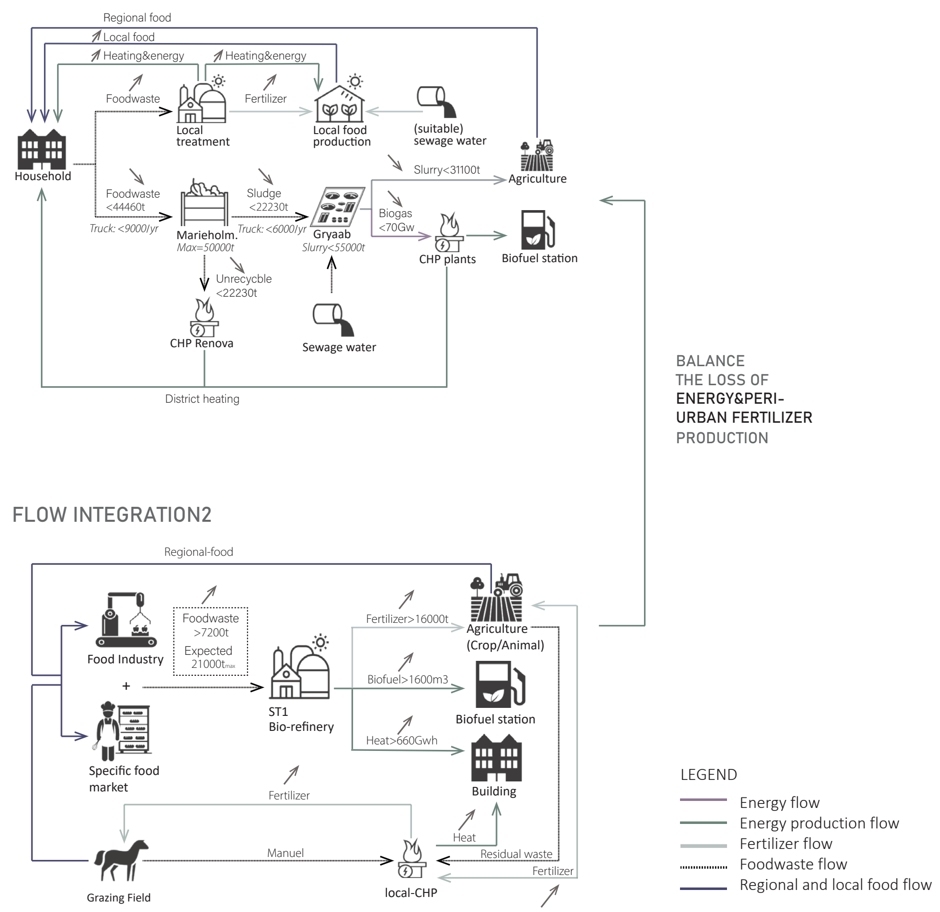


Figure 65.Balance strategies of the new circular food system

3.8. How can the urban circular food system support next step design ?

Peri-urban new actors

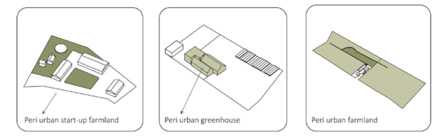
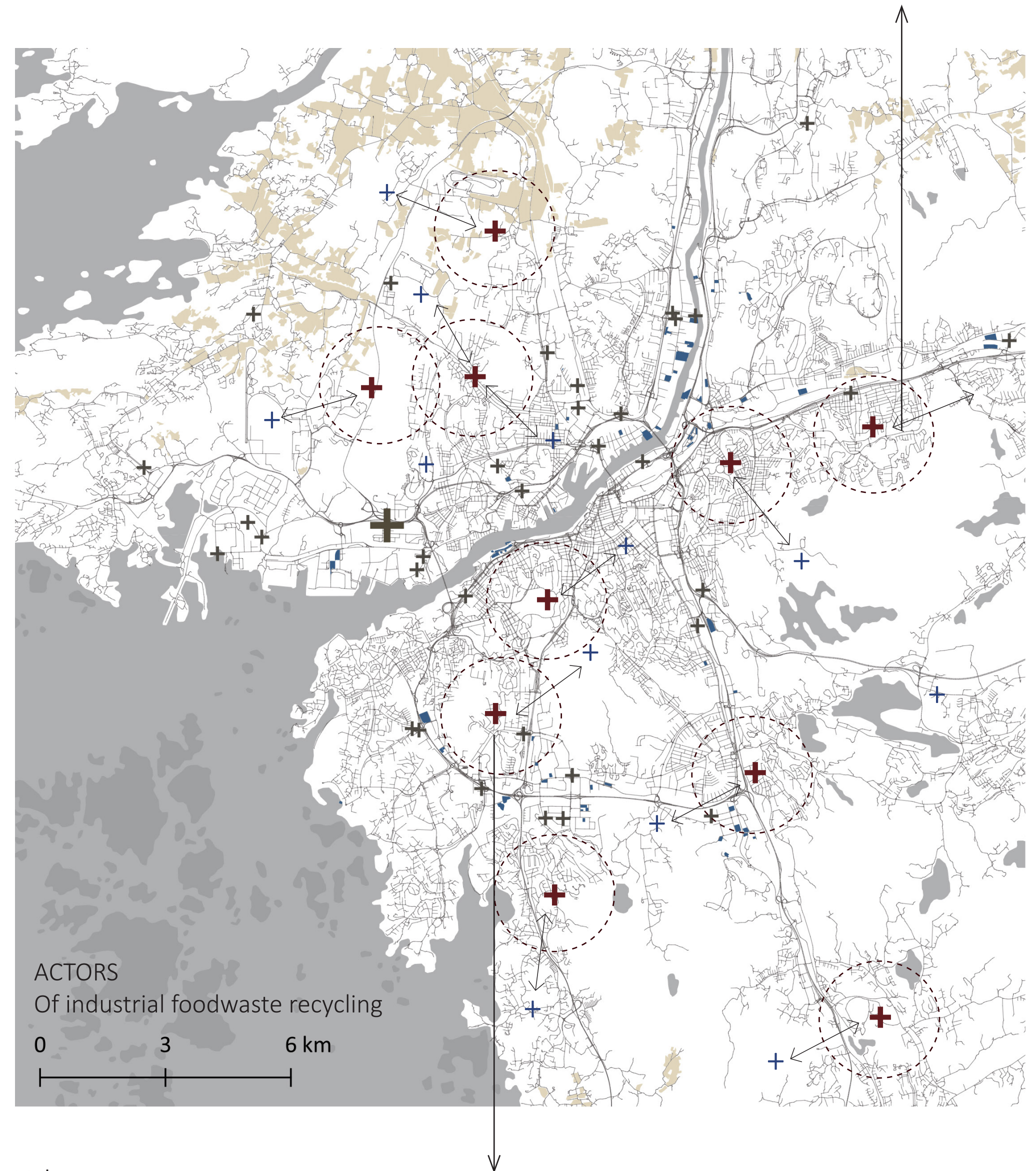
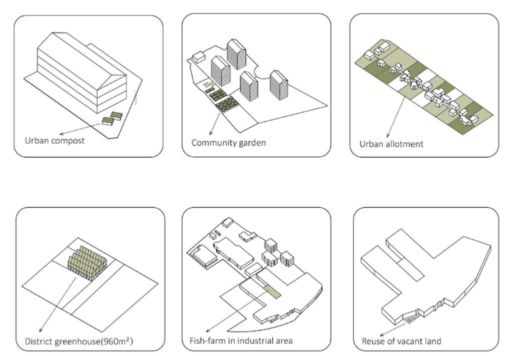


Figure 67.Where to locate suitable new actors in the future's circular food system?



Urban new actors



1.Where to implement new food productioon actors in urban and peri urban area?

2.What's the circular production model of each new actors?

IV.DESIGN OF CIRCULAR FOOD SYSTEM AT NEIGHBOURHOOD SCALE

Brief of this chapter

Based on previous analysis of four main types of new actors that need to be located, in this step, the actors will be classified in four types and the potential food production model of each type of new actors at the neighbourhood scale will be analyzed and proposed , in social and ecological perspective. Then, based on the demand (conditions) of realizing the production model, criterias of locating actors and the related infrastructures would be proposed.

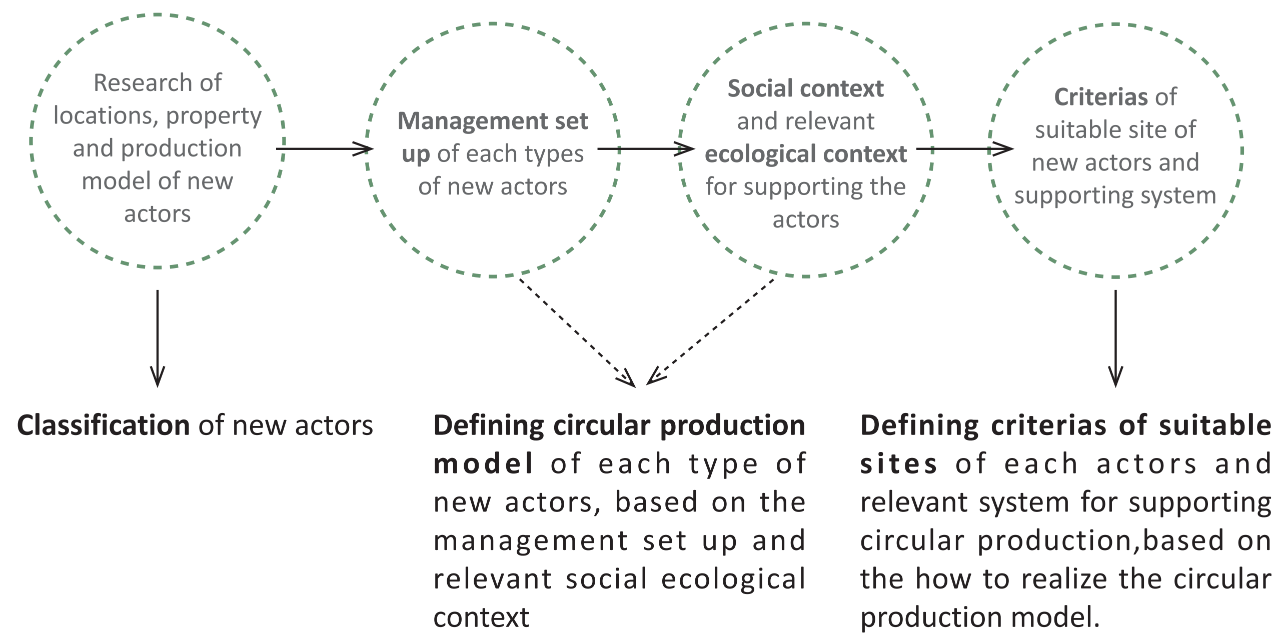
4.1. Classification of new actors and the process of designing

In the first step, the new actors are classified into four types (**1**.community garden, **2**.district greenhouse, **3**.rooftop fish vegetable symbiosis farm and **4**.peri urban start up land), due to similar locations, properties and relevant management set up.

Then, in the second step, the specific management set up, social context and ecological context of four types of new actors are analyzed, in order to find the potential circular food production model, and the conditions (demand) for realizing the circular food production. Finally, in the third step, the criterias for meeting the conditions of a circular food system are proposed, which can support the selection of suitable sites for new actors and relevant supporting systems for circular food production.

The table below shows the four categories of new actors which need to be located and the reason why they are categorized in four types.

Figure 68.Process of designing circular food system for actors at the neighbourhood scale



URBAN (CIRCULAR) FOOD SYSTEM

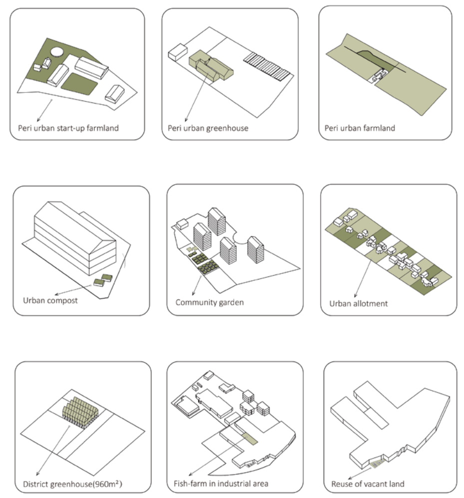
Exsiting actors in the food system

Foodwaste Input actors	Foodwaste Processing actors	Resource Output actors
1.Current recycling stations 2.Peri urban farmland 3.Food market 4.Food industry 5.Sewage system	1.Renova-Marieholm (*Urban treatment facility*) 2.Gryaab(*Slurry treatment and biogas production*) 3.ST1 Refinery(*Biorefinery*) 4.Gothenburg energy **5.Privat farmlan** **6.Local (treatme**	1.Gothenburg energy (*district heating*) 2.Renova CHP plant(heating and energy production) 3.Biofuel stations 4.Surrounding farmland

New actors in the future's food system

New foodwaste Input actors	New Foodwaste Processing actor	New Resource Output actors
	2.New local (community/ neighbourhood) compost facility	1.Peri urban land rental for greenhouse 2.Peri urban land rental for small scale farming 3.Exsiting farms rental for food production 4.Community garden for organic farming 5.allotment 6.District green house 7.Industrial area based fish-vegetable farm and greenhouse 8.Food production in Private garden

New actors



Potential site/Production model/ Property

Classification of new actors

Site of new actors	Type of new actors	Property	The potential location	Classification of the new actors
Peri urban actors	Peri-urban land rental for greenhouse	Municipality (property office) and investors	Peri urban area	Suitable land for peri urban green start up companies
	Peri-urban land rental for small scale farming	Municipality and investors	Peri urban area	
	Exsiting farms rental for food production	Municipality and investors	Peri urban area	
Urban actors	Community garden for organic farming	Neighbourhood association or municipality	Community	Community garden for food production
	Community based allotment	Neighbourhood association or municipality	Community	
	District greenhouse	Municipality	Parking lots	District greenhouse
	Industrial area based fish-vegetable symbiosis farm	Municipality and investors	Rooftop or vacant interior space	Roof top based fish-vegetable symbiosis farm
	Roof-top fish-vegetable farm and greenhouse	Municipality and investors	Rooftop	
	Local compost	Municipality and relevant waste treatment companies	Recycling room	
	Food production in private garden	Private	Private garden	

Table 5.Classification of new actors

4.2. Community garden (actor's type 1)

4.2.1.Management set-up

Currently, community gardens are managed by the property office of Gothenburg municipality *(https://www.naturvation.eu/nbs/goteborg/urban-farming)* and local associations *(Averdal.2014)*, The expansion of the community garden can be supported by the office like Stadsnära odling.

The municipality has the plan to stimulate small-scale and community / urban farming in the city, and also hope to use small-scale farming in the city to grow new types of crops, spread knowledge and create contact between people from different parts of the city.*(source:Göteborgs Stad (n.d.) Stadsnära odling. Goda exempel på miljöarbetet i staden. 2017-06-12)*. Meanwhile, organic farming is supported in the community garden *(Averdal,2014,p41)*.

4.2.2.Production model in social perspective

The main role of community gardens in Gothenburg is to provide food for the residents in the community,it is crucial to make the community garden accessible to residents in the neighbourhood in a walking friendly distance. The 5-minute walk can be regarded as the "neighborhood unit". which is a community model proposed by Clarence Perry in the 1920s, which focuses on neighbourhood social and commercial activity. *(Walker,2014) (source:https://humantransit.org/2011/04/basics-walking-distance-to-transit.html)*

Also, The municipality has the plan to stimulate small-scale and community / urban farming in the city, and also hope to use small-scale farming in the city to spread knowledge and create contact between people from different parts of the city.*(source:Göteborgs Stad (n.d.) Stadsnära odling. Goda exempel på miljöarbetet i staden. 2017-06-12)*. Also, "cooperative agriculture" is a trend in developing future's community garden *(https://www.chalmers.se/en/departments/ace/news/Pages/Urban-Agriculture-gives-sustainable-food-production-new-knowledge-and-work-opportunities.aspx)* and the business model have been identified. That means the new community garden should be accessible to residents in different parts of the city.

Besides, according to Martin Berg, farming in a place like a community garden should be visible and attract more people. so that it is also important to make the community garden close to the road where people are passing by. But that also means there should be 80 cm high fences around the growing space to create a traffic safe zone *(Source:https://greencitygrowers.com)*. Transportation infrastructures like bike parking areas or electric car charges are needed so that people from other parts of the city can arrive more conveniently. Flexibility of the farming facilities itself is also important due to the cost and easier construction. *(Ramos)*

4.2.3.Production model in ecological perspective

NUTRIENTS: For building an efficient circular food production model, reuse of water, nutrients and energy are crucial. Currently, there are already successful models for the compost of food waste from food waste in Majorna where 4 environmental rooms are linked to the compost facilities. *(Source:https://goteborg.se/)*. The municipality is also applying funds from the swedish board of agriculture for expanding this business model and training people to compost food waste, but for expanding the scale of the local compost service, the renovation for facilities in the current recycling room should be improved for composting and transporting local food waste.

WATER: The maintenance of the community garden would be easier if it is close to the water source *(Cristina Ramos),for example:* potential runoff corridor and wadi. Also, rainwater harvesting can become a way of irrigation in the future (for example, irrigation based on the runoff from rooftops and ground). This type of irrigation system can also reduce the runoff flow, erosion and downstream flooding, while at the same time improve the water quality. *(Source:https://grow-here.com/en/snowmelt-harvesting/)*

GREEN: When building the community garden, wind break is important because some crops cannot survive in the wind. The windbreak can be productive hedged around the land or glass,followed by the tradition in the countryside. Meanwhile, the community garden can improve biodiversity and help the pollination, so that it can be built on currently unused grass land in the urban area to increase the biodiversity of specific areas.

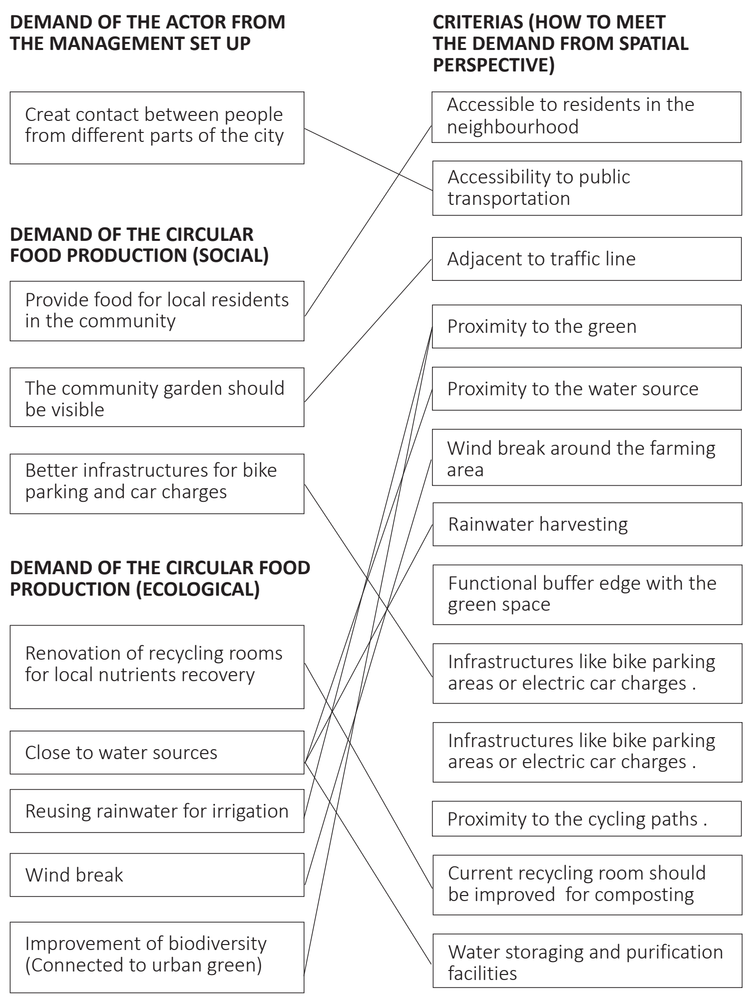


Figure 69. Conditions for realizing circular food production model and relevant criterias

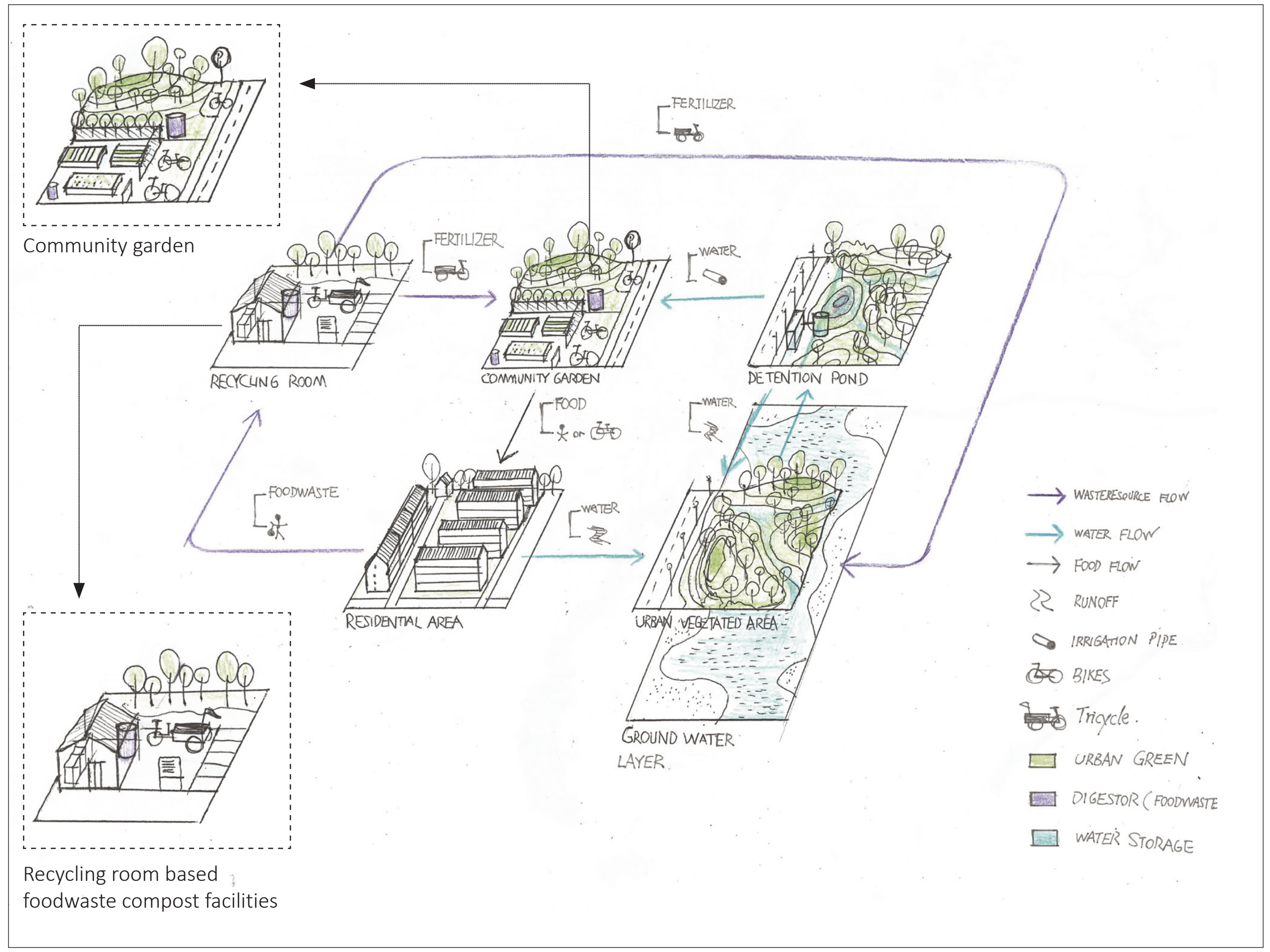
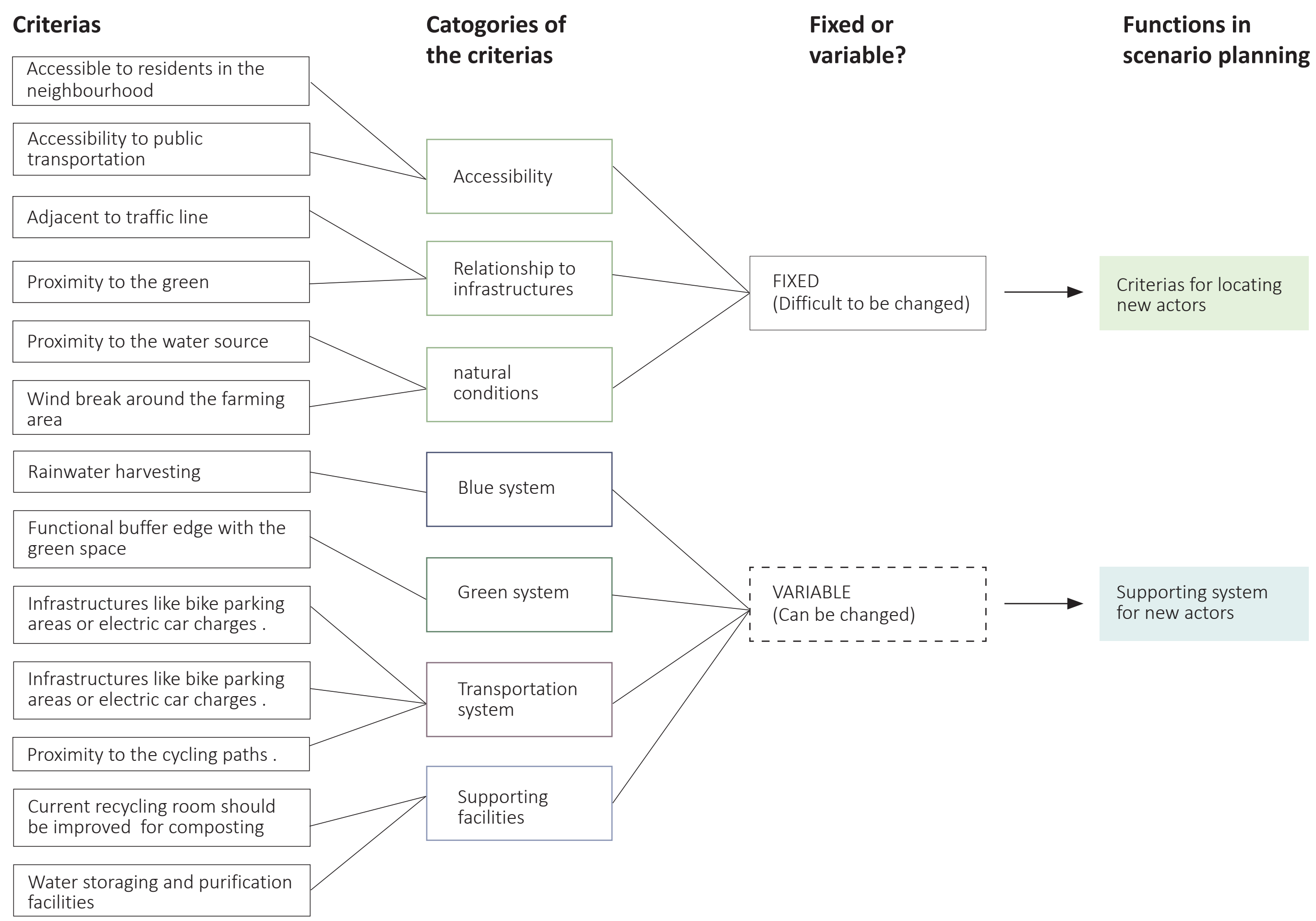


Figure 70.Circular food production model 1.(Community Garden)



URBAN (CIRCULAR) FOOD SYSTEM

4.3 Rooftop based fish-vegetable symbiosis farm (actor's type 2)

4.3.1.Management set-up

Nowadays there are many large scale flat roofs of buildings in Gothenburg which would be an important land resource for food production. Nowadays there are already successful models of rooftop food production,for example: Clarion Post hotel. which shows useful symbiotic partnership where made a profit economically.*(Source:https://grow-here.com*)

Also, many food industries, hotels and restaurants show interest in integrating local food production. According to Gothenburg's plan of green models, The cooperation between the actors in the area through one network (like Stadslandet), can be led by the real estate office and Business Region Gothenburg.
(Många gröna affärsmodeller– så kan hotell, krogar och handel köpa in mer lokalproducerad mat .P1)

4.3.2.Production model in social perspective

Firstly, according to the current founder of the first fish farm in Gothenburg, for the fish farm, the connection to local food markets and restaurants *(Source:https://greencitygrowers.com/blog/urban-farming-in-gothenburg/)* and the expansion of the farmer's market (like car parking area based REKO ring markets) is important for this type of model to make money. In order to build an efficient network, shortening the supply chain would be valuable for the producer as well as for the consumer
(Sen,2018,p29)(source:https://stud.epsilon.slu.se/13256/1/sen_f_180406.pdf).
As a result, accessibility between actors on an urban scale is important for choosing the site of farming because of the convenience of the local food transportation. Meanwhile, accessibility to local residents in different parts of the city is also an important way of expanding the business,like tourism and education, which is now also a common method of running green business in Gothenburg according to the STADLANDET plan. So, connection to public transport stops and proximity to traffic infrastructures also need to be considered in choosing the location.

Secondly, Suitable area of one flat roof is also important for an efficient rooftop fish farm.The area less than 1000m2 would not be economically viable.(Specht,Sawicka et al.2015) *(source:https://stud.epsilon.slu.se/13256/1/sen_f_180406.pdf).*

4.3.3.Production model in ecological perspective

ENERGY: "Industrial symbiosis" is a common way of building an efficient rooftop farm, the example can be referred to architecture cases in the chapter2. Waste heat in buildings can be reused by the roof-top greenhouses, by implementing Integrated heating systems *(Freisinger, Specht, et al. 2015)* which can be used both for heating and cooling. By the way, the integration heating system can help reduce the demand for outside energy and be able to regulate the climate in existing buildings. *(Freisinger, Specht, et al. 2015)*. Using wind, solar and biogas facilities for local renewable energy can also be another consideration.

NUTRIENTS: For fish farming on the rooftop, the nutrients can be supplied by the manure and waste water from the fish,while the residual waste from the crops production can feed the fish.Integrated facilities for nutrients cycle should be implemented for circular food production.

WATER: Water harvesting can also be done in the fish farm by reusing the runoff from rooftops, the water system can be better managed *(source: https://grow-here.com/en/snowmelt-harvesting/).*

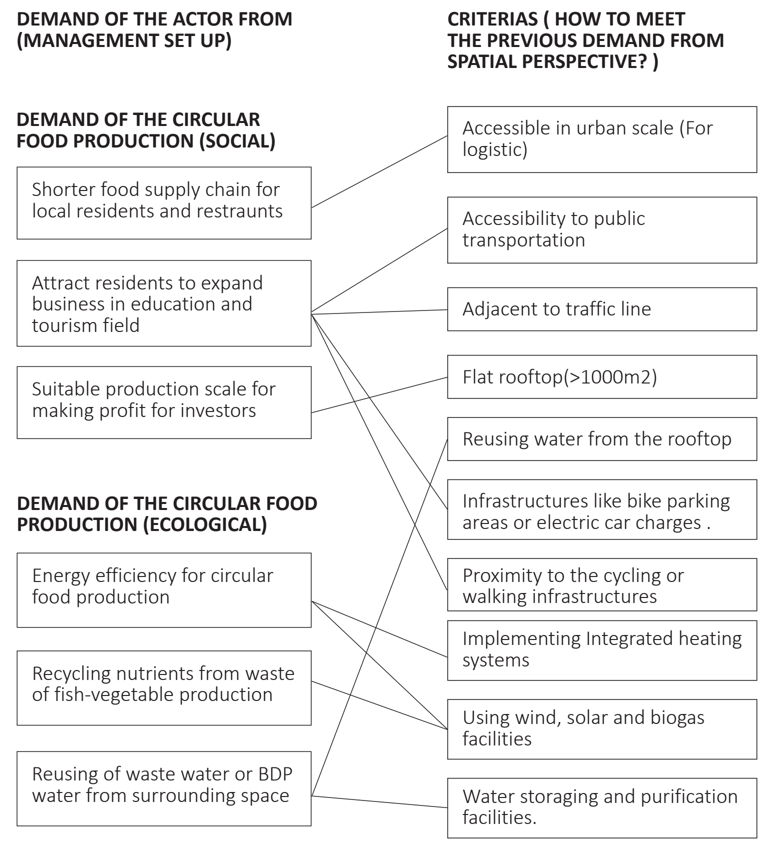


Figure 71. Conditions for realizing circular food production model and relevant criterias

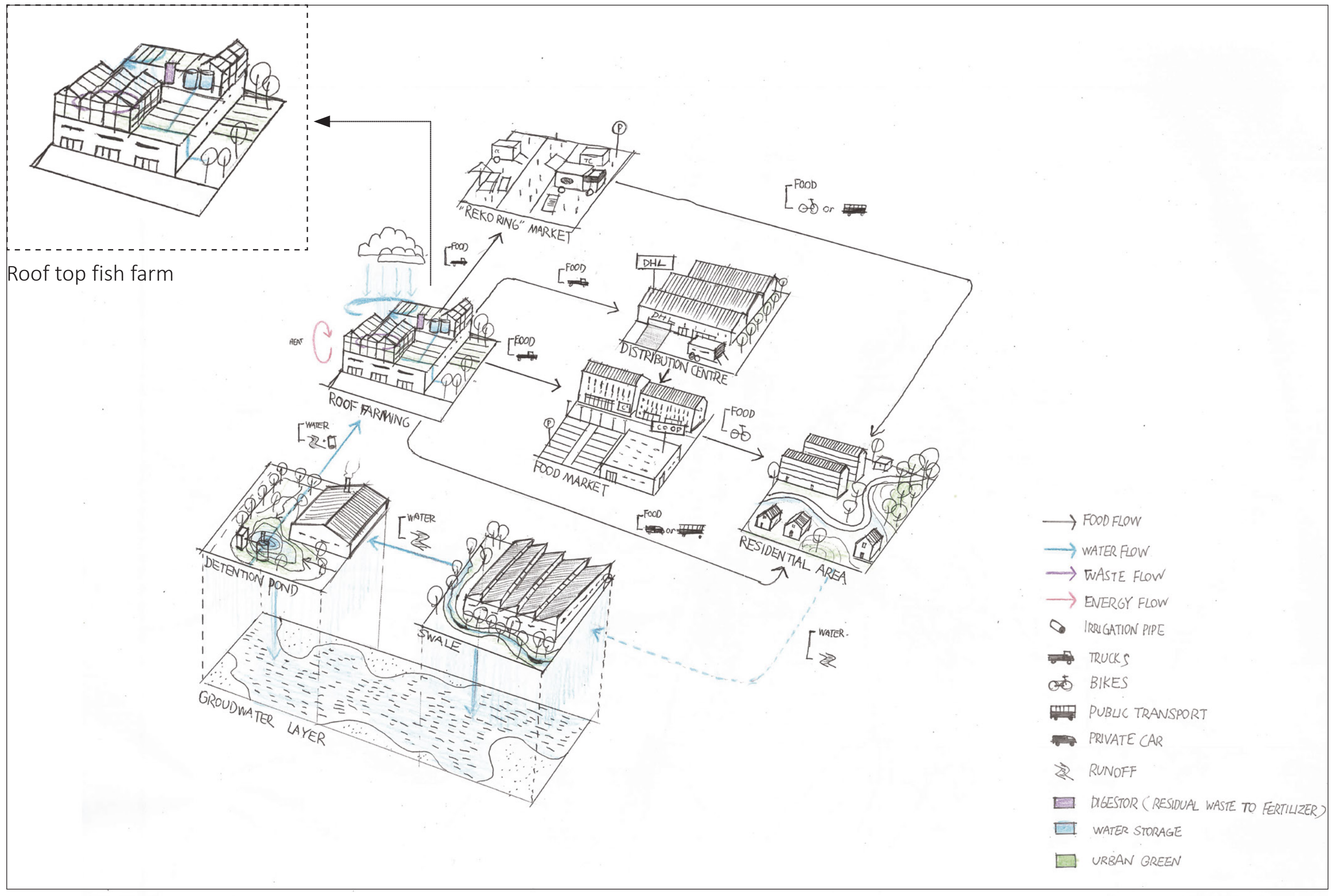
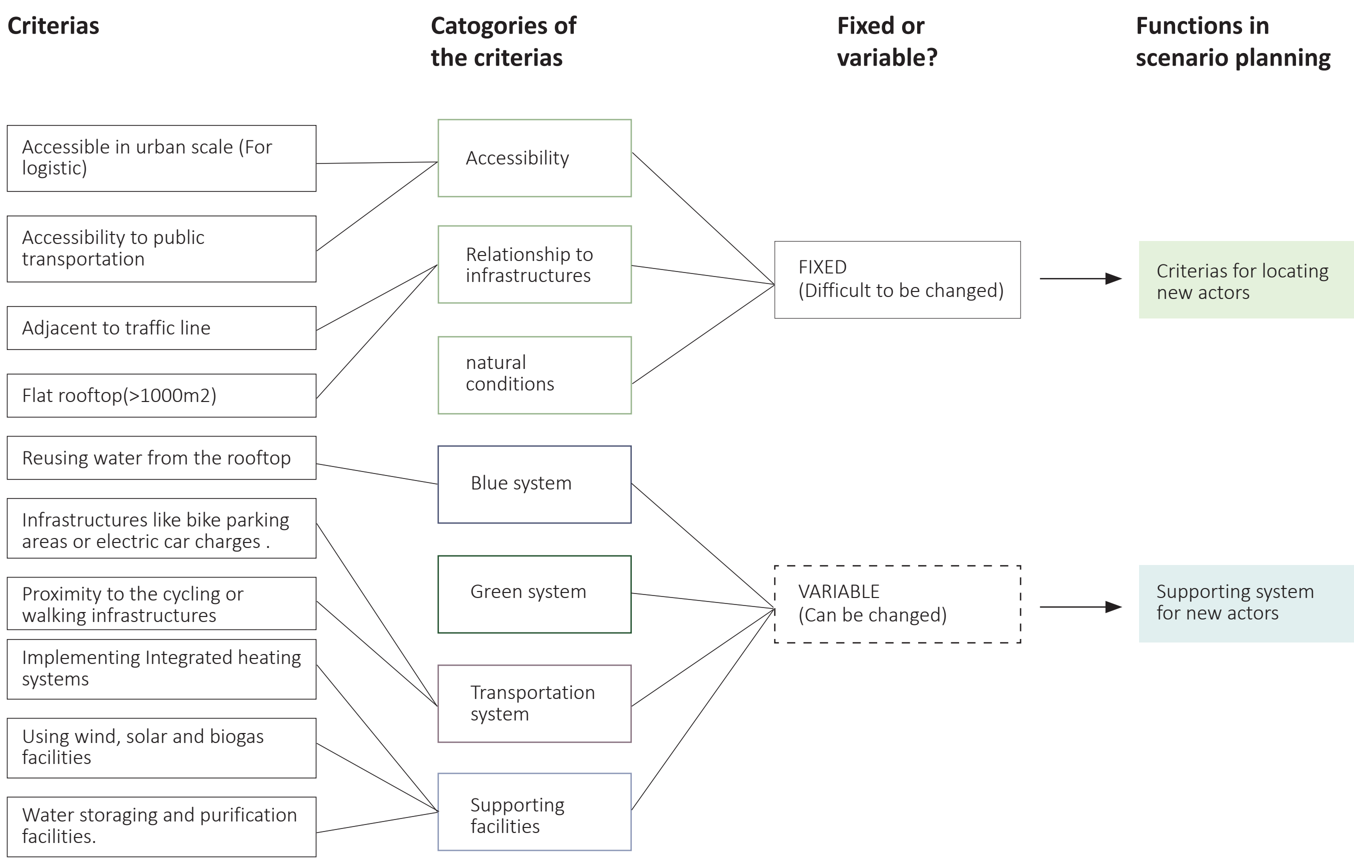


Figure 72: Circular food production model 2.(Roof top fish



4.4 District greenhouse (Actor's type 3)

4.4.1.Management set-up

The planning of the district greenhouse in Gothenburg is funded by the City of Gothenburg, which is an EU-co-financed project. that is run by Business Region Gothenburg in collaboration with the City of Gothenburg and Companion. The City of Gothenburg aims to create conditions for green business development and provide a platform for local actors to realize ideas.(sources:*District greenhouse in gothenburg - pre-study 2019.03.13,p5).* Local green start up companies, like stadssjord will join the management of the district greenhouse.

4.4.2.Production model in social perspective

According to the feasibility study of the district greenhouse in Gothenburg, the district greenhouses are mainly located in existing ground parking lots connected with the public transportation system.*(District greenhouse in Gothenburg - pre-study 2019.03.13,p5***).** That means the accessibility from public transportation to the district greenhouse should be considered in the selection of locations. Also, through the report, the district greenhouse should be built close to the cycling infrastructures to encourage the establishment of "bicycle kitchen and workshop library), so that the suitable distance for people to arrive by bike will also be a factor of the greenhouse.

Meanwhile, for the district greenhouse themselves, there are different types based on the different characteristics of different locations. For example: some can function as meeting centres and some only function as food production.

4.4.3.Production model in ecological perspective

ENERGY: For realizing the circular food production, according to the feasibility study of the district greenhouse, the energy of the greenhouse should be based on reusing the waste heat from the surrounding heat grid.(*Source: District greenhouse in Gothenburg - pre-study 2019.03.13,p6).* In addition, in the previous study of the balance strategies in 4.3, the aerobatic digestion facilities can be used for producing nutrients and bio energy together, so the facilities would have potential to deal with food waste from nearby actors.

NUTRIENTS: In the future, the nutrients for food production in the district greenhouse would be based on the compost of food waste from surrounding restaurants, hotels, and markets. Similar to the rooftop fish farm, some of the district greenhouses are also fish farm based and that means the nutrients can be recycled in the production cycle.

WATER: Water should be collected from the roofs for irrigation,BDT water from n the building can also be used.(sources:*District greenhouse in gothenburg - pre-study 2019.03.13,p15).* Plus, the parking lot for the district greenhouse can become an eco-parking lot which can store and purify the surface runoff through wadi or green corridor.The benefits have been summarized in previous two circular production models.

URBAN (CIRCULAR) FOOD SYSTEM

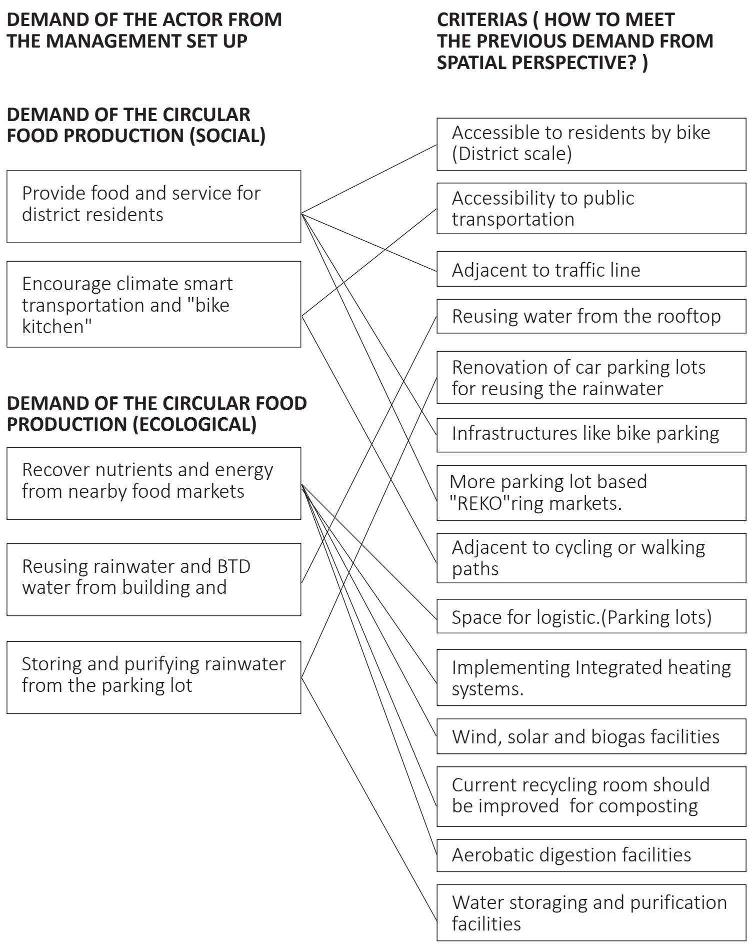


Figure 73. Conditions for realizing circular food production model and relevant criterias

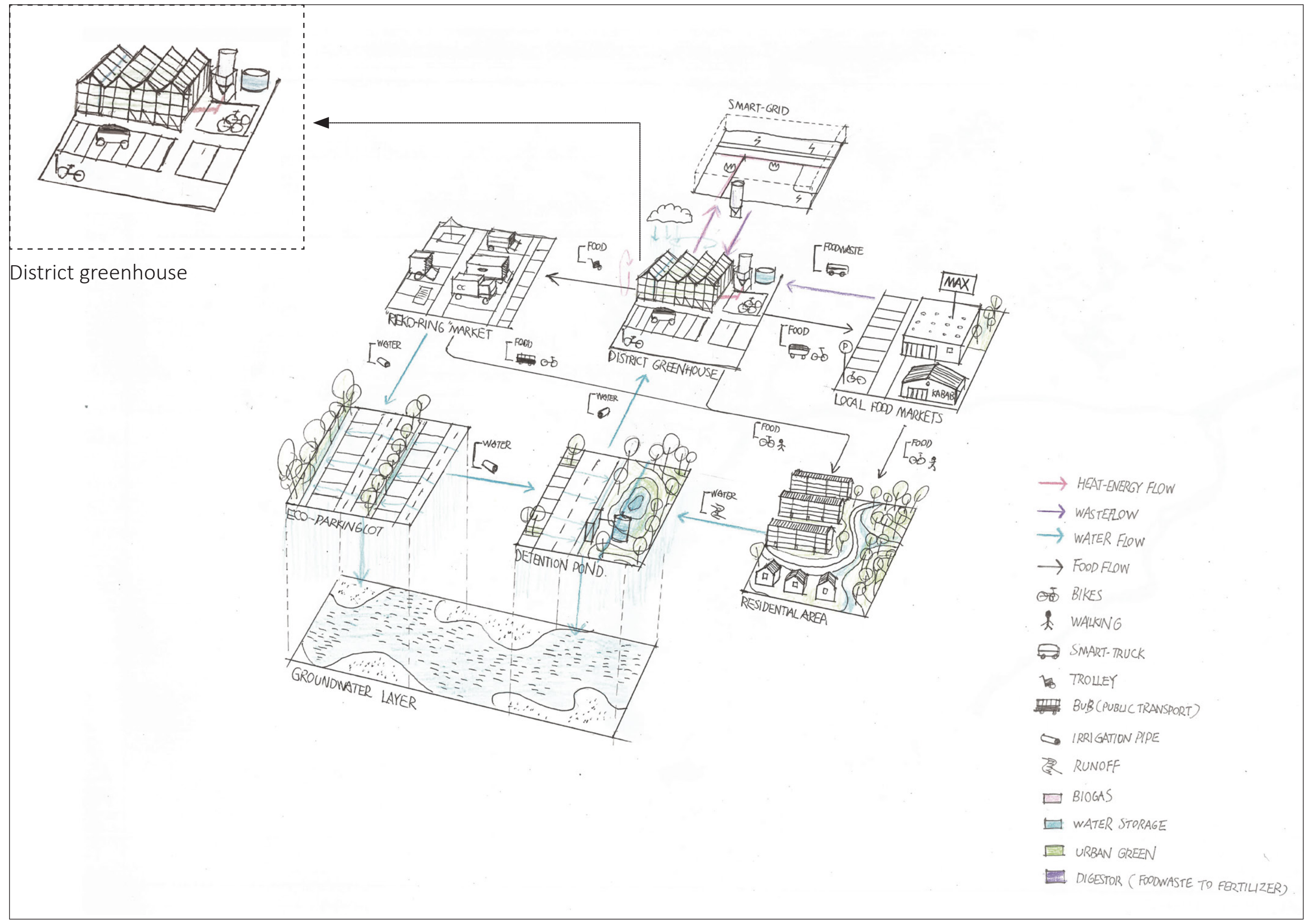
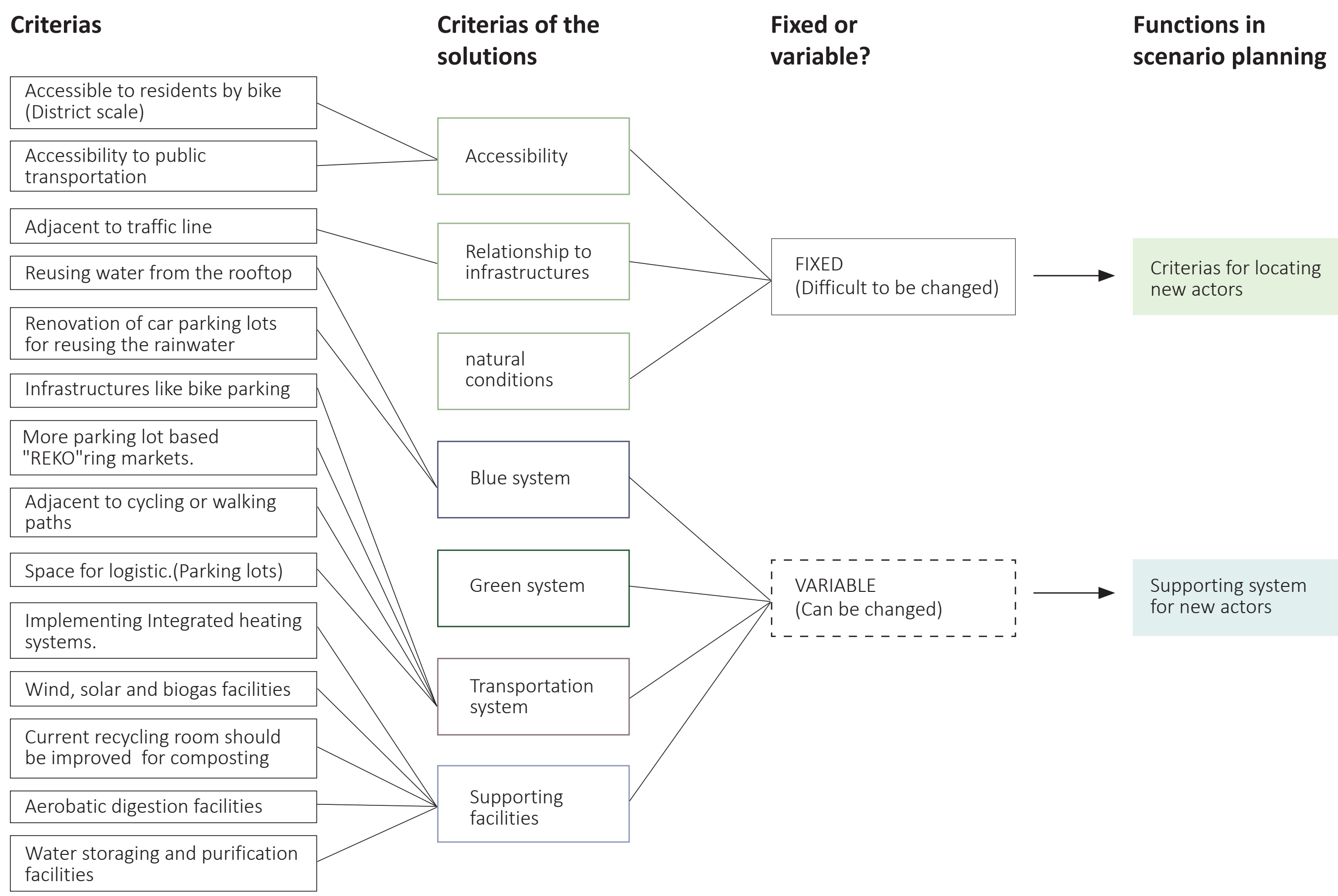


Figure 74: Circular food production model 3.(District greenhouse)



URBAN (CIRCULAR) FOOD SYSTEM

4.5 Peri-urban land for green start up companies (Actor's type 4)

4.5.1.Management set-up

Nowadays, Gothenburg municipality owns 3000ha land in the peri urban farmland and nowadays, the real property office plans to rent some of the land for green start up companies, which is also supported by the climate KIC projects of the EU. The STADLANDET project can also support the start up companies in both financial and knowledge perspectives. There are now some successful small scale organic farms in the peri-urban area in the north of the city. *(source:https://goteborg.se/wps/portal/enhetssida/stadslandet-goteborg)*

At the same time, for supporting the sustainable renovation of infrastructures in the rural area,(for example: an alternative water system), 80 EUR million have been provided by the rural development programme of Sweden. *(A.Tredanari,2011) (source: https://stud.epsilon.slu.se/3351/1/tredanari_a_111017.pdf p18)*

4.5.2.Production model in social perspective

In Gothenburg, the establishment of peri urban green start up companies are now mainly tested by the STADLANDET project, which mainly focus on the strategies in urban-rural linkage and farming can be useful methods. (*source:https://goteborg.se/wps/portal/enhetssida/stadslandet-goteborg).* Small scale farming in the peri urban area can be considered as a way of developing local food production strategy-----food from actors of peri urban area would be transported to actors in urban area. So, the accessibility in urban scale for better logistics and infrastructures for climate smart transportation tools should be considered in the peri urban area.

Also, especially in the north of Gothenburg, where traveling is an important sector in the economy. Some of the existing peri urban start up companies in Angered have expanded their business from only food production to trainee and public restaurants, which shows a successful business model. For attracting more people to the peri urban area, visibility, the relevant infrastructures for cycling and walking should also be considered in locating start up companies.

4.5.3.Production model in ecological perspective

NUTRIENTS: Based on the previous analysis of the balance strategies in 4.3, More anaerobic digestion facilities can be built in the current peri-urban farmland because the digestion process can use the oversupplied manure from grazing to produce efficient local fertilizer and energy. The energy can also be linked to the smart grid. Local food waste and residual waste can also be digested to become fertilizer. However, according to the demand analysis of fertilizer in 4.2, the composition of different types of fertilizer for crops still needs to be researched.

Besides, according to recent research by METABOLIC, it is also important to implement nature based solutions in the farmland for avoiding the pollution of over supplied phosphorus, which have polluted the Baltic sea. Grassstrip with a buffer zone along the runoff would be an efficient way of reducing the phosphorus flow. Grass buffer strips of 1m width along the runoff found a 60–80% retention of both phosphorus during runoff events.*(Vallières.2005)*. Also, grass shrub buffers along the grass strip can reduce phosphorus by 91.8%.(*(A.Tredanari,2011. p6-7).* In order to keep the nutrients, the basin would be crucial in the phosphorus management.

WATER: Rainwater harvesting can be done on a farm with a large land area through a system of swales, based on the runoff corridor. In Sweden, most of the water resources come in the Spring while the highest demand for water is in the summer. In the field, the detention pool or wadi can also be used for purifying the runoff and storage water for peri-urban start up companies to irrigate crops. *(grow-here.com/en/snowmelt-harvesting/)*

GREEN: Based on the theories of landscape ecology, boundaries between different types of land use are important for keeping biodiversity *(Herlin,2001,p27-43)*. For setting up an efficient peri urban start-up land that can keep biodiversity, functional buffer zones along natural forest,patches,streams and wadi should be protected and built. Especially for water sources,buffer strips along the water surface can limit the loss of topsoil for farming and are used for animal forage, also can become a green corridor. *(Krueger,2020) (source: https://www.cleanlakesalliance.org/).*

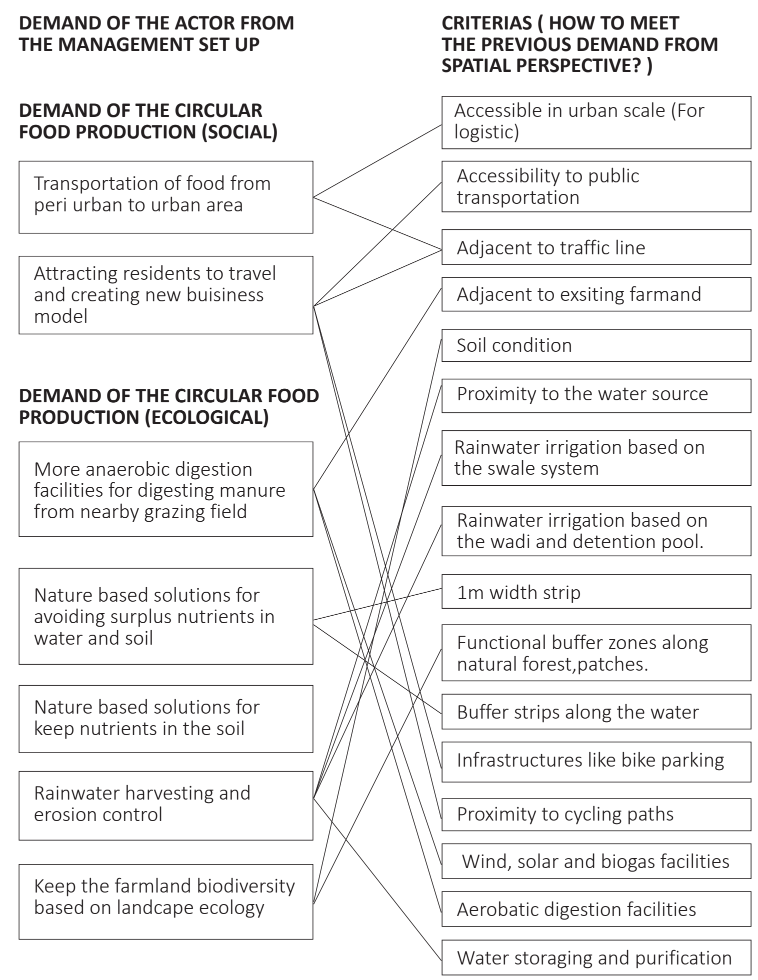


Figure 75. Conditions for realizing circular food production model and relevant criterias

URBAN (CIRCULAR) FOOD SYSTEM

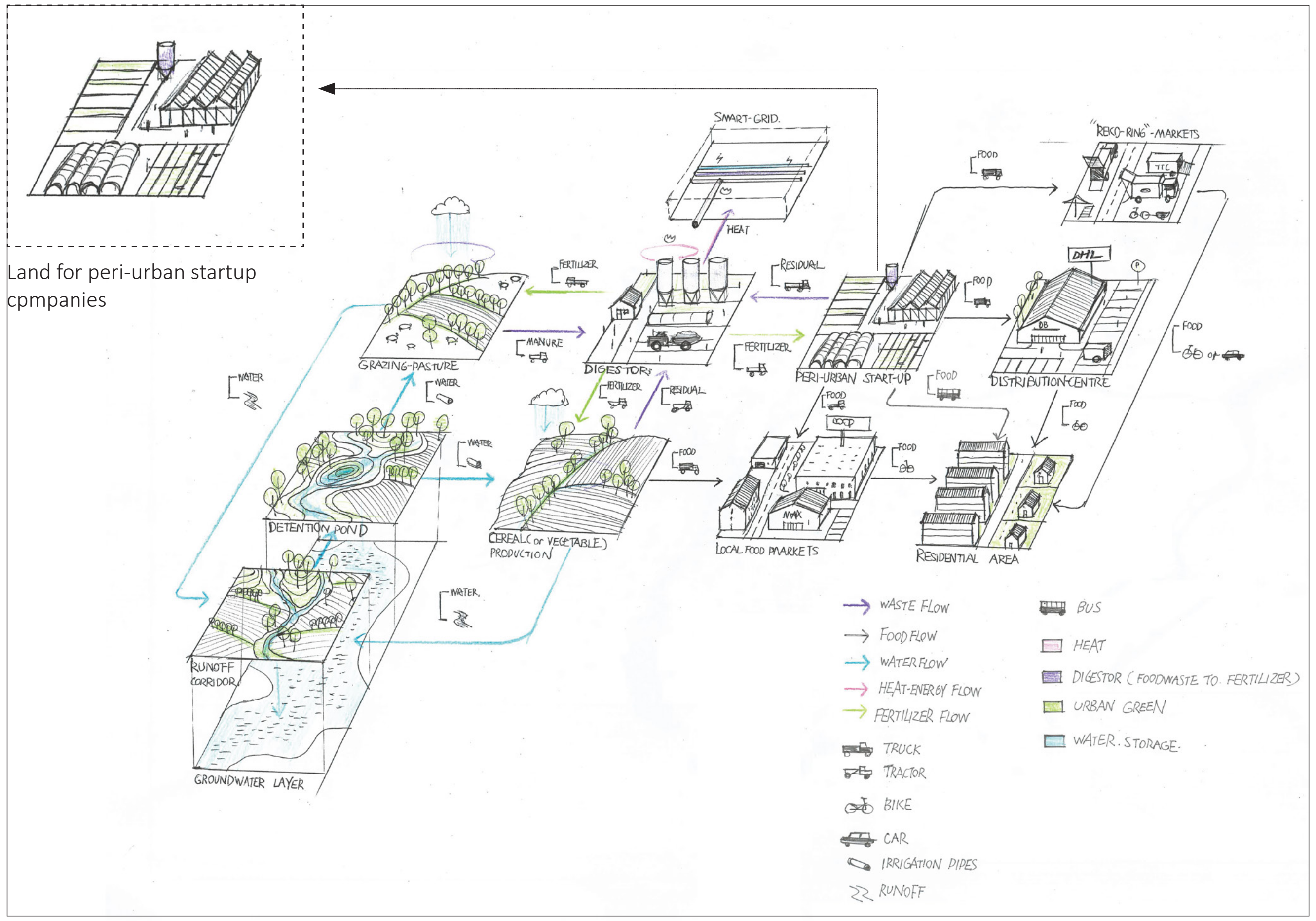
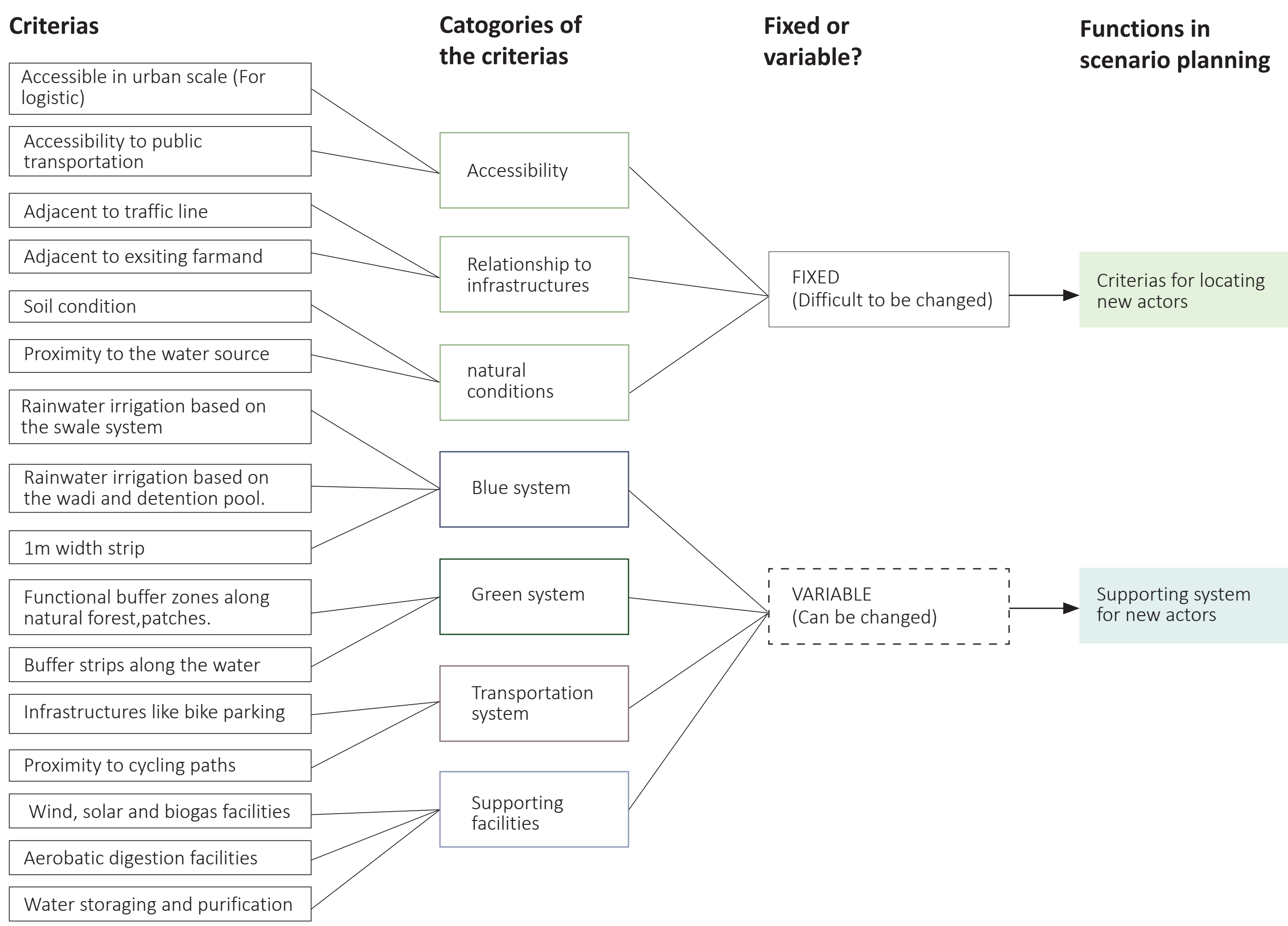


Figure 76.Circular food production model 4.(Land for peri-urban green start up companies)



4.6. Summary of the circular food production model at neighbourhood scale

In conclusion, in order to design an efficient circular food production model at neighbourhood scale, both the location's criterias of different types of new actors and the future's supporting systems are crucial.

In the next step, the scenario planning of urban circular food production systems in Gothenburg would be based on the criterias proposed in this chapter.

Followed by previous analysis, criterias for locating four types of new food production actors and the strategies for designing the supporting systems for circular production are categorized and listed in this table below, for guiding the next step: GIS based scenario planning.

Table: Criterias for actor's locations and solutions of the supporting system

Criterias of site selection of new actors — *The criterias of locating new actors are categorized for GIS analysis.*

Type of actors \ Criterias		Accessibility					Relation to current infrastructures				Natural condition			
		Accessibility(Urban scale)	Accessibility(district)	Accessibility(neighbourhood)	Accessibility to public transportation	Accessibile by bike	Adjacent to traffic line	Flat rooftop(>1000m2)	Adjacent to exsiting farmland	Parking lot (Ground type)	Solar condition	Soil condition	Proximity to the water source	Proximity to green space
Urban new actors	Community garden			√	√		√						√	√
	Rooftop fish farm	√			√		√	√						
	District greenhouse		√		√	√	√			√				
Peri-urban new actors	Peri-urban green start-up farming	√			√	√	√		√			√	√	

Supporting systems for new actors — *The strategies of designing the supporting system for new actors are categorized for GIS analysis and editing.*

Type of actors \ Supporting systems		Blue systems (water)	Green systems	Transportation systems	Supporting facilities for resources management and production
Urban new actors	Community garden	**1.**Proximity to water sources for rainwater/snowmelt harvesting. (Through wadi or runoff corridor)	**1**.Wind break around the farming area **2**.Functional buffer edge with the green space	**1.**Transportation infrastructures like bike parking areas or electric car charges . **2.**Proximity to the cycling or walking infrastructures.	**1.**Facilities in the current recycling room should be improved for composting and transporting local food waste. **2**.Water storaging and purification facilities
	Rooftop fish farm	**1.**Reusing water from the rooftop and surrounding		**1**.Transportation infrastructures like bike parking areas or electric car charges . **2.**Proximity to the cycling or walking infrastructures.	**1.**Implementing Integrated heating systems **2.**Using wind, solar and biogas facilities **3.**Water storaging and purification facilities
	District greenhouse	**1.**Reusing water from the rooftop and surrounding **2.**Renovation of car parking for water by reusing the rainwater		**1.**Transportation infrastructures like bike parking area or electric car charges. **2.**More parking lot based "REKO"ring markets. **3**.Adjacent to cycling or walking infeastructures **4**.Space for logistic	**1.**Implementing Integrated heating systems **2.**Using wind, solar and biogas facilities **3.**Aerobatic digestion facilities connecting with district heating grid **4.**Water storaging and purification facilities
Peri-urban new actors	Peri urban start up farming	**1.**Rainwater irrigation based on the swale system **2.**Rainwater irrigation based on the wadi and detention pool. **3.**1m width strip based on the runoff for the retention of nutrients.	**1.**Functional buffer zones along natural forest,patches. **2**.Buffer strips along the water surface **3.**Grass strips buffer along the stream corridor	**1.**Transportation infrastructures like bike parking area or electric car charges. **2.**Proximity to cycling or walking infrastructures. **3.**Space for logistic	**1.**Using wind, solar and biogas facilities **2.**Aerobatic digestion facilities connecting with district heating grid **3.**Water storaging and purification facilities

V.PLANNING OF SCENARIO: URBAN CIRCULAR FOOD SYSTEM IN GOTHENBURG

Brief of this chapter

In this chapter, the planning process and final results of the urban circular food system in Gothenburg will be presented. There are three steps in the scenario planning. In the first step (see section 5.1), the criterias for four types of new actor's site selection and supporting systems will be listed in four toolboxes based on the analysis results in 4.4. The second step (see section 5.2) shows the process of site selection and results of the new actor's scenario. The third step (see section 5.3) shows the planning process and results of the supporting system.

5.1.Analysis toolbox for locating new actors and the supporting system

The scenario planning of the urban circular food production network is based on the criterias for suitable site selection and supporting systems summarized before. In order to execute GIS analysis for finding suitable space based on the criterias, relevant data (like road network, land use,DEM) are required. After finding the data, the parameters for calculating suitable land based on analyzing the data should be defined, based on existing resources of suitable parameters and experiments of results's feasibility (for example: angular integration and attraction reach). Four tool boxes below show the analyzing methods, relevant data ,data sources and parameters for criterias of four new circular food production actors in Gothenburg.

The first step of the scenario planning in this chapter is to find suitable locations for four main types of actors, the second step is to set up the supporting system for the new actors together, since the toolbox below shows that some of the solutions in planning the supporting system which can be shared by 4 types of actors together. (For example: solutions for planning the blue system and green system).

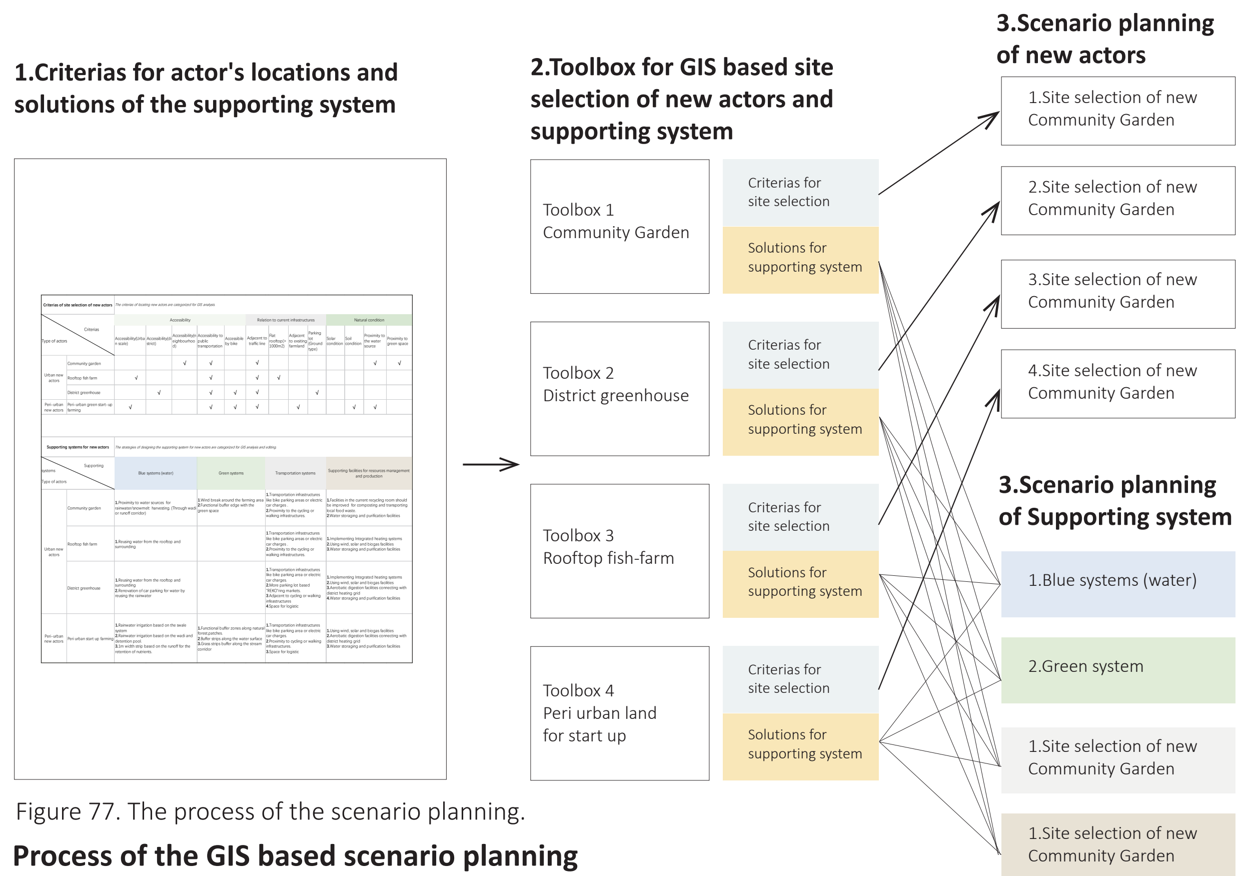


Figure 77. The process of the scenario planning.

Process of the GIS based scenario planning

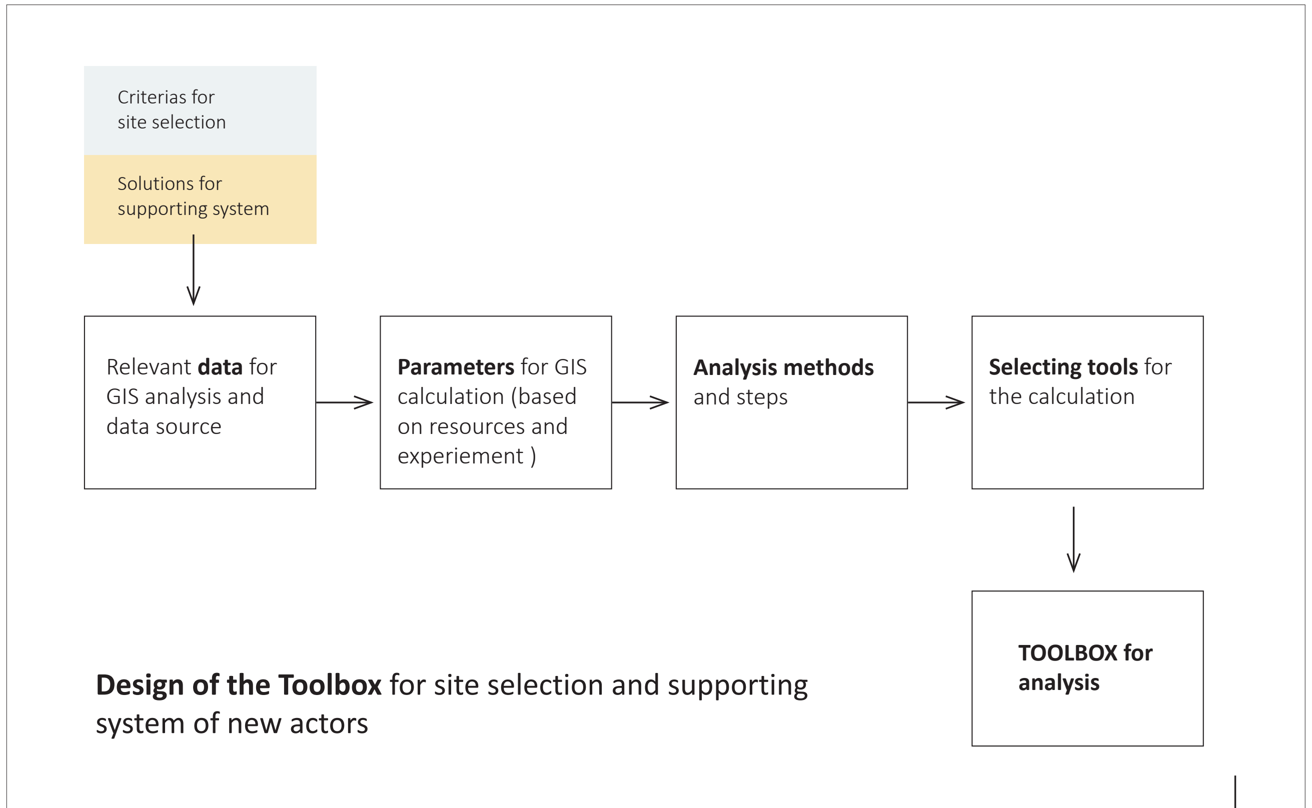


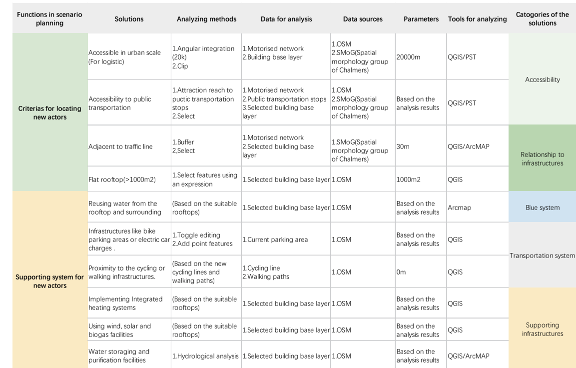
Figure 78. Design of the Toolbox for site selection and supporting system

Toolbox example: (Site selection and desiging supporting system for community garden)

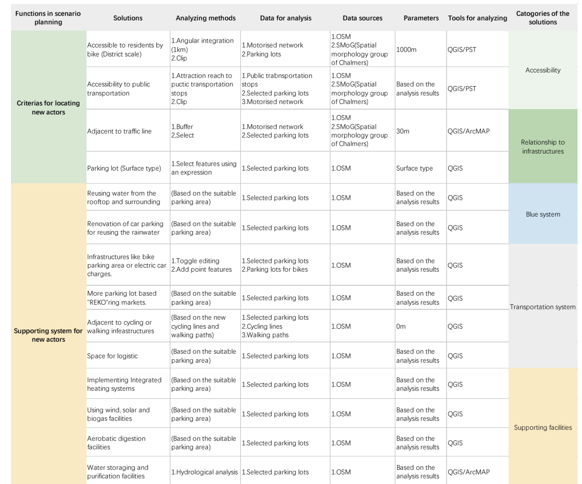
Functions in scenario planning	Solutions	Analyzing methods	Data for analysis	Data sources	Parameters	Tools for analyzing	Catogories of the solutions
Criterias for locating new actors	Accessible in urban scale (For logistic)	1.Angular integration (20k) 2.Clip	1.Motorised network 2.Building base layer	1.OSM 2.SMoG(Spatial morphology group of Chalmers)	20000m	QGIS/PST	Accessibility
	Accessibility to public transportation	1.Attraction reach to puctic transportation stops 2.Select	1.Motorised network 2.Public transportation stops 3.Selected building base layer	1.OSM 2.SMoG(Spatial morphology group of Chalmers)	Based on the analysis results	QGIS/PST	
	Adjacent to traffic line	1.Buffer 2,Select	1.Motorised network 2.Selected building base layer	1.SMoG(Spatial morphology group of Chalmers)	30m	QGIS/ArcMAP	Relationship to infrastructures
	Flat rooftop(>1000m2)	1.Select features using an expression	1.Selected building base layer	1.OSM	1000m2	QGIS	
Supporting system for new actors	Reusing water from the rooftop and surrounding	(Based on the suitable rooftops)	1.Selected building base layer	1.OSM	Based on the analysis results	Arcmap	Blue system
	Infrastructures like bike parking areas or electric car charges .	1.Toggle editing 2.Add point features	1.Current parking area	1.OSM	Based on the analysis results	QGIS	Transportation system
	Proximity to the cycling or walking infrastructures.	(Based on the new cycling lines and walking paths)	1.Cycling line 2.Walking paths	1.OSM	0m	QGIS	
	Implementing Integrated heating systems	(Based on the suitable rooftops)	1.Selected building base layer	1.OSM	Based on the analysis results	QGIS	Supporting infrastructures
	Using wind, solar and biogas facilities	(Based on the suitable rooftops)	1.Selected building base layer	1.OSM	Based on the analysis results	QGIS	
	Water storaging and purification facilities	1.Hydrological analysis	1.Selected building base layer	1.OSM	Based on the analysis results	QGIS/ArcMAP	

Table 6 Design of the Toolbox for site selection and supporting system

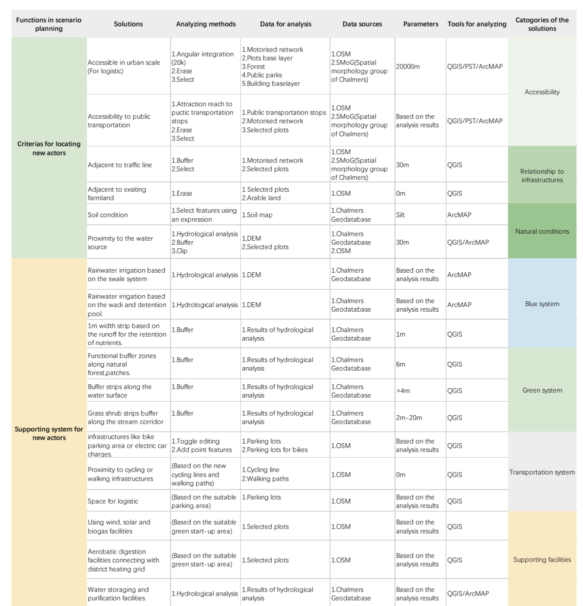
TOOLBOX (District greenhouse)
Figure.79.Criterias for site selection and supporting system
(See appendix)



TOOLBOX (Rooftop fishfarm)
Figure 80.Criterias for site selection and supporting system



TOOLBOX (Peri-urban green start up companies)
Figure 81.Criterias for site selection and supporting system



5.2.Scenario planning of new actors

5.2.1. Locations of new community garden

STEP1: Basic GIS data preparation: Unused open green space

All of the unused urban green land chosen for site selection,which is based on the data “open green land” and “ Parks “. The unused land would be a base for further site selection

Figure 82: Basic data (Open green area and park area)

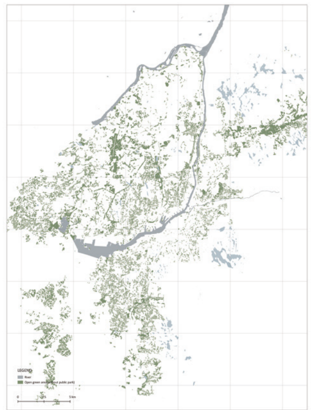


Figure 83: Urban green area (Public parks are excluded)

STEP2: Unused open green area proximity to transportation network (Angular integration 500m>106

In this step, in order to select suitable areas which are accessible to the neighbourhood, Unused open green area proximity to transportation networks (Angular integration>106) are selected for calculation.The result will be a base for next step calculation (Attraction reach>9)

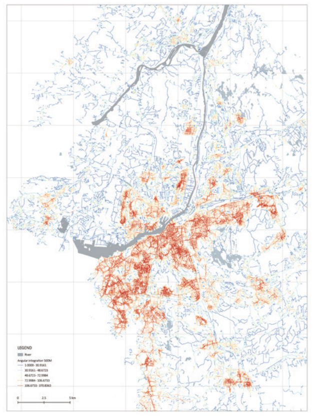


Figure 84: Angular integration 500m

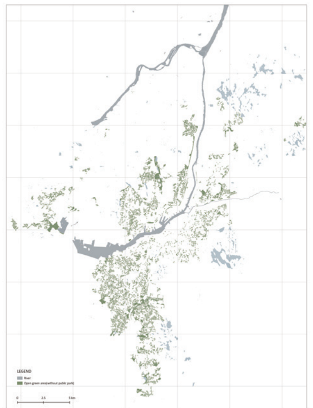


Figure 85: Proximity to network (Angular integration 500m>106)

STEP3: Unused open green space proximity to public transportation stops (Attraction reach>9)

In order to formulate “cooperative agriculture” and create contact between people from different parts of the city, the location of new community gardens should be close to public transport stops. As a result, open space close to the network (Attraction reach>9) are selected.

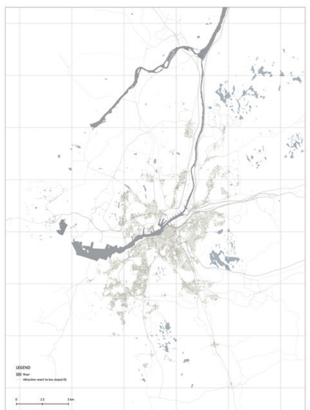


Figure 86: Attraction reach to bus/ tram stops

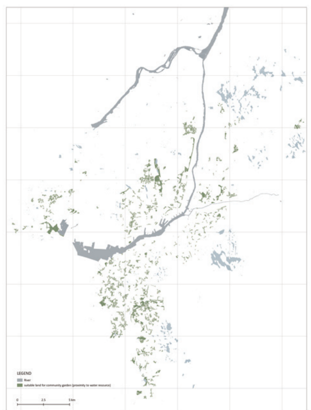


Figure 87: Proximity to network (Attraction reach>9)

STEP4: Unused open space proximity to water sources (Potential wadi)

Based on the ecological solutions summarized in chapter 4, community gardens should be close to water sources. In order to reduce the cost of building new irrigation infrastructures, wadi of the runoff system are chosen to be potential water sources. Then, suitable open green areas close to the wadi (max=30m) are selected.

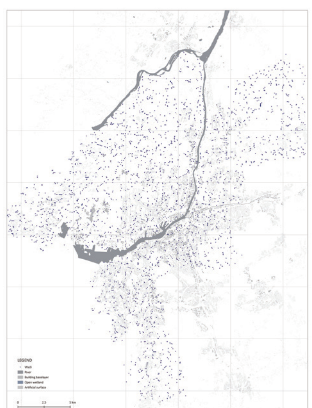


Figure 88: Wadi (Hydrological analyisis)

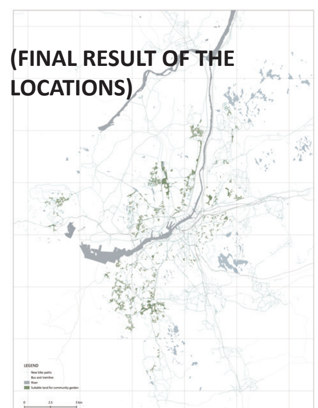


Figure 89: Suitable area proximity to water source (30m)

5.2.2. Locations of rooftop fish farms

STEP1: Basic GIS data preparation: Building base layer of Gothenburg

Here the database of building base layers are prepared for analysing suitable rooftop areas.

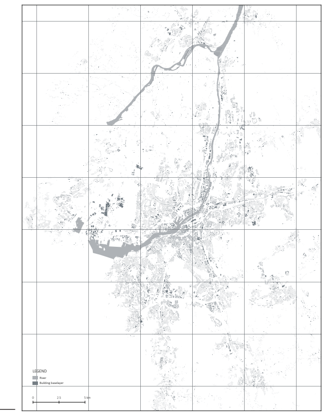


Figure 90: Basic data (building baselayers)

STEP2: Selecting suitable flat rooftop (area>1000m2)

In order to make the rooftop fish make profit according to previous research, flat rooftop (S>1000m2) are selected.

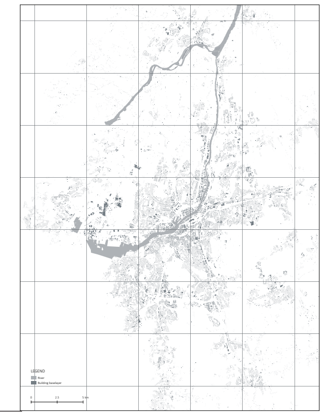


Figure 91: Selecting flat roof from all of the rooftops

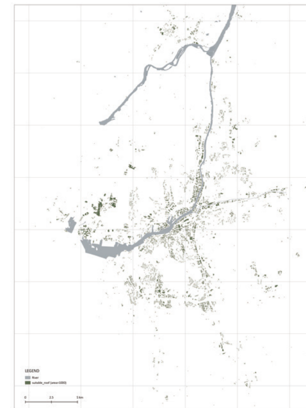


Figure 92: Map of flat rooftop (area>1000m2)

STEP3: Suitable rooftop proximity to transportation network (Angular integration 20k >3779)

For finding a suitable rooftop area which is convenient for logistics, the rooftop area should be close to a traffic network which is accessible to urban areas. (Angular integration 20k > 3779)

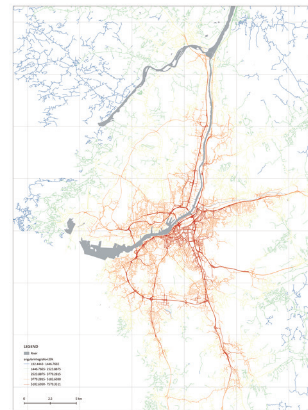


Figure 93: Angular intergation 20k (Accessible to urban)

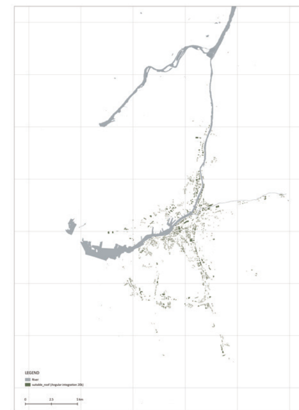


Figure 94: Proximity to network (Angular integration 20k>3779)

STEP4: Suitable rooftop close to public transportation stops (Attraction reach>9)

The rooftop fish farm also functions like tourism and education, so it needs to be accessible to people from every part of the city. So that the rooftop near public transportation stops (attraction reach>9) are selected.

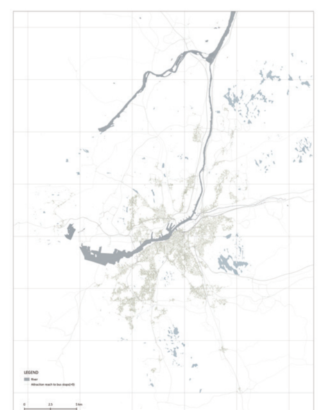


Figure 95: Proximity to network (Attraction reach>9)

Figure 96: Proximity to network (Attraction reach>9)

URBAN (CIRCULAR) FOOD SYSTEM

5.2.3.
Locations of new district greenhouse

STEP1: Basic GIS data preparation: parking lots of Gothenburg

Here the database of current parking lots are used for analysing suitable land for building district greenhouses.

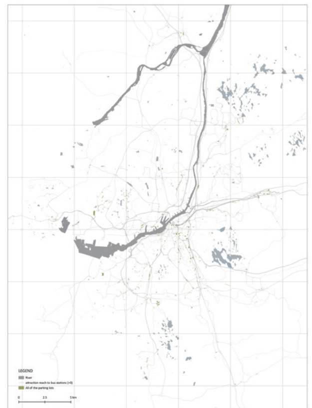


Figure 97: Basic data (
All of the parking lots in

STEP2: Selecting suitable parking lots for district greenhouse (Surface type)

There are 3 types of parking lots in Gothenburg. (Surface,multi-storey and underground). In this step the surface type is chosen because the multi-storey parking lots are included in the previous analysis of suitable rooftop fish farms.

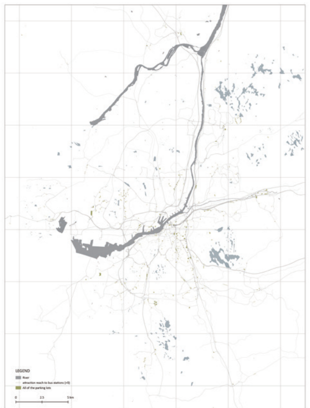


Figure 98: Selecting parking lots on the ground surface

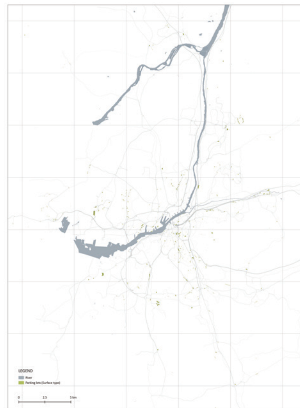


Figure 99: Parking lots (Surface type on ground)

STEP3: Suitable parking lots proximity to transportation network (Angular integration 1k > 256)

For finding suitable places for district greenhouse which are convenient for local residents by bikes or walking, the parking lots should be close to a traffic network which is accessible to the district. (Angular integration 1k > 256)

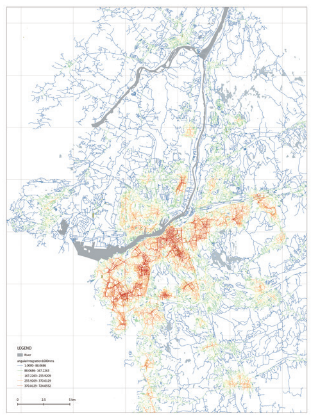


Figure 100: Angular intergation 1k (Acessibility in the district)

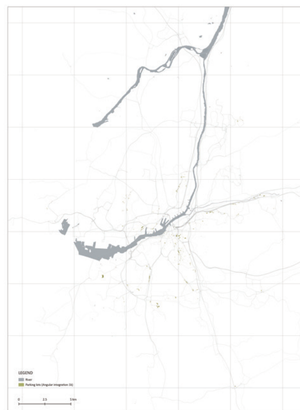


Figure 101: Proximity to network (Angular integration 1k>256)

STEP4: Suitable parking lots close to public transportation stops (Attraction reach>9)

The parking lots also function like tourism, education and meeting, so it needs to be accessible to people from every part of the city. So that the parking lots near public transportation stops (attraction reach>9) are selected.

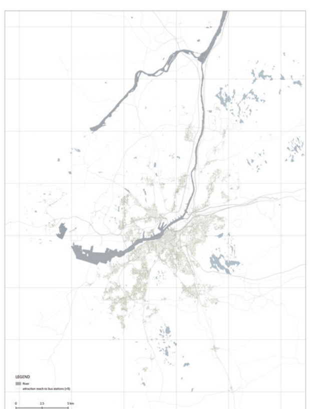


Figure 102: Attraction reach to tram/bus stops (Non motorised)

Figure 103: Proximity to network (Attraction reach>9)

5.2.4.
Location of suitable peri-urban land for green start up companies

STEP1: Basic GIS data preparation: Suitable plot area proximity to farmland

For better recycling the organic waste and surplus phosphorus from current farmland, it is necessary to locate the peri urban farmland proximity to existing farmland like grazing and monoculture land.

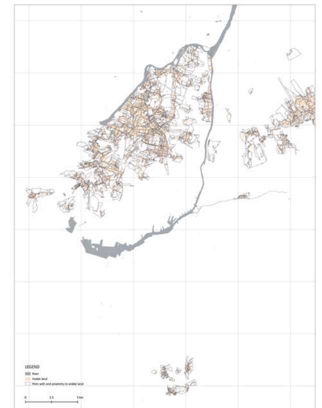


Figure 104: Basic data： Plots with existing farmland/grazing

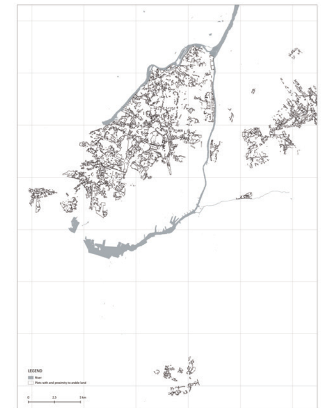


Figure 105: Suitable plot area (Proximity to farmland)

STEP2: Suitable open land for peri-urban start up in the selected plots A

When selecting feasible open land based on the selected plots above, there are natural areas like forest and current public parks, which need to be erased.

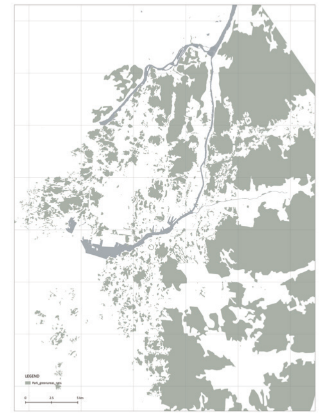


Figure 106: Parking and natural area

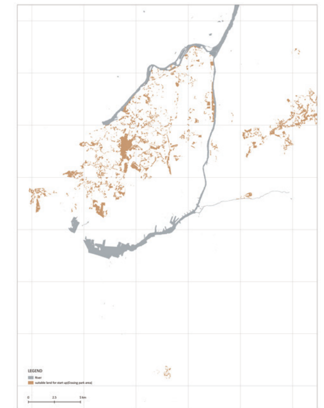


Figure 107: Suitable plot area (Forest,parks are reduced)

STEP3:
Suitable open land for peri-urban start up in the selected plots B

Area for building and artificial land under use should be erased.

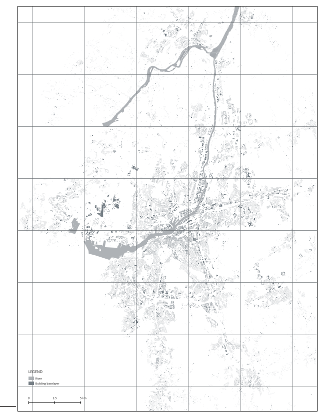


Figure 108: Building baselayer

+

Figure 109: Artificial surface

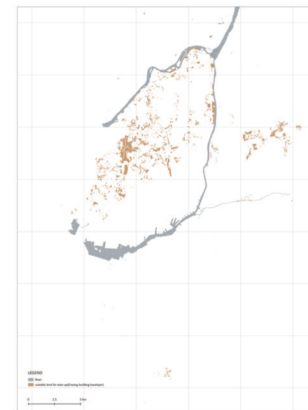


Figure 110: Suitable plot area (Building surface are reduced)

STEP4:
Suitablwe open land proximity to transportation network and public transportation stops.

(Angular integration 20k >3779 & Attraction reach>9)

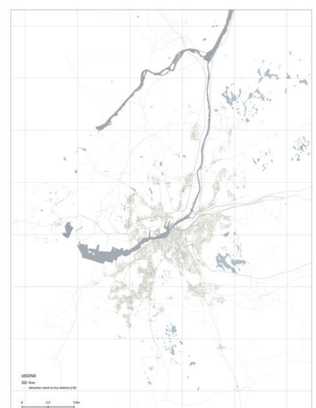


Figure 111: Public transportation system

+

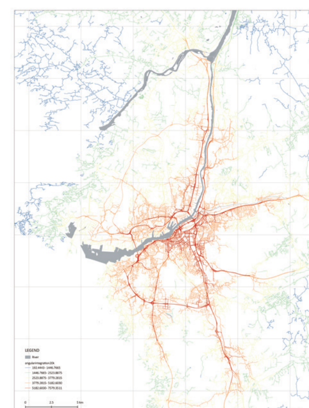


Figure 112: Angular integration 20k

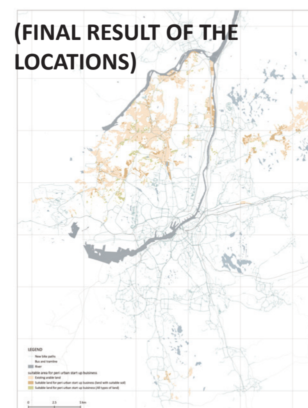


Figure 113: Suitable area proximity to netwwork.

URBAN (CIRCULAR) FOOD SYSTEM

5.3.Scenario planning of the supporting system

5.3.1.Supporting system (type1): Vision of the blue system

Blue system is the first supporting system for urban circular food production systems, according to previous analysis of ecological solutions in chapter4, the irrigation system can be combined with urban stormwater/snowmelt water management in both urban and rural areas. Nowadays, research shows that integrative and synergistic approaches should be applied to landscape planning when dealing with water management in different scales of a city *(Baccin,Ashley.et.al.2014,p8)*, and the nature based hydrological process can be translated to spatial solutions in different scales of urban space. Meanwhile, a basin can be a hydrologic unit to manage the runoff and water pollution. In this part of the design, the potential runoff corridor and wadi in Gothenburg is analyzed through GIS based hydrological analysis, in order to find where water can be collected potentially and the boundary of the basin.

The vision of the blue system includes 4 maps: 1.map of groundwater reservoir and suitable soil. 2.Map of runoff and stream system, 3.Map of potential wadi, 4.Map of current water body. The aim of this map is to provide reference for relevant actors to utilise, protect and improve the water system.

Figure 114: Map of groundwater reservoir and suitable soil for farming (silt)

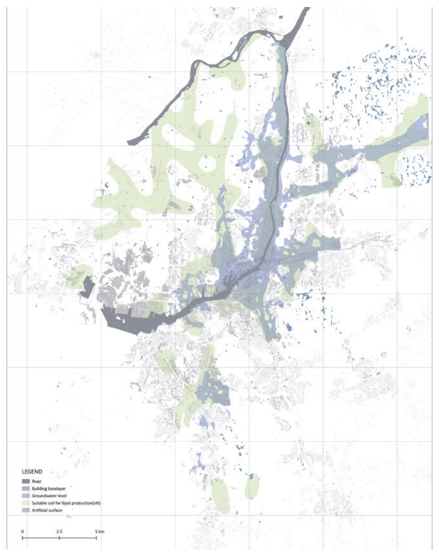


Figure 115: Map of runoff and stream system of Gothenburg

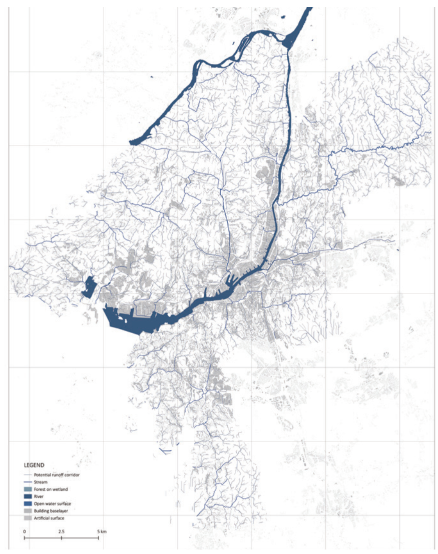


Figure116: Map of potential wadi for rainwater detention

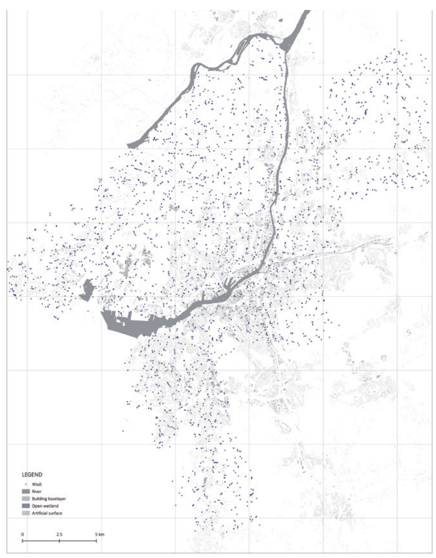
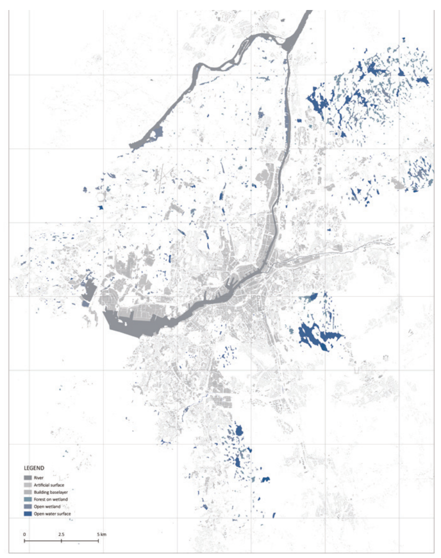


Figure 117: Map of open water surface and lakes in Gothenburg



5.3.2.Supporting system (type2): Vision of the green system

Based on the mapping of the blue system in the previous step, in order to keep the safety of the water environment and biodiversity when integrating the food production system in the city, it is crucial to have an integrated green system in Gothenburg. The green system includes 2 parts: one is different types of green filter for the water body and potential stream/wadi in the city. The other are functional buffer zones on the boundary of existing natural forest and green areas.

The vision of the green system includes 4 maps: a. Map of current urban green area and forest, b. Map of functional buffer of current forest and urban green area, c. Map of green filter for the potential runoff and wadi. d. Map of green filter for the existing open water surface.

Figure 118: Map of current urban green area and forest area

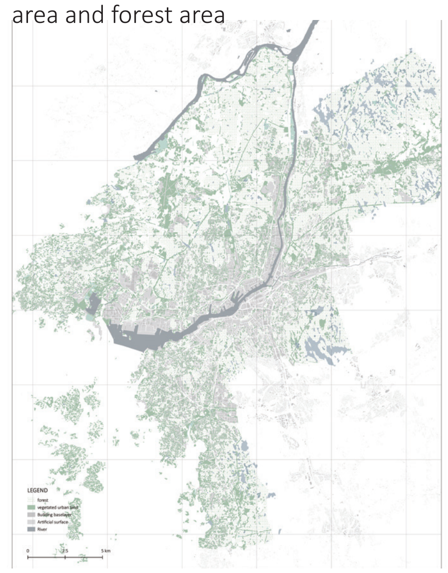


Figure 119: Map of functional buffer for forest patches

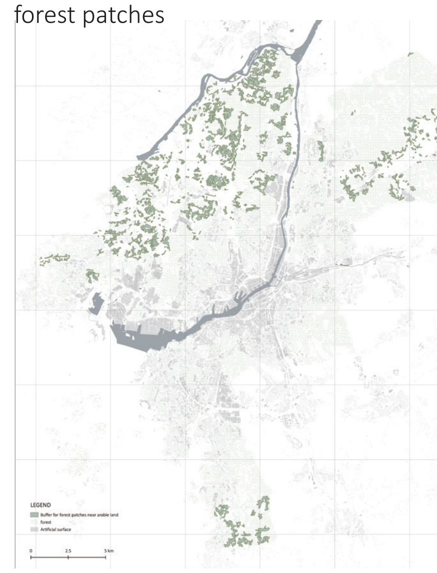
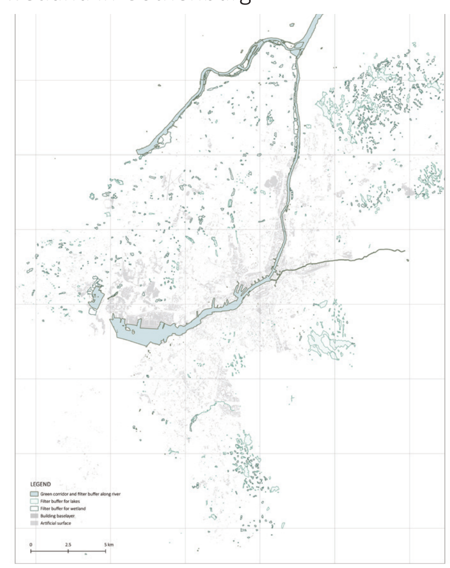


Figure 120: Map of buffer filter for runoff/ streams and green corridor along river

Figure 121: Map of buffer for lakes and wetland in Gothenburg



5.3.3.Supporting system (type3): Vision of the transportation system

In order to make the new actors in the food production system better connected to residents of Gothenburg through walking, cycling and public transportation, the transportation system should be improved. The vision maps below show how current transportation systems are improved for supporting circular food production systems. According to the mapping of current bike lanes and parking space, it is obvious that most of the parking space of bikes is concentrated in the city centre and the cycling/walking lines are not linked to the peri-urban area where green start up companies are located. So the first step is to add cycling lines/walking lines to the peri urban area by expanding/transforming the current network in the countryside, then at the space near the intersection points of cycling lines and walking paths in the peri urban area are selected to be new parking lots for bikes, where people can easily walking to the field after parking their bikes. Besides, current parking lots in the city should be transformed to support the farmers markets and sustainable logistics, for meeting the demand of district greenhouse, rooftop fish farm and peri-urban green start up companies.

The vision of the transportation system includes 4 maps: a. Map of parking lots suitable for farmers markets and facilities for logistics. b. Map of existing and new parking lots for bikes.c. Map of existing and new cycling paths. d.Map of existing and new walking paths.

Figure 122: Map of exsisting parking space for bikes and new parking space for bikes

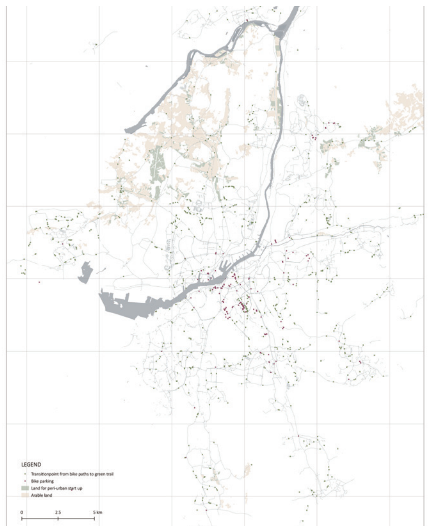


Figure 123: Map of parking lots where farmers market and relevant facilities can be built

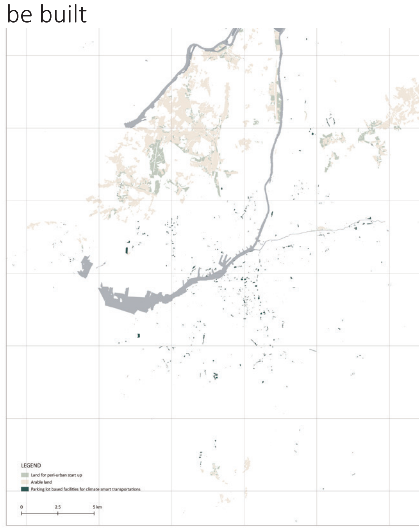


Figure 124: Map of existing cycling line and new cycling line

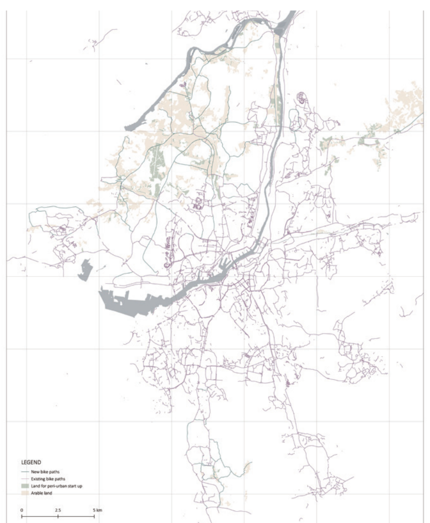
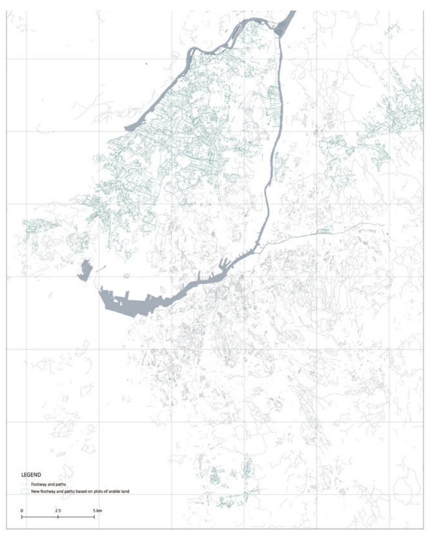


Figure 125: Map of existing walking paths and new walking paths



5.3.4.Supporting system (type4): Resource management facilities and management unit

In this step, several types of possible facilities are listed. Firstly, for better managing the water in the process of circular food production, it is important to install facilities like overflow pipes and water storing/purification systems, so that the runoff water from the green space can be used. Secondly, for the district greenhouse and rooftop fish farm, it is important to install rooftop and parking lots based on irrigation and water purification systems. Thirdy, since food waste is an important local resource for composting, current recycling rooms should be renovated and facilities for foodwate composting should be installed, while at the same time, the real time information system of actor's demand of food waste is also important for calculating how much compost the actors need, for better managing local resources.

Finally, basin (watershed) based on the hydrological analysis in GIS can become a basic unit for water quality and nutrients (like Phosphorus and Nitrogen) management in the circular food production system.

The vision of the resource management facilities and hydrological management unit includes 4 maps: a. Map of wadi based water storing and purification system; b. Map of rooftop/parking lots based rainwater storing and irrigation system; c. Map of recycling room based food waste composting and resource demand information system; d. Map of basin for water quality and surplus nutrients management.

Figure 126: Map of water storing and purification

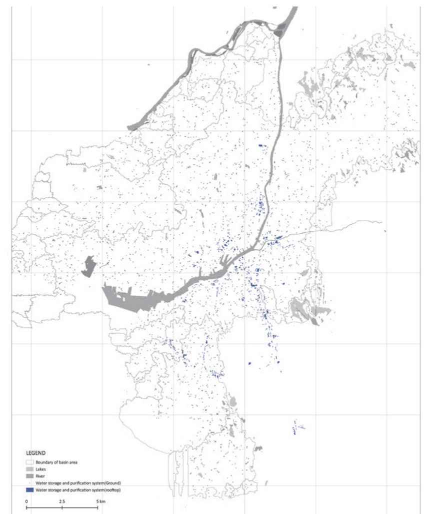


Figure 127: Map of smart facilities for rainwater irrigation

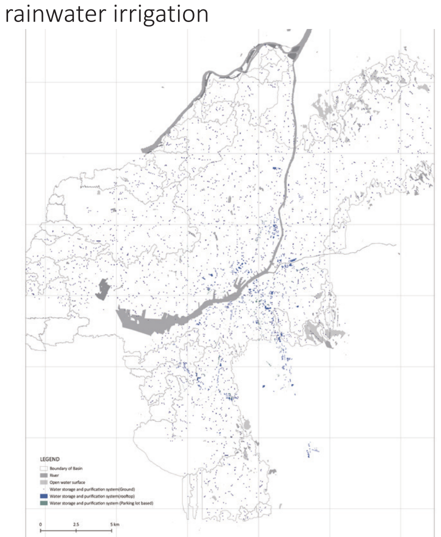


Figure 128: Map of (Recycling room based) food waste composting and information system

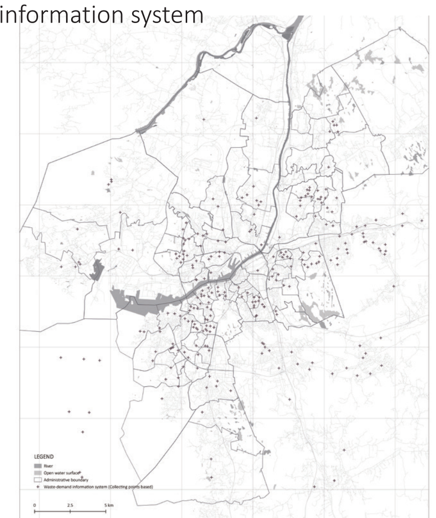
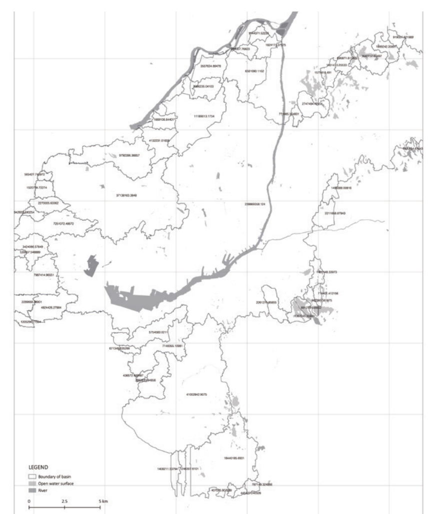


Figure 129: Map of basin for water and nutrients management



5.4.Final result of the scenario: urban circular food system

5.4.1.Scenario of new food production actors

The map belows is the presents the overlay of all of the new actors analysed above and existing peri urban agriculture land, shows all of the possible locations for different types of local food production. (More detailed map are listed in the appendix)

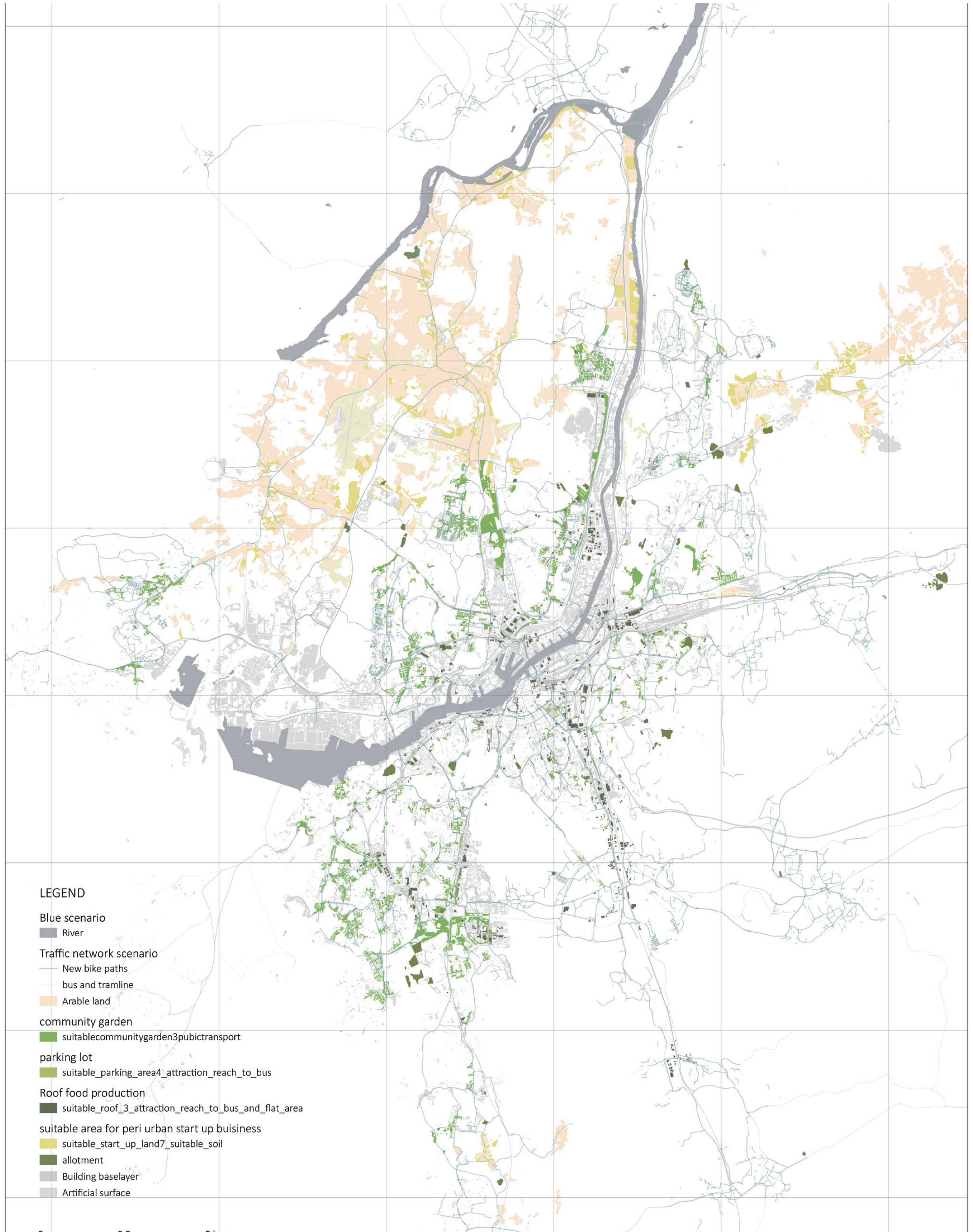


Figure 130: Map of 4 types of new actors

5.4.2.Vision of the supporting systems for circular food production

The four maps below present the overlay of different layers in 4 main types of supporting system based on the maps produced in 5.3. The maps below are: a.Vision of blue system; b.Vision of green system; c.Vision of transportation infrastructures; d.Vision of resource management facilities and hydrological management unit.(More detailed map are listed in the appendix)

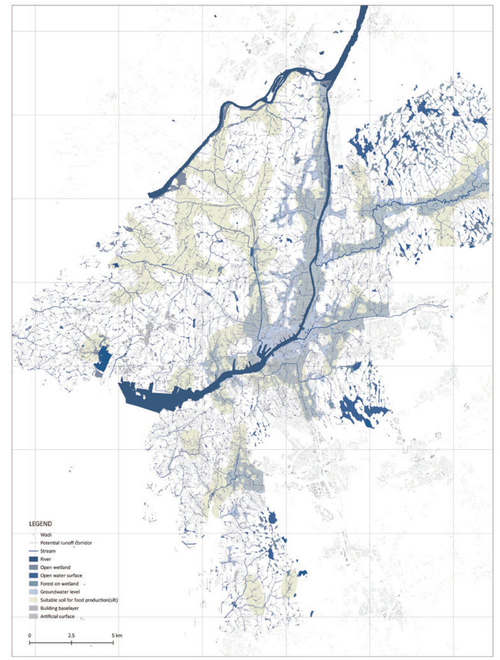


Figure 131: Vision of blue system

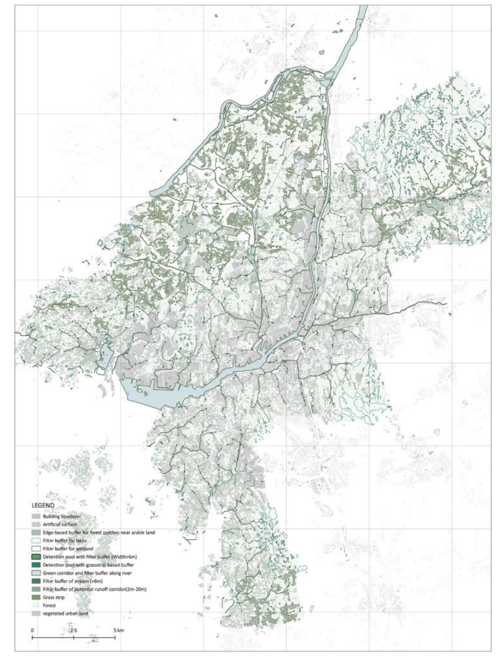


Figure 132: Vision of green system

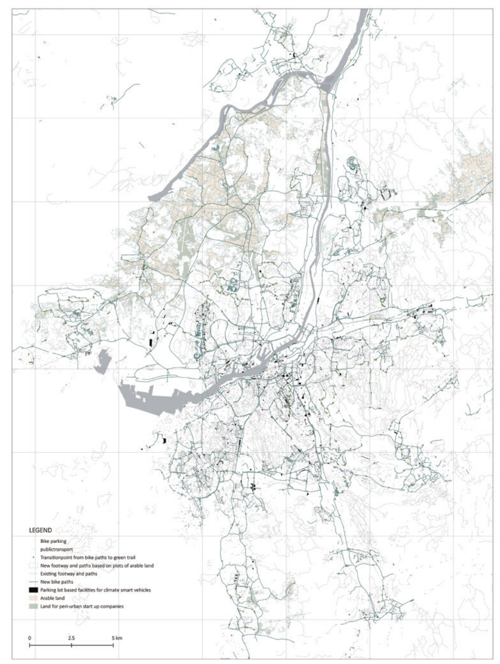


Figure133: Vision of transportation infrastructures

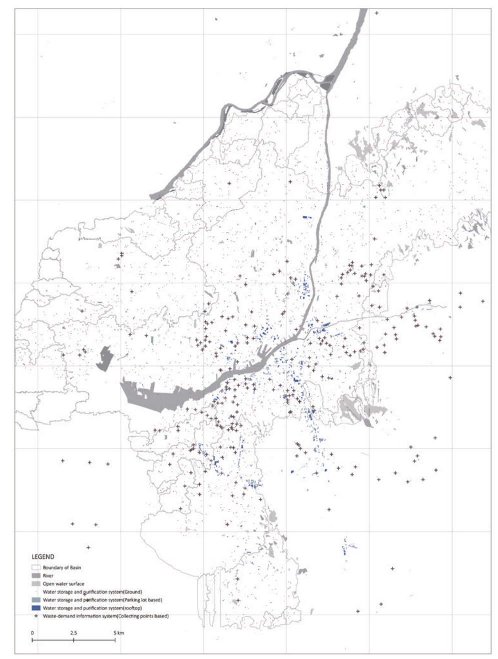


Figure134: Map of potential resource management facilities for supporting urban circular food production

VI.ZOOM-IN URBAN DESIGN

Brief of this chapter

Based on the scenario of the urban circular food system, in this chapter, three specific areas which include four main types of new actors are chosen, for testing how circular food production models may change urban landscape.

The axonometric drawing of the 3 selected zoom-in areas will show how urban circular food production systems can be integrated in actual urban space in different scales, followed by the scenario of urban circular food production model proposed in chapter 5.4.

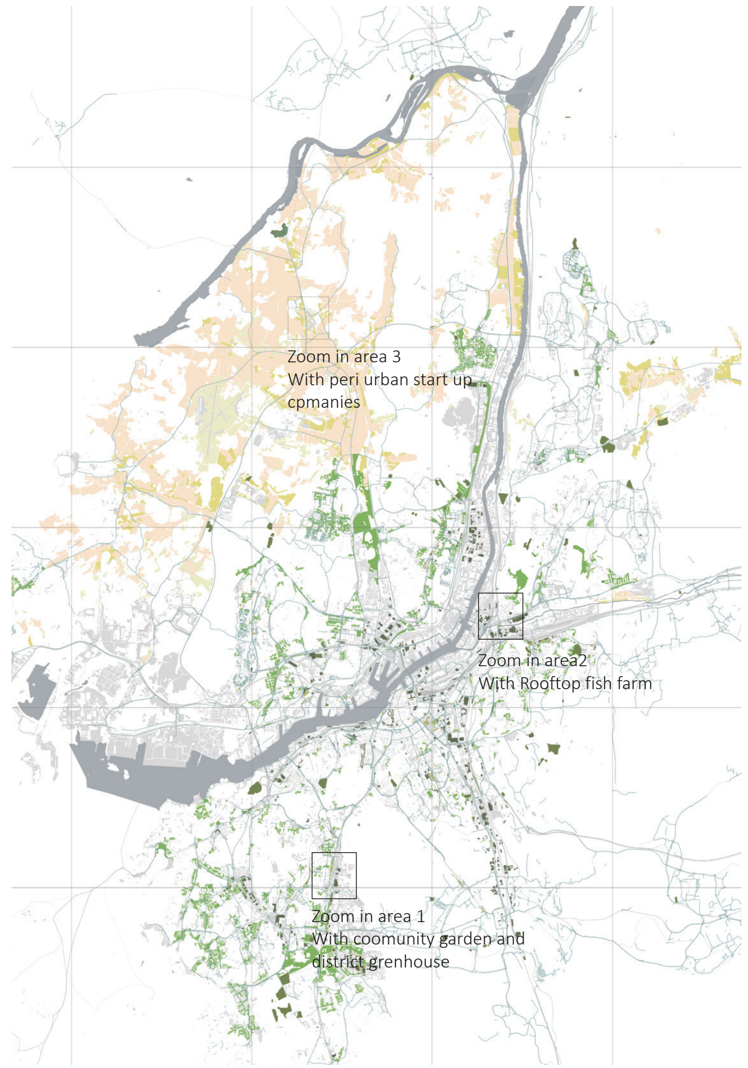


Figure135: Selection of zoom in area

Figure139: Zoom in area 1-community garden and dostrict greenhouse

Figure137: Zoom in area 2-Rooftop fish farm

Figure 138: Zoom in area 3-Suitable area for peri urban green start up companies

6.1.Community garden and district green house

6.1.1.Development plan of the zoom-in area (community garden and district greenhouse)

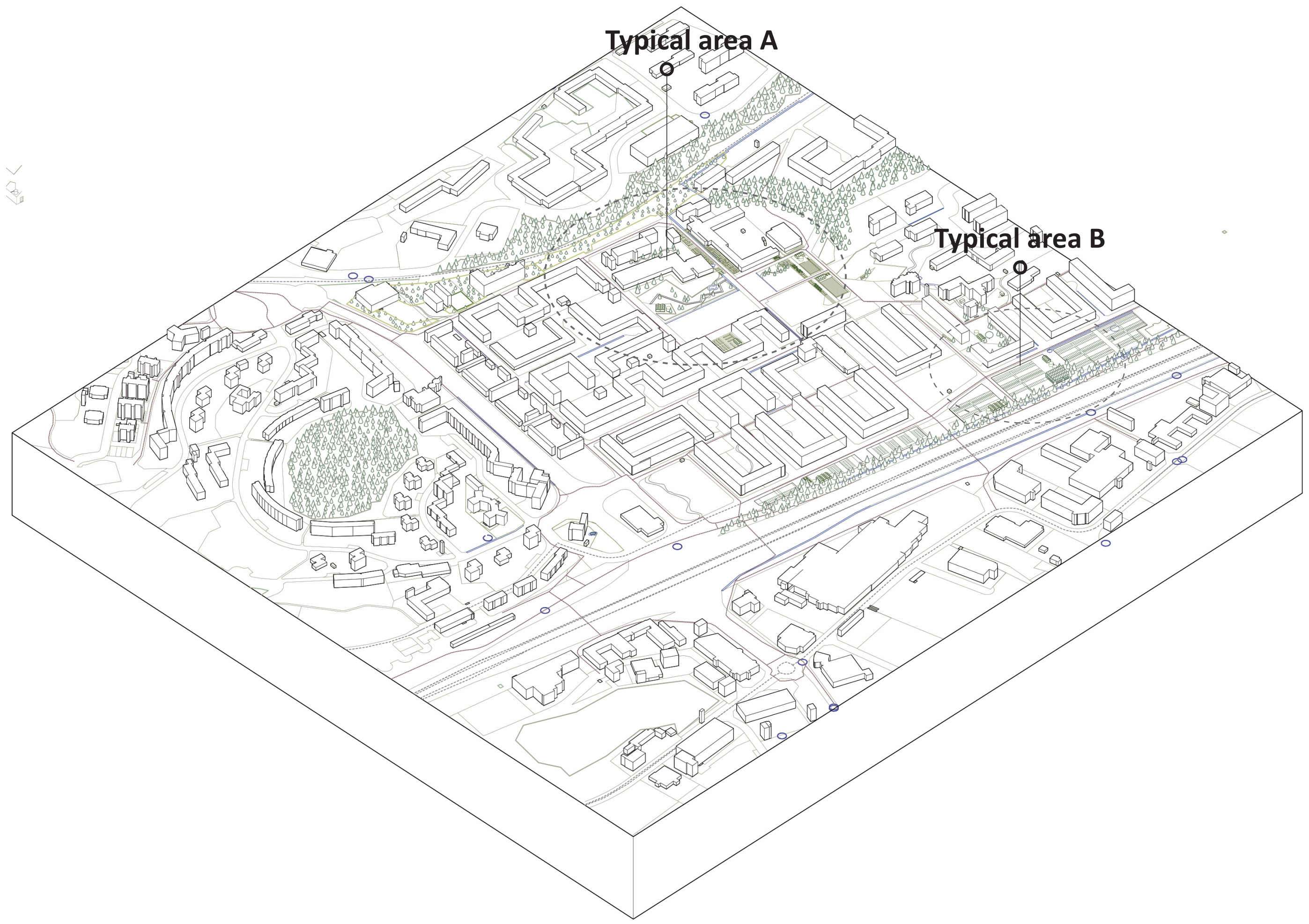
Figure 139: Development plan and the selection of typical area

LEGEND

- public transportation stops
- Transitionpoint from bike paths to green trail
- New bike paths
- Existing bike paths
- bus and tramline
- Footway and paths
- Detention pool with filter buffer (Width>6m)
- Detention pool with grassstrip based buffer
- Park_greenareas_nms
- Forest
- Vegetated urban land
- Food industry area
- Allotments
- Suitable parking lots for district greenhouse
- Suitable area for community garden
- Building baselayer
- Food waste compost facilities (Recycling room based)

6.1.1.Development plan of the zoom-in area

Figure 140: Spatial quality of the zoom in area



6.1.2. Spatial quality of typical area A

Figure 141: Typical area with different types of actors (community garden) based on the location in the

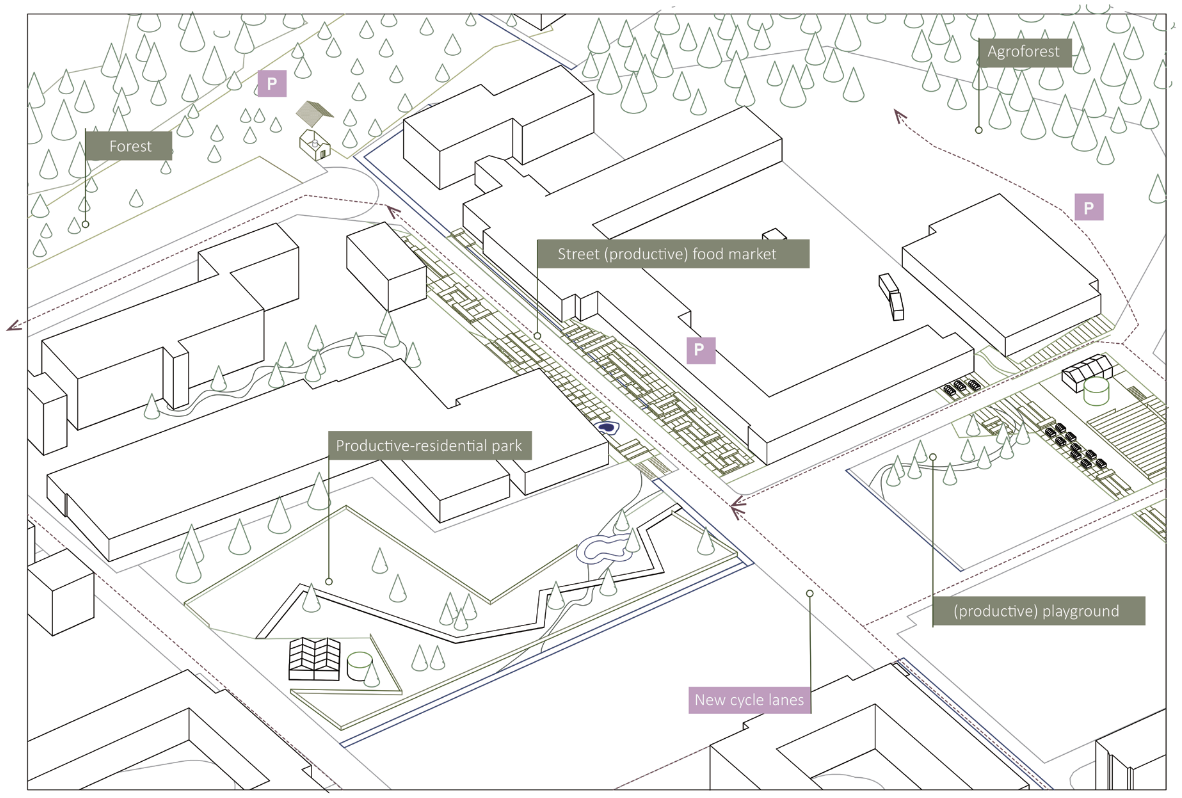
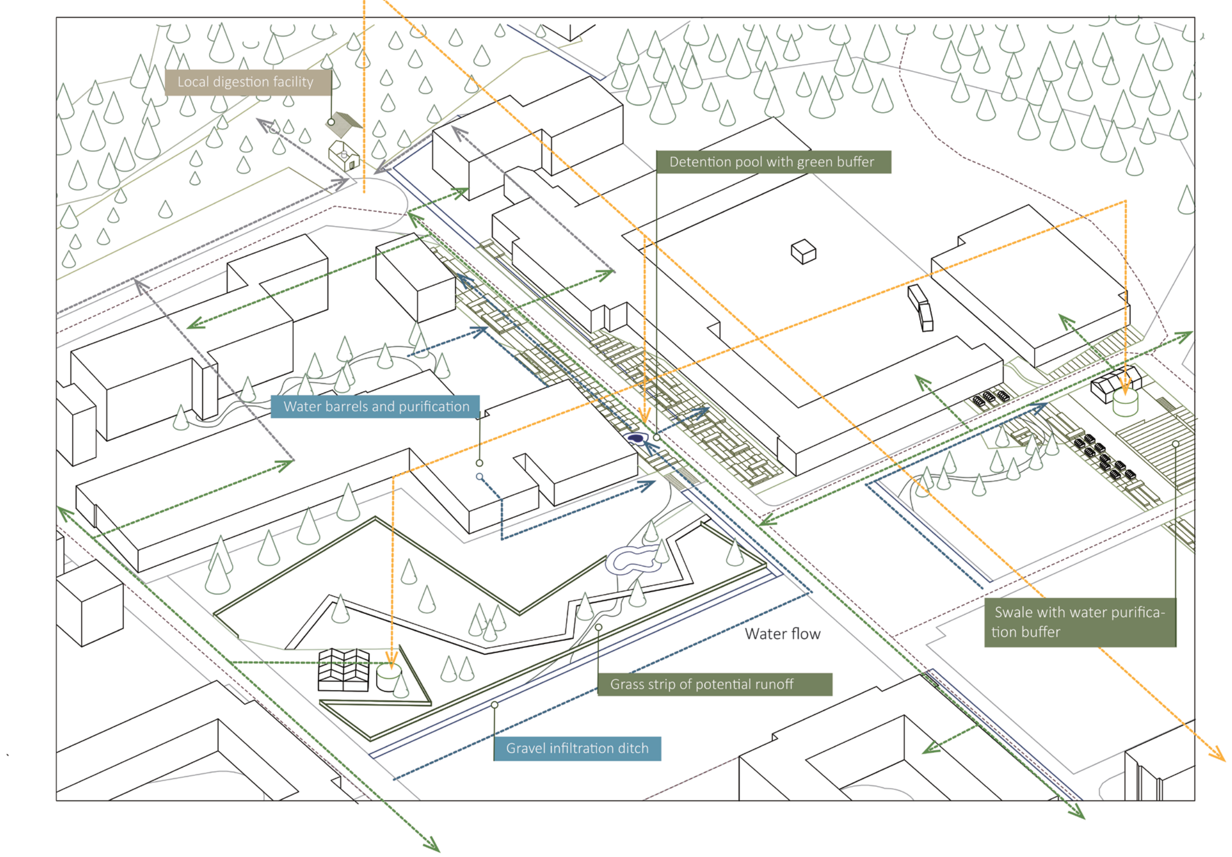


Figure142: Circular food production model and the supporting system of the community garden



Local resource flow
Social flow
Food flow
Food waste flow
Water flow

6.1.3.Spatial quality of typical area B

Figure 143: Spatial quality of actors (district greenhouse)

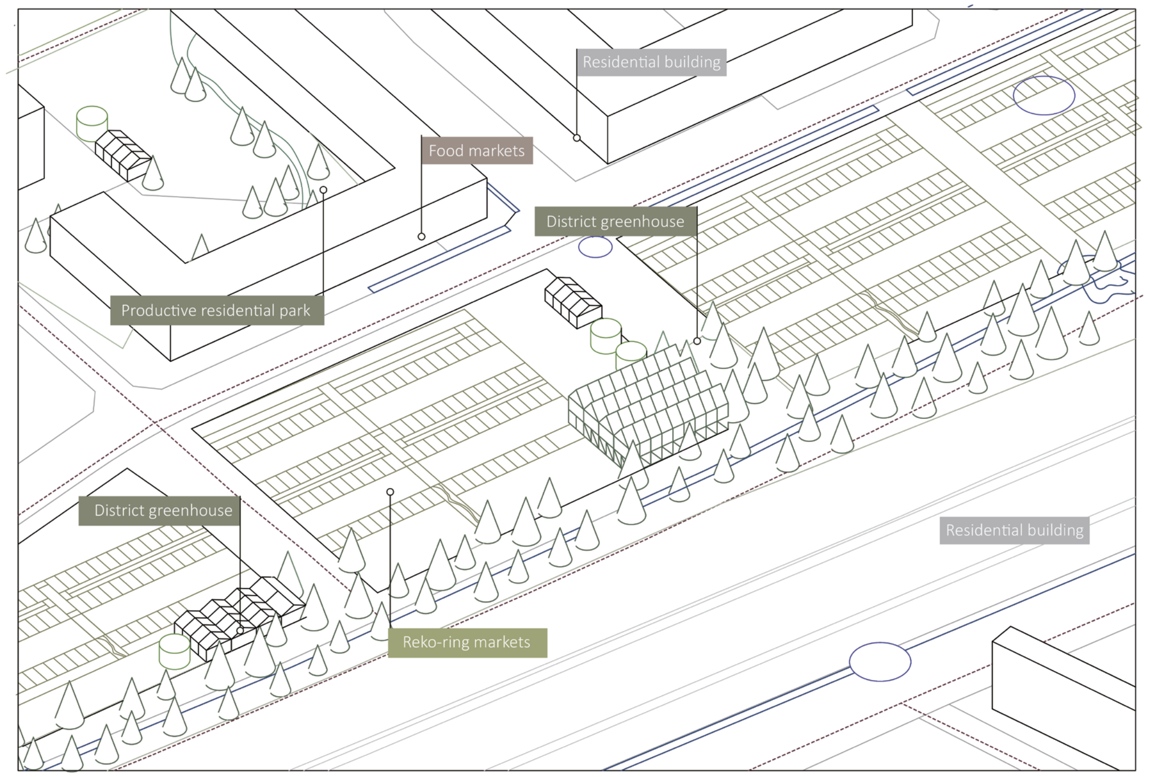
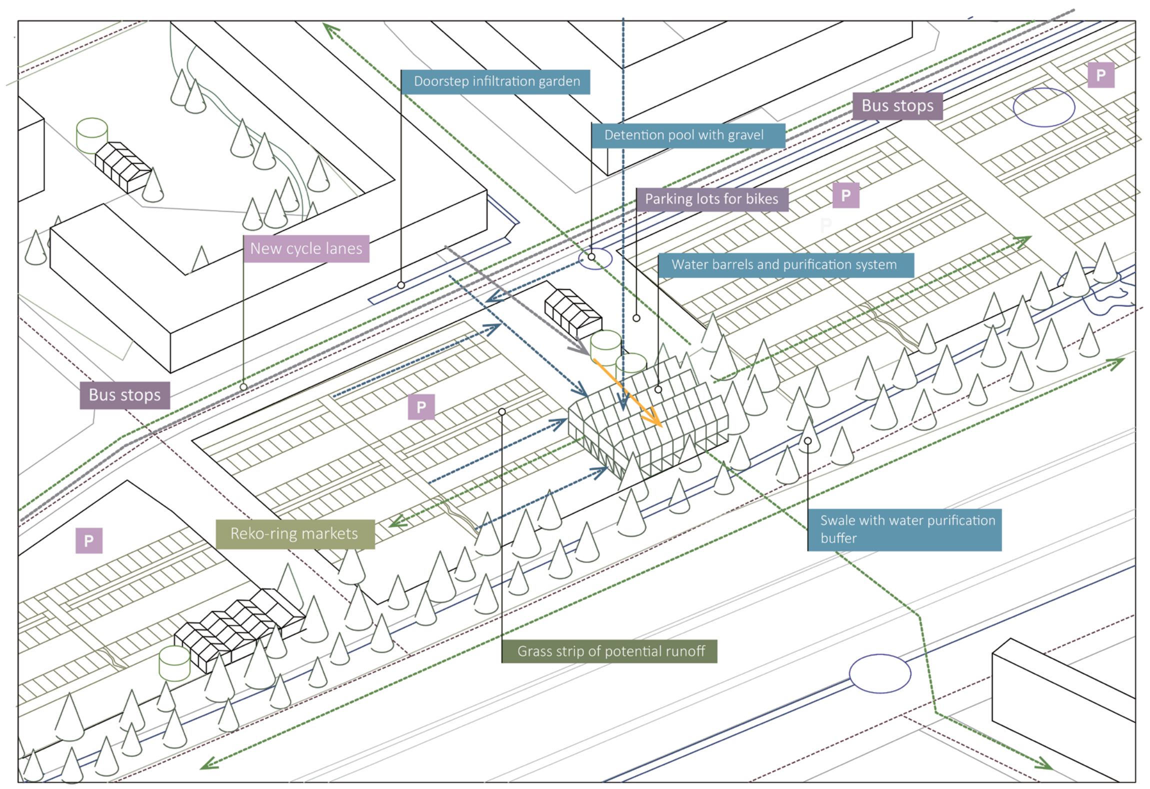


Figure 144: Circular food production model and supporting system of the district greenhouse

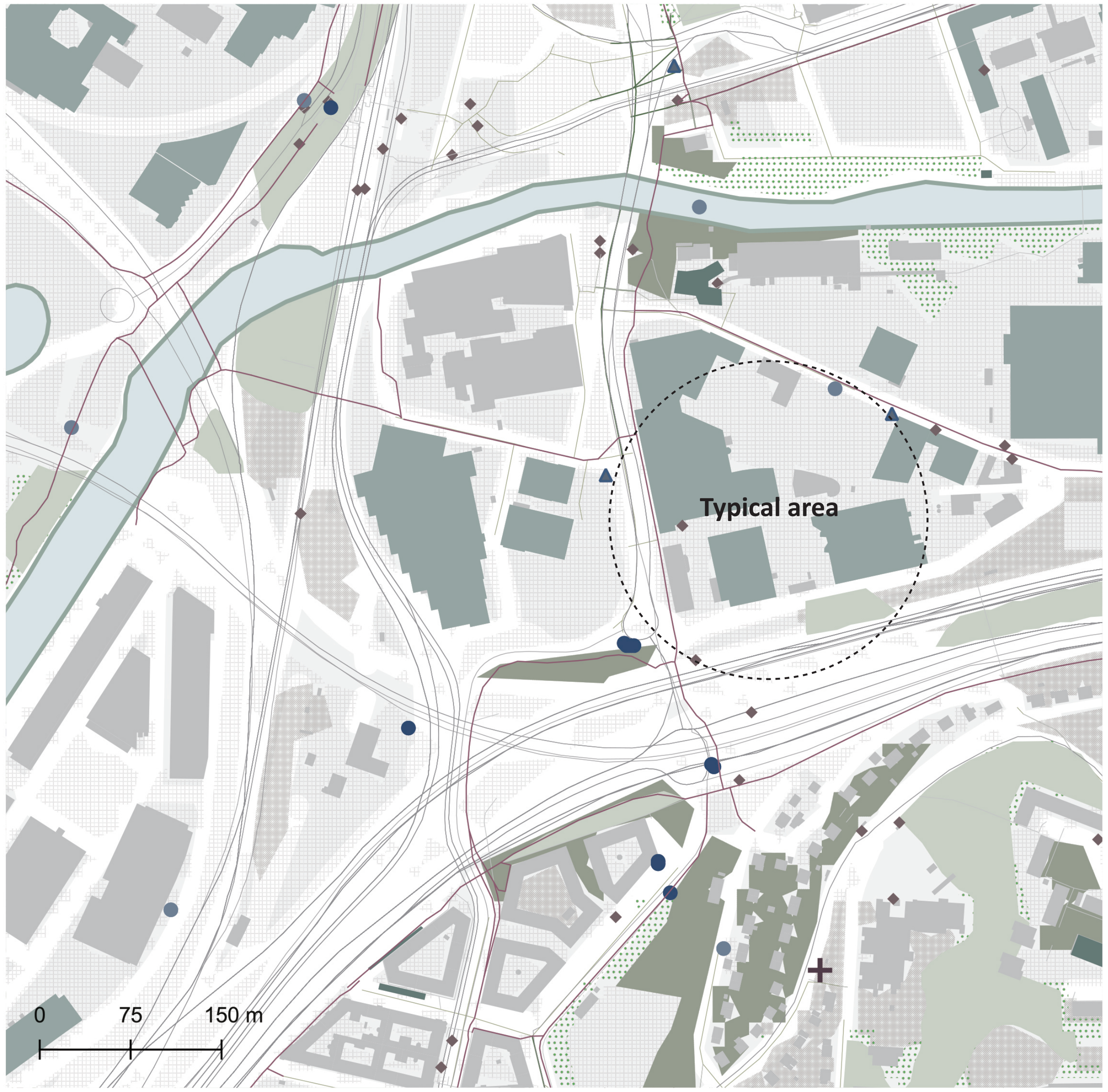


Local resource flow
Social flow
Food flow
Food waste flow
Water flow

6.2.Rooftop fish-vegetable symbiosis farm

6.2.1.Development plan of the zoom-in area (Roof top fish-vegetable symbiosis farm)

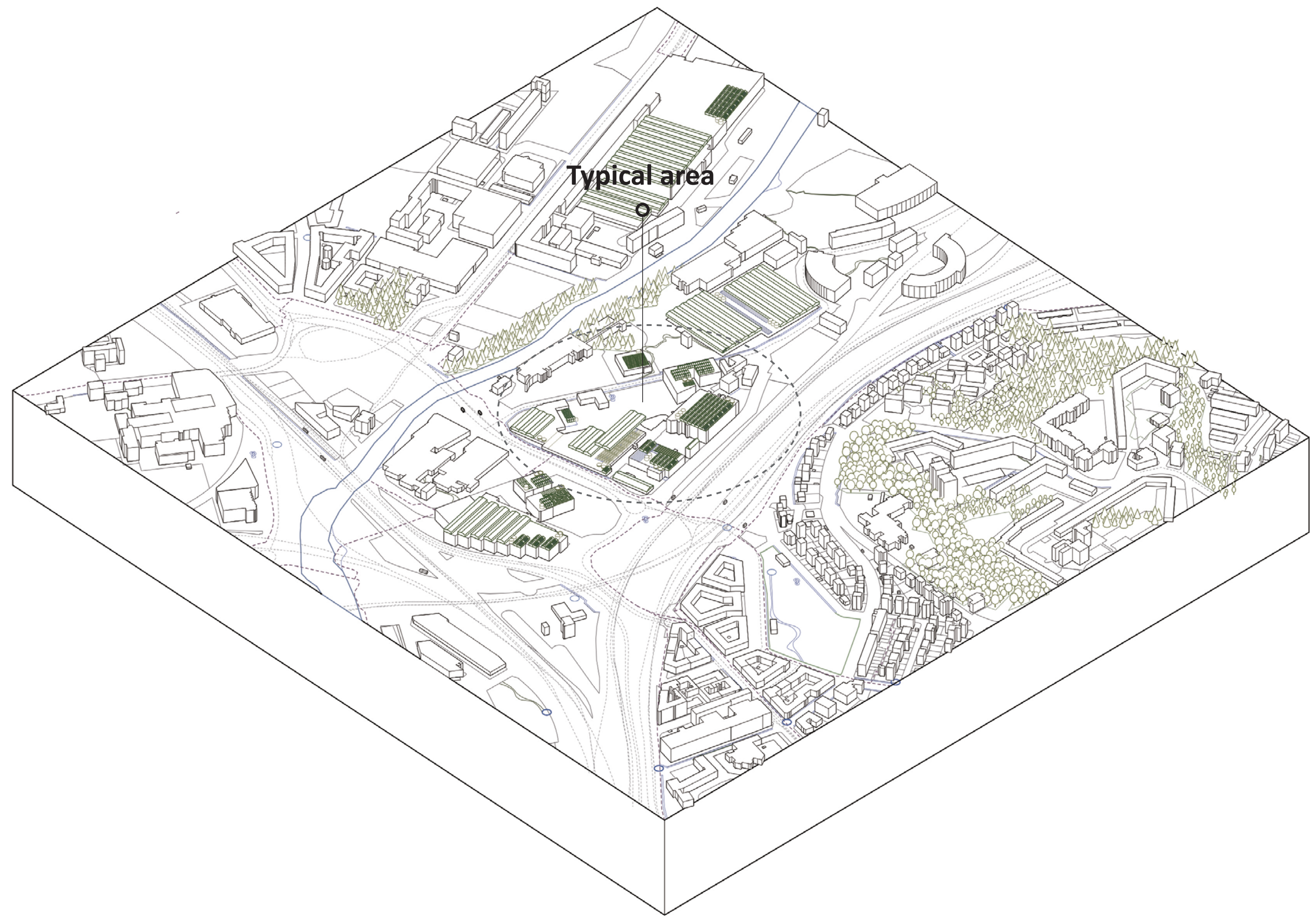
Figure 145. Development plan and the selection of typical area



LEGEND

- public transportation stops
- Transitionpoint from bike paths to green trail
- New bike paths
- Existing bike paths
- bus and tramline
- Footway and paths
- Detention pool with filter buffer (Width>6m)
- Detention pool with grassstrip based buffer
- Artificial surface
- Park_greenareas_nms
- Forest
- Bike parking
- Food waste compost facilities (Recycling room based)
- Food industry area
- Allotments
- Suitable rooftop for fish farm
- Suitable area for community garden
- Building baselayer
- Suitable parking lots for district greenhouse

Figure 146: Spatial quality of the zoom in area



6.2.2. Spatial quality of typical area

Figure 147: Spatial quality of actors (fish-vegetable symbiosis farm)

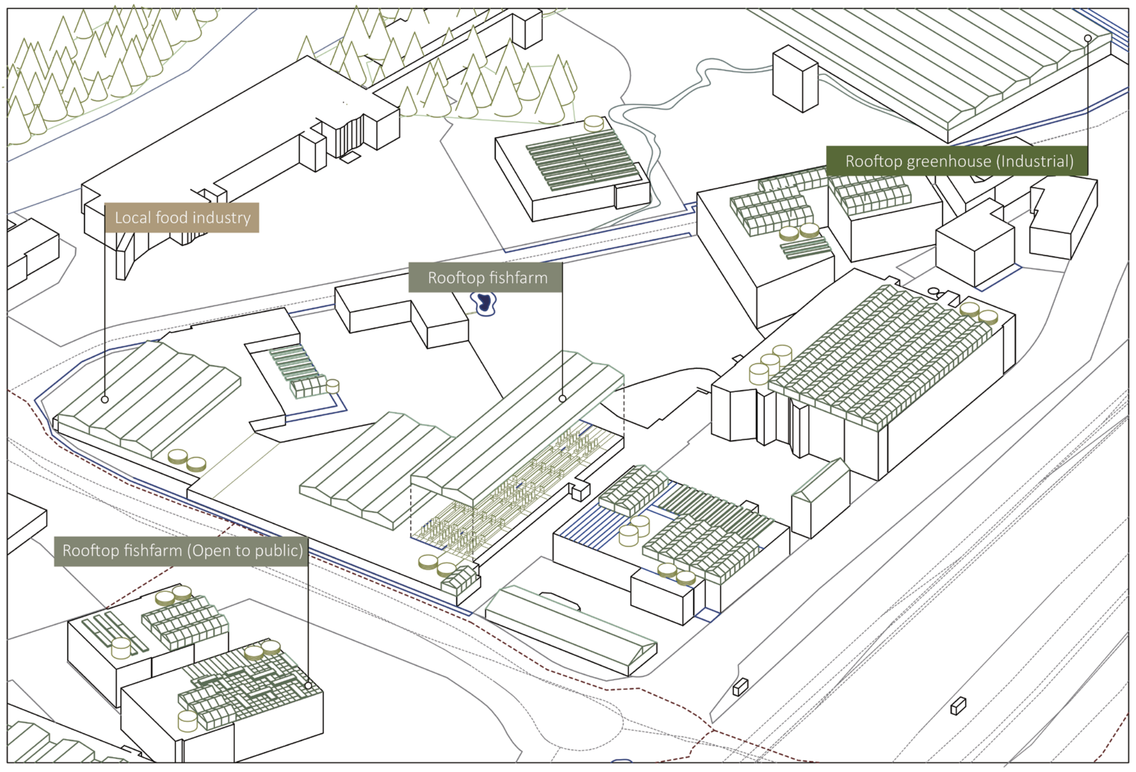


Figure 148 Circular food production model and supporting system of the fish-vegetable

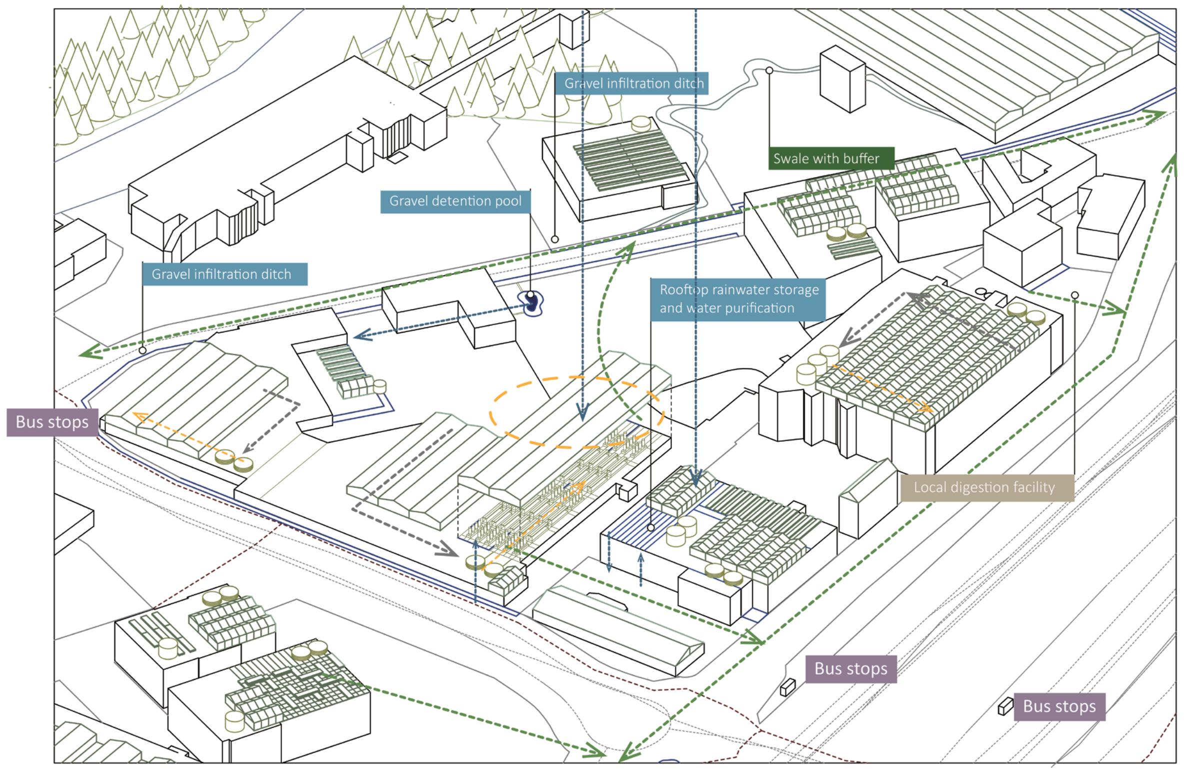


Figure: Selection of zoom in area

Local resource flow
Social flow
Food flow
Food waste flow
Water flow

6.3.Periurban green start up companies

6.3.1.Development plan of the zoom-in area (Suitable land for peri urban start up companies)

Figure 149: Development plan of the zoom in area (suitable land for peri urban start up

Figure: Selection of zoom in area

LEGEND

- public transportation stops
- Transitionpoint from bike paths to green trail
- bus and tramline
- New bike paths
- Existing bike paths
- New footway and paths based on boundary of plots
- Footway and paths
- Detention pool with filter buffer (Width>6m)
- Detention pool with grassstrip based buffer
- Park_greenareas_nms
- Forest
- Suitable land for peri urban green start up companies
- Current arable land (grazing and monoculture)
- Building baselayer
- REKO ring market
- Food waste compost facilities (Recycling room based
- Buffer of potantial runoff corridor(2m-20m)
- Buffer for forest patches near arable land(>6m)
- Buffer for stream(>6m)
- Grass strip (1m)
- Buffer for current river(>6m)
- Plots_Baselayer_10km

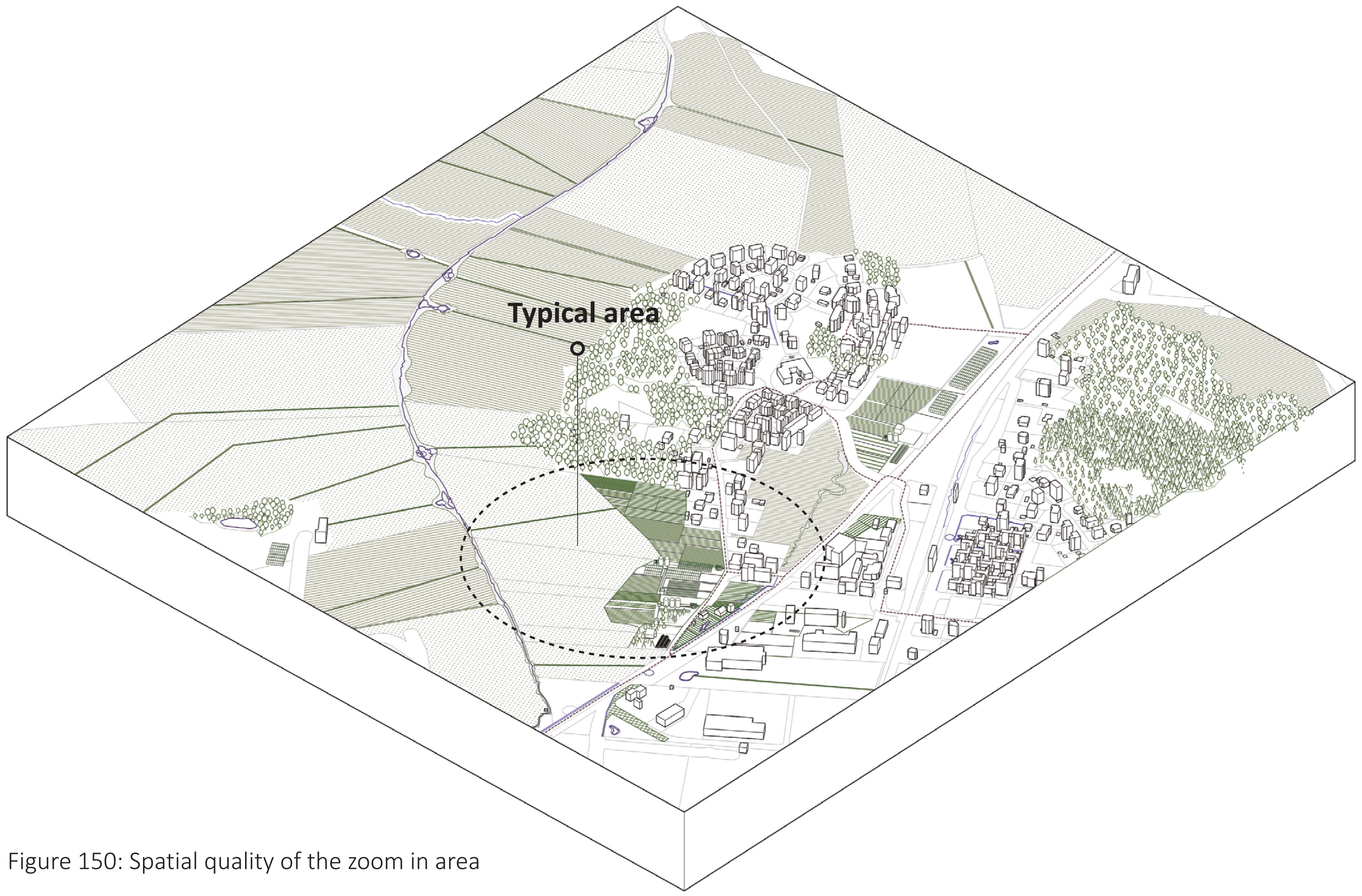


Figure 150: Spatial quality of the zoom in area

6.3.2. Spatial quality of typical area

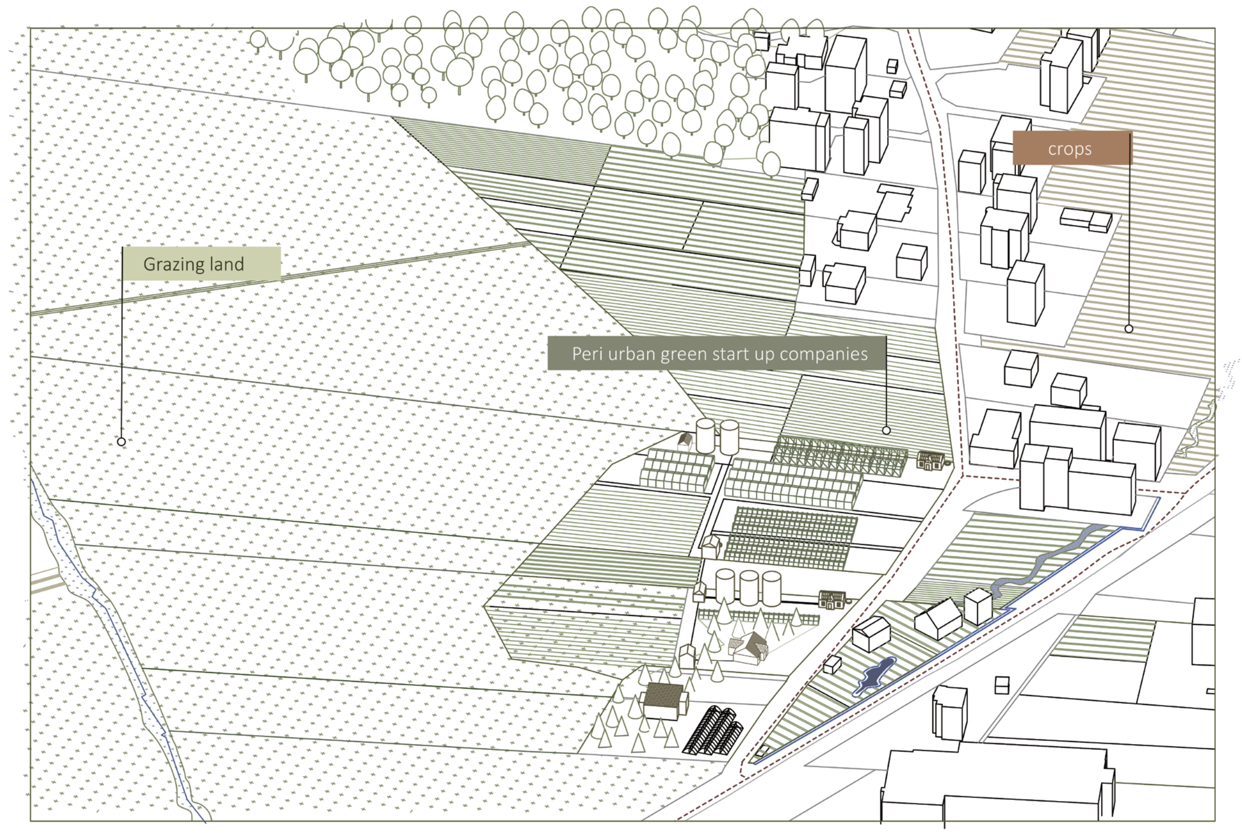
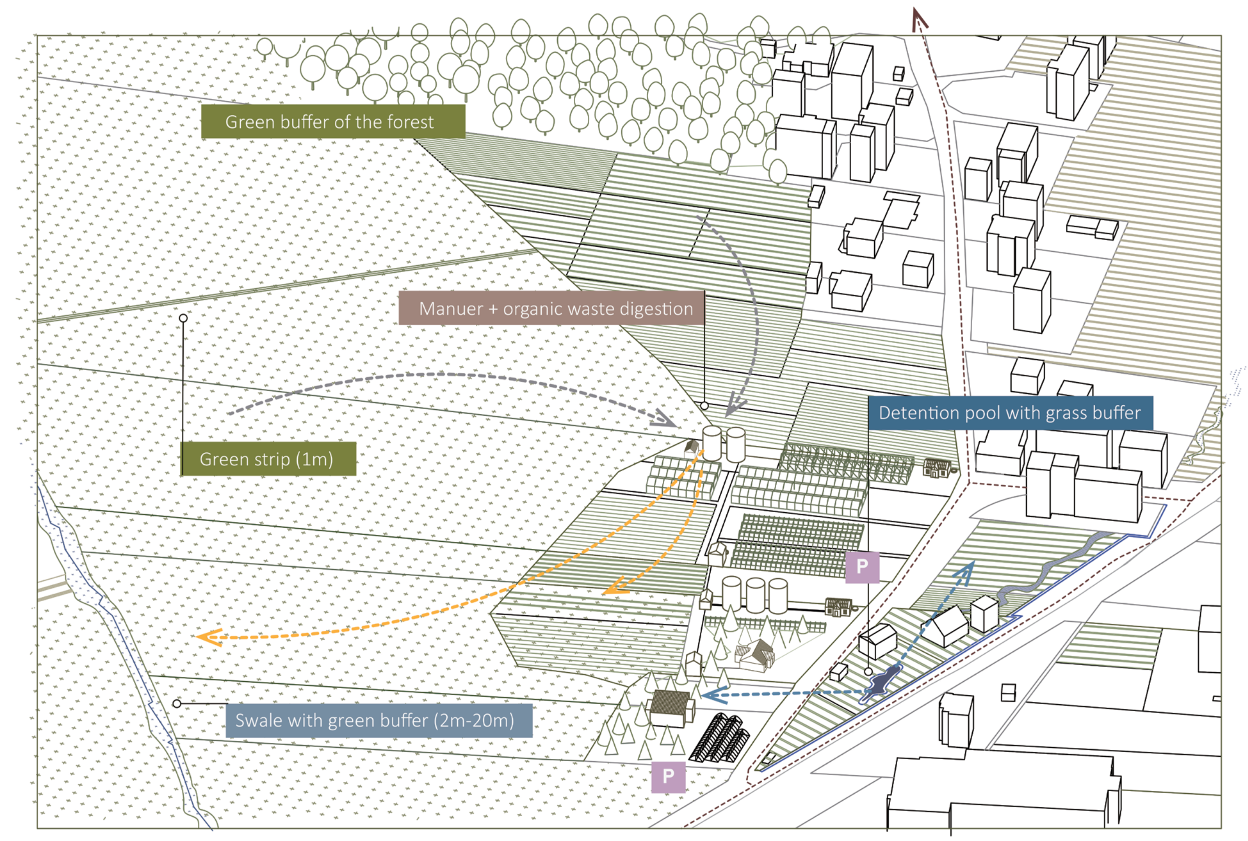


Figure 151: Spatial quality of actors (peri urban start up land and existing grazing land)



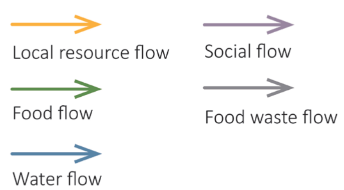


Figure 152: Circular food production model of the peri urban start up land and the supporting system of current grazing&monoculture farm

VII.CONCLUSION & DISCUSSION

7.1. Conclusion of the thesis

7.1.1. Conclusion of the process of planning

Based on the whole planning process of the urban circular food system, in this chapter, the results of the thesis and how the results have answered the guiding questions of the thesis are discussed below.

Firstly, the thesis shows the general process of how to facilitate the circular food system in Gothenburg, the process can be summarized as four main steps. The four main steps are: step1: Investigation of current linear flow model and find the demand between actors in the system(see chapter 2 and chapter 4). Step 2: Speculate and experiment new flow model based on the analysis results (see section 4.3). Step3: Finding criterias for locating different new actors and supporting systems based on the design concepts in 4.3 and relevant production models, policies(see chapter 4.4). Step 4: Using GIS to do scenario planning based on the criterias summarized in 4.4 (see chapter 5), then zoom into a typical area to see how a circular system changes the urban landscape.(see chapter 6).

The most important findings are: From a circular flow's perspective, after bringing new actors into a system, the demand gap may occur between different actors, and the balance strategies can be proposed after comparing the demand gap with the actor's actual demand. Also,In order to plan an efficient urban circular system, it is important to think about the circular production model and business model at different scales before planning. Meanwhile, for locating urban circular food systems, it is important to categorize the spatial indicators into "fixed" and "variable", the fixed indicators can help selecting suitable location, while the "variable" indicators means the relevant facilities for food production can be improved to become a supporting system and the new actors can benefit from the improved system.

Secondly, this thesis explored the methods of " design with flow" specifically. One of the important methods is to experiment the new circular flow by bringing new actors (see section 4.1), and see how the data of the material flow are changed. This method is important in setting new flow models and finding balance strategies (especially at the urban scale). The other important method in flow design is " zoom in and out" (see section 4.4), which means designing and investigating the flow of actors in different scales based on how a food production model can be circular. These methods are important in helping understand the circular flow spatially and can help find criterias for locating actors and supporting systems. In this thesis, the potential food production model of four main types of actors are analyzed and became a stepstone for more precise scenario planning.

7.1.2. How can the final results contribute to the city of Gothenburg?

The final results of the thesis shows that for all of the new actors, there are still potential suitable sites for local food production. There are mainly 3 contributions of this thesis, the first contribution is to provide a general circular food production system for Gothenburg at urban scale (mainly answered about the what is the flow of the new system in the city).

The second contribution is to provide the circular food production model for different food production actors at local scale (mainly answering how to implement the flow & system specifically in urban space).

The third contribution is providing a scenario of a circular food system in Gothenburg.
In all, this work can support the city of GBG to make a more self-sufficient circular food production system, linked to current strategies and initiatives. and the methods of planning can be used by other cities that have similar social and natural conditions.

7.2. Limitations of the study

7.2.1. Limitations of the methods in looking for suitable location for actors

The first limitation of this thesis is about the defining of criterias for selecting suitable food production locations. After finding the locations of suitable food production sites in Gothenburg, it is obvious from the map that the suitable land for farming is imbalanced between different areas. For example: in the north-east of Gothenburg it is hard to get enough food production locations mainly due to the network accessibility, however there are still a lot of residents in that area. As a result, the current way of finding suitable land for food production is still limited and there should be different optimized methods for defining criterias and GIS analysis.

Also, when defining criterias for site selection, it is crucial to think about not only suitable sites for food production, but also how to choose priority areas for executing the circular food production plan. Besides, when one location is suitable for different types of actors, how to choose suitable actors is also important and criterias are required.

7.2.2 .Feasibility study of the implementation of the circular food system

Obviously, the feasibility of the plan is limited. In some of the suitable sites for locating community gardens (for example: in Frolunda and Backadalen), the total land area is covered by the suitable farming area and that means a huge amount of construction work. As a result, the feasibility study of the planning for community gardens is still limited. Also, For rooftop fish farms and peri-urban green start up companies, the property of a specific building and how to achieve a successful symbiosis business model between new actors and factories is an issue.

7.2.3.Is the planned circular model really efficient ?

Firstly, due to time constraints and scope of this thesis. The third limitation is the absence of a method to study the efficiency of the circular food system compared to the existing system. It is important to evaluate the performance of the designed system and find solutions to improve the system. In this thesis, the comparison between the current linear food system and circular food production system are required and there should be indicators to evaluate the system's performance between each other. For example: reduction of food waste, percentage of food demand that local food production can provide and GHG emission from transporting food waste.

Secondly, whether it makes sense or efficient to develop circularity within the boundaries of a city, is still a question, more study should be conducted, for looking into the scale of implementing a circular food system.

7.2.4.Absence of public participation

Due to coronavirus, it is hard to interview and visit some of the actors to get suggestions and information and relevant stakeholders are not engaged directly in the planning process. which is also a limitation in this study.

7.3.Further work

Based on the limitation of the study summarized in 7.2, two main directions of possible further works are discussed below, for finding solutions for bridging the limits in current study.

7.3.1. Public participation platform

According to the analysis results of the study of exemplary projects studied in chapter 2, successful planning projects related to the circular economy are always integrated with public participation. Since the planning of urban circular food production systems is related to public participation. An important prerequisite to public participation means all of the relevant actors from general public and societal actors should be able to gather together to discuss the project (*manyoky. 2011),* that means there should be an efficient platform for showing the planning. For this thesis project, there should also be a platform like a website for showing and discussing circular food production models in different scales, and related actors can provide suggestions to decide where the pilot area should be and how much land should be taken from the results of suitable areas for food production. Nowadays there are many methods in integrating planning with public participation that need further study, for example: Geodesign, which was created by Carl Steintz, has been applied in the planning process of urban scale projects regarding the design of alternative food waste recycling systems. (see section 2.2.2)

7.3.2. Key performance indicators (KPIs)

In order to assess whether the planning of the urban circular food system is feasible and efficient, it is crucial to evaluate the performances of the system. After the urban circular food system is planned, finding KPIs (key performance indicators) can be useful in evaluating the performances of the scenario and can compare the performances of different scenarios. KPIs refer to a set of quantifiable measurements used that can evaluate a system's or a new circular economy model's long-term performance. It can also specifically help determine the achievements of the circulatory system especially compared to existing linear systems by comparing specific indicators in linear and circular systems. *(Twin,James,2020).*

In this thesis, the KPIs can be used to compare the performances between the existing linear food waste recycling model and the urban circular food production model, by comparing indicators mentioned in 7.2.3. Meanwhile, the KPIs can at the same time help calculate whether the urban circular food system can meet the goal of the waste management plan of Gothenburg region, (see section 1.3.2).

URBAN (CIRCULAR) FOOD SYSTEM

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APPENDIX

Table 7: TOOLBOX (District greenhouse)
Criterias for site selection and supporting system

Functions in scenario planning	Solutions	Analyzing methods	Data for analysis	Data sources	Parameters	Tools for analyzing	Catogories of the solutions
Criterias for locating new actors	Accessible in urban scale (For logistic)	1.Angular integration (20k) 2.Clip	1.Motorised network 2.Building base layer	1.OSM 2.SMoG(Spatial morphology group of Chalmers)	20000m	QGIS/PST	Accessibility
	Accessibility to public transportation	1.Attraction reach to puctic transportation stops 2.Select	1.Motorised network 2.Public transportation stops 3.Selected building base layer	1.OSM 2.SMoG(Spatial morphology group of Chalmers)	Based on the analysis results	QGIS/PST	
	Adjacent to traffic line	1.Buffer 2,Select	1.Motorised network 2.Selected building base layer	1.SMoG(Spatial morphology group of Chalmers)	30m	QGIS/ArcMAP	Relationship to infrastructures
	Flat rooftop(>1000m2)	1.Select features using an expression	1.Selected building base layer	1.OSM	1000m2	QGIS	
Supporting system for new actors	Reusing water from the rooftop and surrounding	(Based on the suitable rooftops)	1.Selected building base layer	1.OSM	Based on the analysis results	Arcmap	Blue system
	Infrastructures like bike parking areas or electric car charges .	1.Toggle editing 2.Add point features	1.Current parking area	1.OSM	Based on the analysis results	QGIS	Transportation system
	Proximity to the cycling or walking infrastructures.	(Based on the new cycling lines and walking paths)	1.Cycling line 2.Walking paths	1.OSM	0m	QGIS	
	Implementing Integrated heating systems	(Based on the suitable rooftops)	1.Selected building base layer	1.OSM	Based on the analysis results	QGIS	Supporting infrastructures
	Using wind, solar and biogas facilities	(Based on the suitable rooftops)	1.Selected building base layer	1.OSM	Based on the analysis results	QGIS	
	Water storaging and purification facilities	1.Hydrological analysis	1.Selected building base layer	1.OSM	Based on the analysis results	QGIS/ArcMAP	

Table 8: TOOLBOX (Rooftop fishfarm)
Criterias for site selection and supporting system
(See appendix)

Functions in scenario planning	Solutions	Analyzing methods	Data for analysis	Data sources	Parameters	Tools for analyzing	Catogories of the solutions
Criterias for locating new actors	Accessible to residents by bike (District scale)	1.Angular integration (1km) 2.Clip	1.Motorised network 2.Parking lots	1.OSM 2.SMoG(Spatial morphology group of Chalmers)	1000m	QGIS/PST	Accessibility
	Accessibility to public transportation	1.Attraction reach to puctic transportation stops 2.Clip	1.Public trabnsportation stops 2.Selected parking lots 3.Motorised network	1.OSM 2.SMoG(Spatial morphology group of Chalmers)	Based on the analysis results	QGIS/PST	
	Adjacent to traffic line	1.Buffer 2,Select	1.Motorised network 2.Selected parking lots	1.OSM 2.SMoG(Spatial morphology group of Chalmers)	30m	QGIS/ArcMAP	Relationship to infrastructures
	Parking lot (Surface type)	1.Select features using an expression	1.Selected parking lots	1.OSM	Surface type	QGIS	
Supporting system for new actors	Reusing water from the rooftop and surrounding	(Based on the suitable parking area)	1.Selected parking lots	1.OSM	Based on the analysis results	QGIS	Blue system
	Renovation of car parking for reusing the rainwater	(Based on the suitable parking area)	1.Selected parking lots	1.OSM	Based on the analysis results	QGIS	
	Infrastructures like bike parking area or electric car charges.	1.Toggle editing 2.Add point features	1.Selected parking lots 2.Parking lots for bikes	1.OSM	Based on the analysis results	QGIS	Transportation system
	More parking lot based "REKO"ring markets.	(Based on the suitable parking area)	1.Selected parking lots	1.OSM	Based on the analysis results	QGIS	
	Adjacent to cycling or walking infeastructures	(Based on the new cycling lines and walking paths)	1.Selected parking lots 2.Cycling lines 3.Walking paths	1.OSM	0m	QGIS	
	Space for logistic	(Based on the suitable parking area)	1.Selected parking lots	1.OSM	Based on the analysis results	QGIS	
	Implementing Integrated heating systems	(Based on the suitable parking area)	1.Selected parking lots	1.OSM	Based on the analysis results	QGIS	Supporting facilities
	Using wind, solar and biogas facilities	(Based on the suitable parking area)	1.Selected parking lots	1.OSM	Based on the analysis results	QGIS	
	Aerobatic digestion facilities	(Based on the suitable parking area)	1.Selected parking lots	1.OSM	Based on the analysis results	QGIS	
	Water storaging and purification facilities	1.Hydrological analysis	1.Selected parking lots	1.OSM	Based on the analysis results	QGIS/ArcMAP	

Table 9: TOOLBOX (Peri-urban green start up companies)
Criterias for site selection and supporting system

Functions in scenario planning	Solutions	Analyzing methods	Data for analysis	Data sources	Parameters	Tools for analyzing	Catogories of the solutions
Criterias for locating new actors	Accessible in urban scale (For logistic)	1.Angular integration (20k) 2.Erase 3.Select	1.Motorised network 2.Plots base layer 3.Forest 4.Public parks 5.Building baselayer	1.OSM 2.SMoG(Spatial morphology group of Chalmers)	20000m	QGIS/PST/ArcMAP	Accessibility
	Accessibility to public transportation	1.Attraction reach to puctic transportation stops 2.Erase 3.Select	1.Public transportation stops 2.Motorised network 3.Selected plots	1.OSM 2.SMoG(Spatial morphology group of Chalmers)	Based on the analysis results	QGIS/PST/ArcMAP	
	Adjacent to traffic line	1.Buffer 2,Select	1.Motorised network 2.Selected plots	1.OSM 2.SMoG(Spatial morphology group of Chalmers)	30m	QGIS	Relationship to infrastructures
	Adjacent to exsiting farmland	1.Erase	1 Selected plots 2.Arable land	1.OSM	0m	QGIS	
	Soil condition	1.Select features using an expression	1.Soil map	1.Chalmers Geodatabase	Silt	ArcMAP	Natural conditions
	Proximity to the water source	1.Hydrological analysis 2.Buffer 3,Clip	1,DEM 2,Selected plots	1.Chalmers Geodatabase 2.OSM	30m	QGIS/ArcMAP	
Supporting system for new actors	Rainwater irrigation based on the swale system	1.Hydrological analysis	1.DEM	1.Chalmers Geodatabase	Based on the analysis results	ArcMAP	Blue system
	Rainwater irrigation based on the wadi and detention pool.	1.Hydrological analysis	1.DEM	1.Chalmers Geodatabase	Based on the analysis results	ArcMAP	
	1m width strip based on the runoff for the retention of nutrients.	1.Buffer	1.Results of hydrological analysis	1.Chalmers Geodatabase	1m	QGIS	
	Functional buffer zones along natural forest,patches.	1.Buffer	1.Results of hydrological analysis	1.Chalmers Geodatabase	6m	QGIS	Green system
	Buffer strips along the water surface	1.Buffer	1.Results of hydrological analysis	1.Chalmers Geodatabase	>4m	QGIS	
	Grass shrub strips buffer along the stream corridor	1.Buffer	1.Results of hydrological analysis	1.Chalmers Geodatabase	2m-20m	QGIS	
	infrastructures like bike parking area or electric car charges.	1.Toggle editing 2.Add point features	1.Parking lots 2.Parking lots for bikes	1.OSM	Based on the analysis results	QGIS	Transportation system
	Proximity to cycling or walking infrastructures	(Based on the new cycling lines and walking paths)	1.Cycling line 2.Walking paths	1.OSM	0m	QGIS	
	Space for logistic	(Based on the suitable parking area)	1.Parking lots	1.OSM	Based on the analysis results	QGIS	
	Using wind, solar and biogas facilities	(Based on the suitable green start-up area)	1.Selected plots	1.OSM	Based on the analysis results	QGIS	Supporting facilities
	Aerobatic digestion facilities connecting with district heating grid	(Based on the suitable green start-up area)	1.Selected plots	1.OSM	Based on the analysis results	QGIS	
	Water storaging and purification facilities	1.Hydrological analysis	1.Results of hydrological analysis	1.Chalmers Geodatabase	Based on the analysis results	QGIS/ArcMAP	

Table 10: Analysis of food demand, land demand and nutrition demand for self sufficiency in 2030

1.
Estimation of food demand of Gothenburg in 2030+ Area for food production

Consumption of each types of crops	kg/person/year	Demand2030	yield,kg/ha	Area2030(average)	Area(low biointensive methods)	AreaMedium biointensive methods	Area(Current Situation)
Wheat flour	6.6	4365952.8	6080	718.0843421			183
Rye flour	0.1	66150.8	6510	10.16141321			
Oatmeal and other cereals	3.9	2579881.2	4960	520.1373387			216
Flour of mixtures of wheat and rye and flour of other cereals	0.3	198452.4	3384	58.64432624			3
Total flour and ground	17.4	11510239.2		**1307.02742**			**492**
potato	46.5	30760122	36200	**849.7271271**			**3**
Carrots	9.6	6350476.8	61300	103.5966852	88.54417535	51.79834258	
Cucumbers(green house)	6.2	4101349.6	443300	9.25186014	7.907572769	4.62593007	
onion	8.1	5358214.8	46300	115.7281814	98.91297558	57.86409071	
salad	14.7	9724167.6	19700	493.6125685	421.8910842	246.8062843	
Cabbage, red cabbage, Brussels sprouts, kale, broccoli	4.7	3109087.6	27400	113.4703504	96.98320544	56.73517518	
other kitchen plants	7.4	4895159.2	33700	145.2569496	124.1512389	72.62847478	
leek	0.8	529206.4	30200	17.52339073	14.97725703	8.761695364	
Cauliflower	1.5	992262	17300	57.35618497	49.02238032	28.67809249	
other root plants	1.6	1058412.8	34100	31.03849853	26.52863123	15.51924927	
tomato(greenhouse)	9	5953572	396500	15.015314	12.83360171	7.507656999	
Total vegetable	63.6	42071908.8		**1101.849983**	**941.7521226**	**550.9249917**	**≈30**

2.
Summary of land area demand based on demand of food and methods of growing

	LAND DEMAND(2030MAX)	LAND DEMAND(2030)	LAND DEMAND(2030MIN)	CURRENT AREA
FLOUR/CEREAL PRODUCT	1307ha	1307ha	1307ha	492ha
VEGETABLE PRODUCT	1101ha	942ha	551ha	≈30ha
POTATOES PRODUCT	849ha	849ha	849ha	3ha

3.
Estimation of nutrition demand based on land area, species and types of fertilizer

Crops Type （N）	Mineral fertilizers	Plant-available nitrogen(manual)	Total nitrogen(manuel)	demand(max)mineral/manuel	demand mineral/manuel	demand（min)mineral/manuel
cereals product	107	10	28	13070/36596kg	13070/36596kg	13070/36596kg
vegetables product	51	9	27	56151/29727kg	48042/25434kg	28101/14877kg
potatoes product	96	5	11	81504/9339kg	81504/9339kg	81504/9339kg
Crops Type （P）	**Mineral**		**Manuel**	**demand(max)**	**demand**	**demand(min)**
cereals product	12		7	15684/9149	15684/9149	15684/9149
vegetables product	10		7	11010/7707	9420/6594	5510/3857
potatoes product	38		3	32262/2547	32262/2547	32262/2547
Crops Type （K）	**Mineral**		**Manuel**	**demand(max)**	**demand**	**demand(min)**
cereals product	15		28	19605/36596	19605/36596	19605/36596
vegetables product	26		29	28626/31929	24492/27318	14326/15979
potatoes product	192		8	163008/6792	163008/6792	163008/6792

4.
Summary of nutrients demand and land area based on Gothenburg's food demand

	AREA2030(mineral/manuel) max/kg	AREA2030(mineral/manuel)/kg	AREA2030(mineral/manuel)min/kg	CURRENT (mineral/manuel) /kg
N DEMAND(total)	150725/75662	142616/71369	122675/60812	54569/14647
P DEMAND(total)	58956/19403	57366/18290	53456/15553	6330/3670
K DEMAND(total)	211239/75317	207105/70706	196939/59367	8751/14698
AREA DEMAND FOR GROWING	**3257ha**	**3098ha**	**2707ha**	**≈526ha**

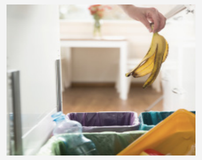
*Data source
The data for calculation here are collected from Swdish agriculture board and SCB.

URBAN (CIRCULAR) FOOD SYSTEM

Table 11: Analysis of the demand gap between actors after expanding local food production

URBAN (CIRCULAR) FOOD SYSTEM

FOODWASTE INPUT ACTORS



Household foodwaste

Industrial foodwaste

Waste Plan in 2030

Total foodwaste:25799t/yr
(18661t less than 2020)

Foodwaste for **biotreatment**:18059t/yr
(4171t less than 2020)

Foodwaste →

FOODWASTE PROCESSING ACTORS

a.Renova pre-tre

Pre-treatment facility

c.ST1 Biore

ST1 bio-refinery

b.Gryaab Sewag

Gryaab sewage plant

d.Göteborg E

CHP plants of Gothenburg

Actor's production demand (Heating)

Renewable + Heat recovery: 100% in 2025
(11% more production than 2020)

Actor's production demand (Electric)

Renewable power: 100% in 2040
(29% more production than 2020)

Actor's (ST1) demand for foodwaste input

Expected Industrial foodwaste for production: 21000t
(13800t more input than 2020)

Energy →

Nutrients →

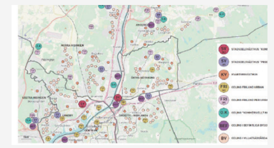
RESOUECE-OUTPUT ACTORS

Current user a.Peri-urban Agriculture

Peri-urban agriculture

Current user b.Biofuel stations

Biofuel station



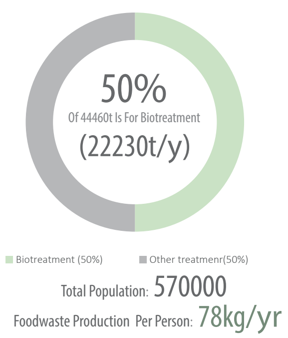
Potential user:.Stadslandet Göteborg

Future's actors

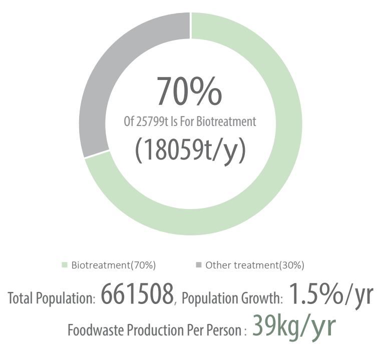
Demand of **nutrients** for growing regional food in 2030 (population:661508) kg/ha

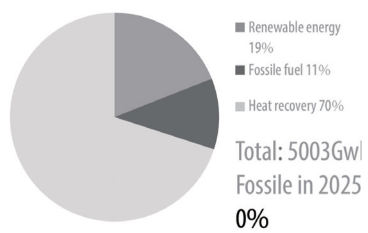
Average demand for N: 142616(mineral);71369(mamual)
Average demand for P: 57366(mineral);18290(manual)
Average demand for K: 207105(mineral);70706(manual)
(N=Nitrogen;P=Phosphorus;K=Potassium)

Foodwaste for Biotreatment (2020)

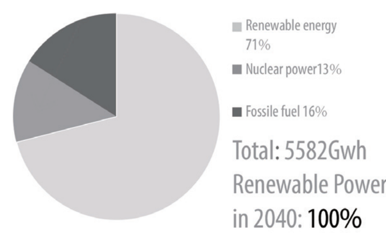


Foodwaste for Biotreatment(2030)





Composition of Gothenburg's district heating



Composition of total electricity sales

Population in 2030: **661508** (1.5% incerease every year)

Estimation of total vegetable consumption in 2030 based on population : **42071908.8kg**

Estimation of total potatoes consumption in 2030 based on population : **30760122kg**

Estimation of total flour/cereal consumption in 2030 based on population : **11510239.2kg**

URBAN (CIRCULAR) FOOD SYSTEM

Figure 153: Suitable land for community garden

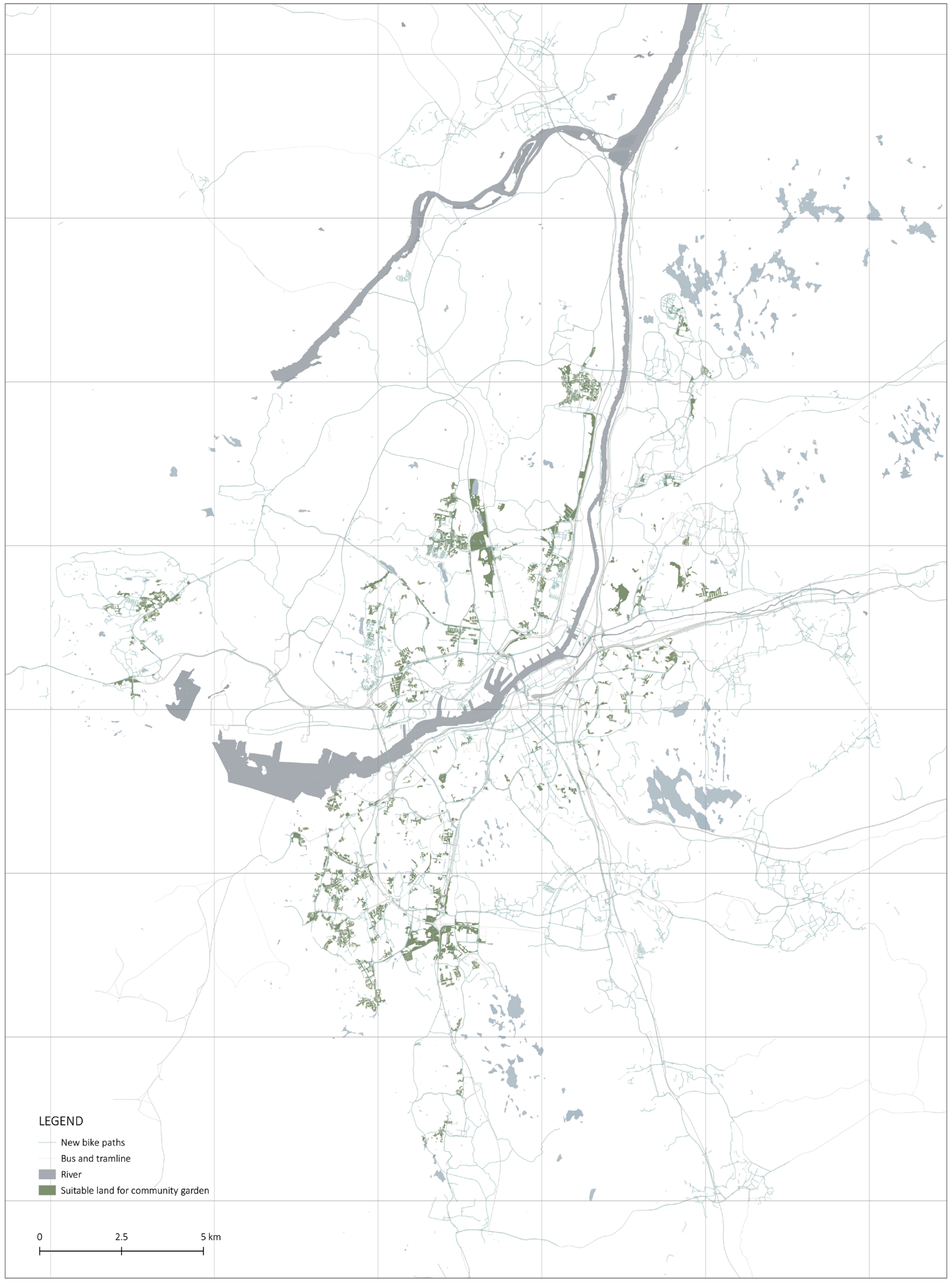


Figure 154: Suitable land for rooftop fish farms

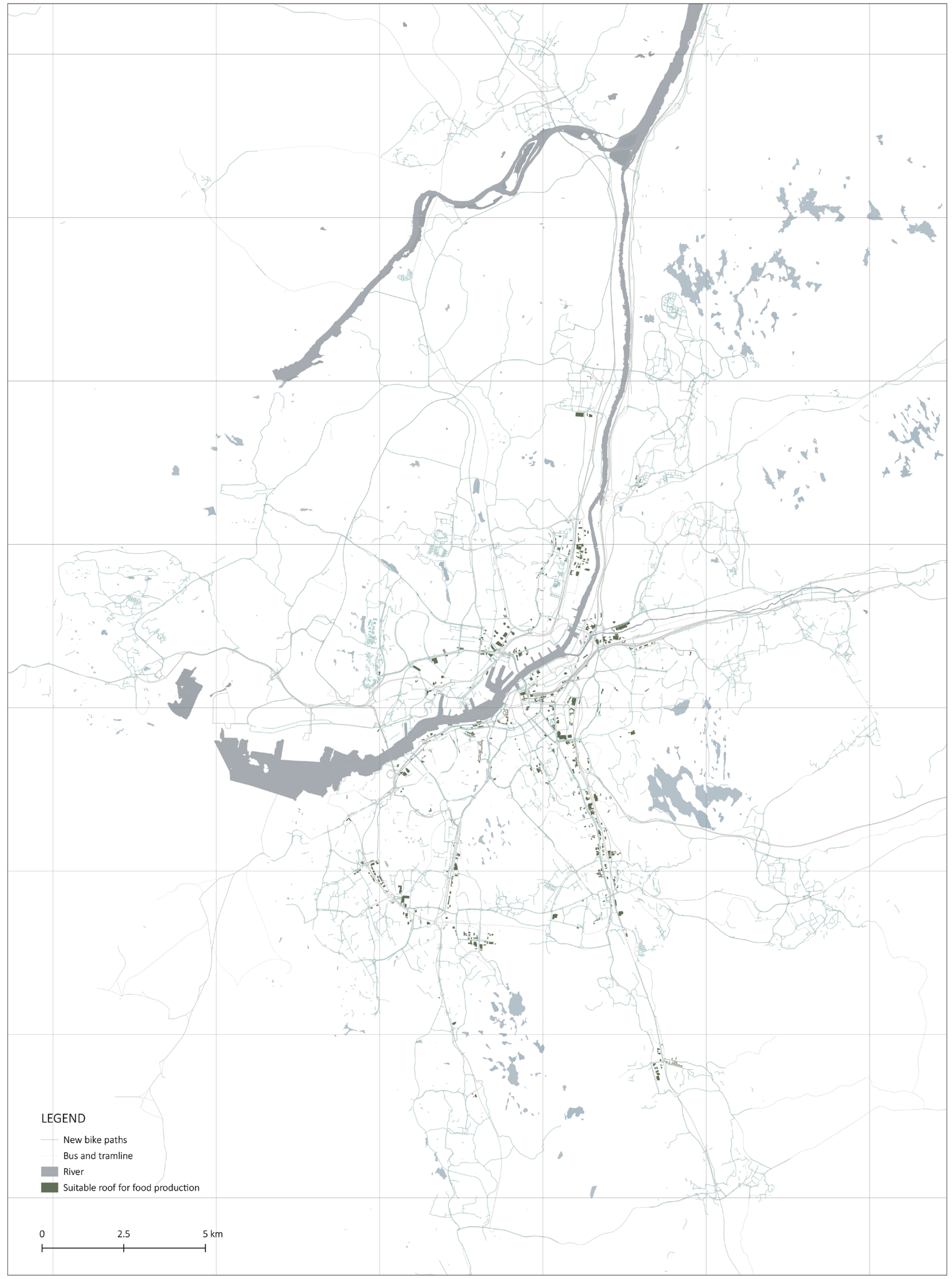


Figure 155: Suitable land for district greenhouses

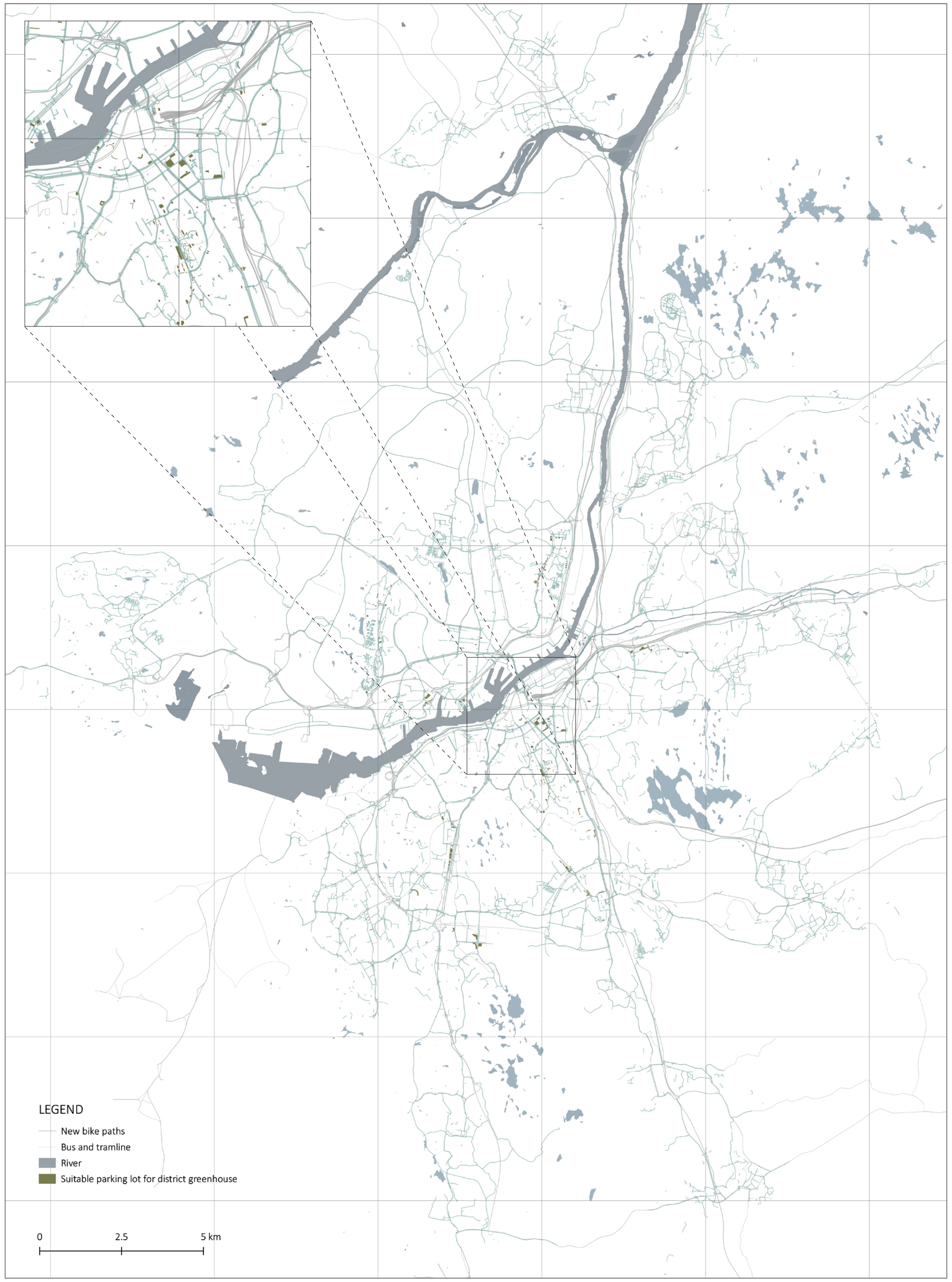


Figure 156: Suitable land for Peri-urban green start-up companies

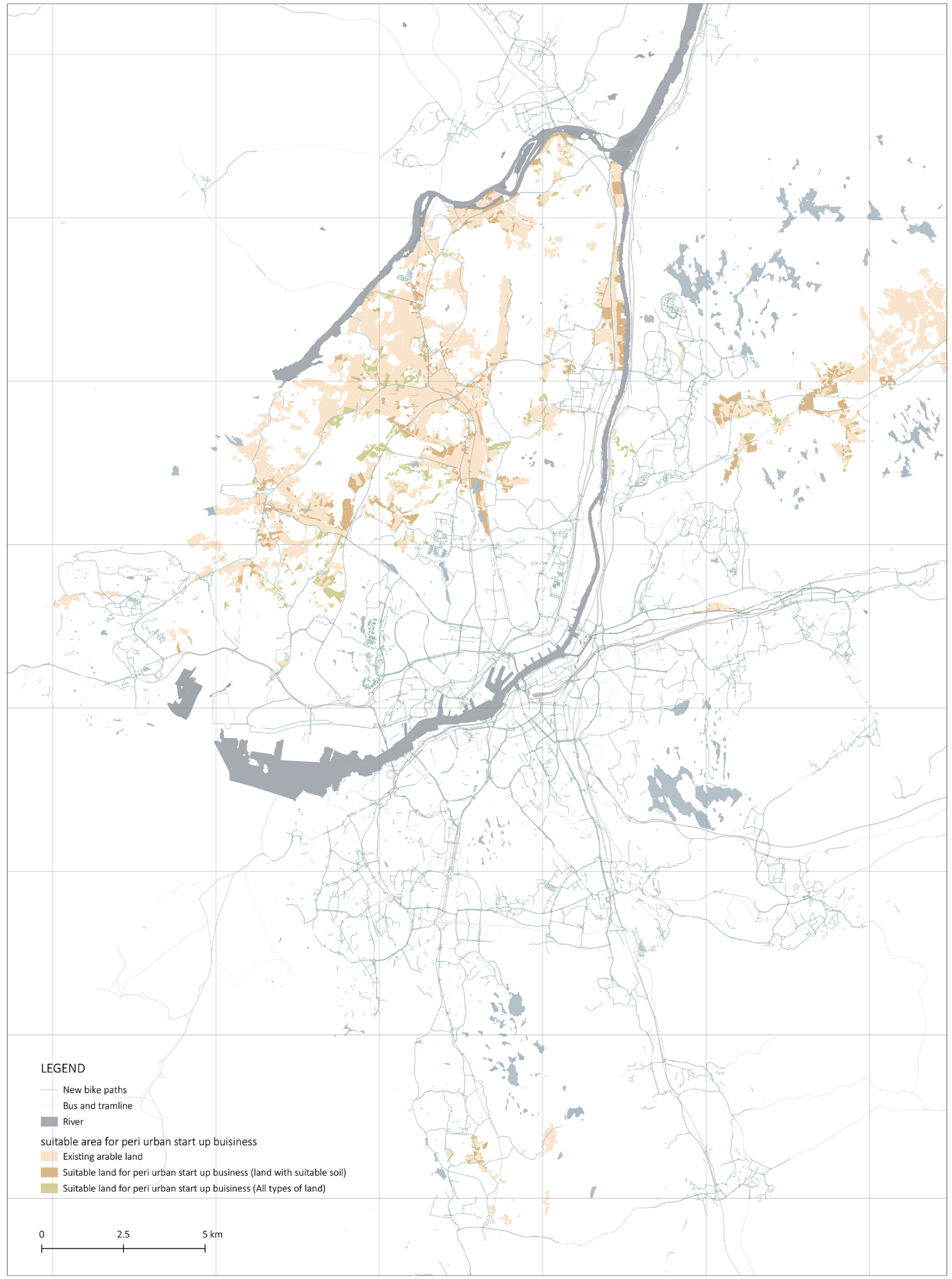


Figure 157: Supporting system1-(Vision of future's blue system)

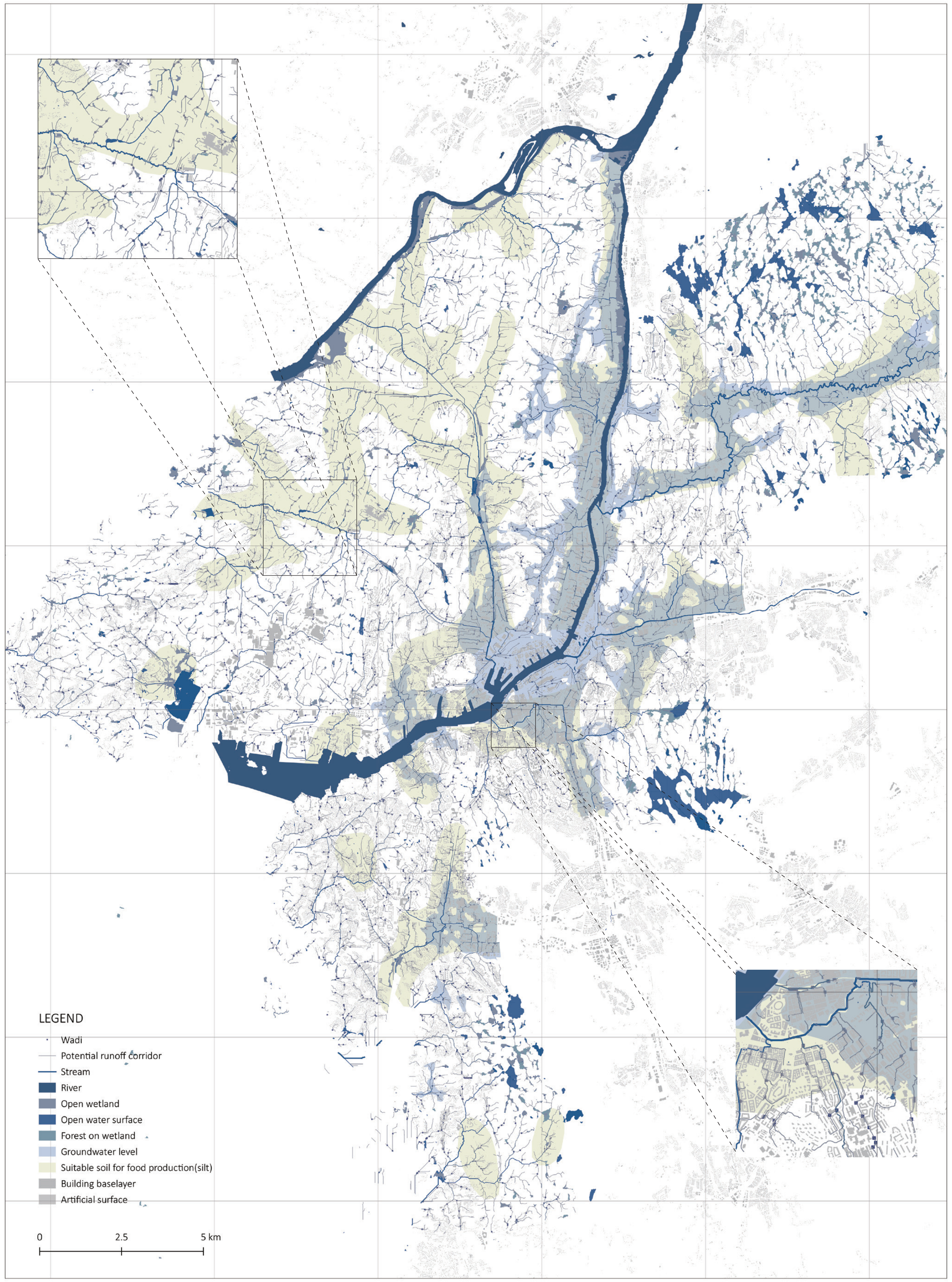
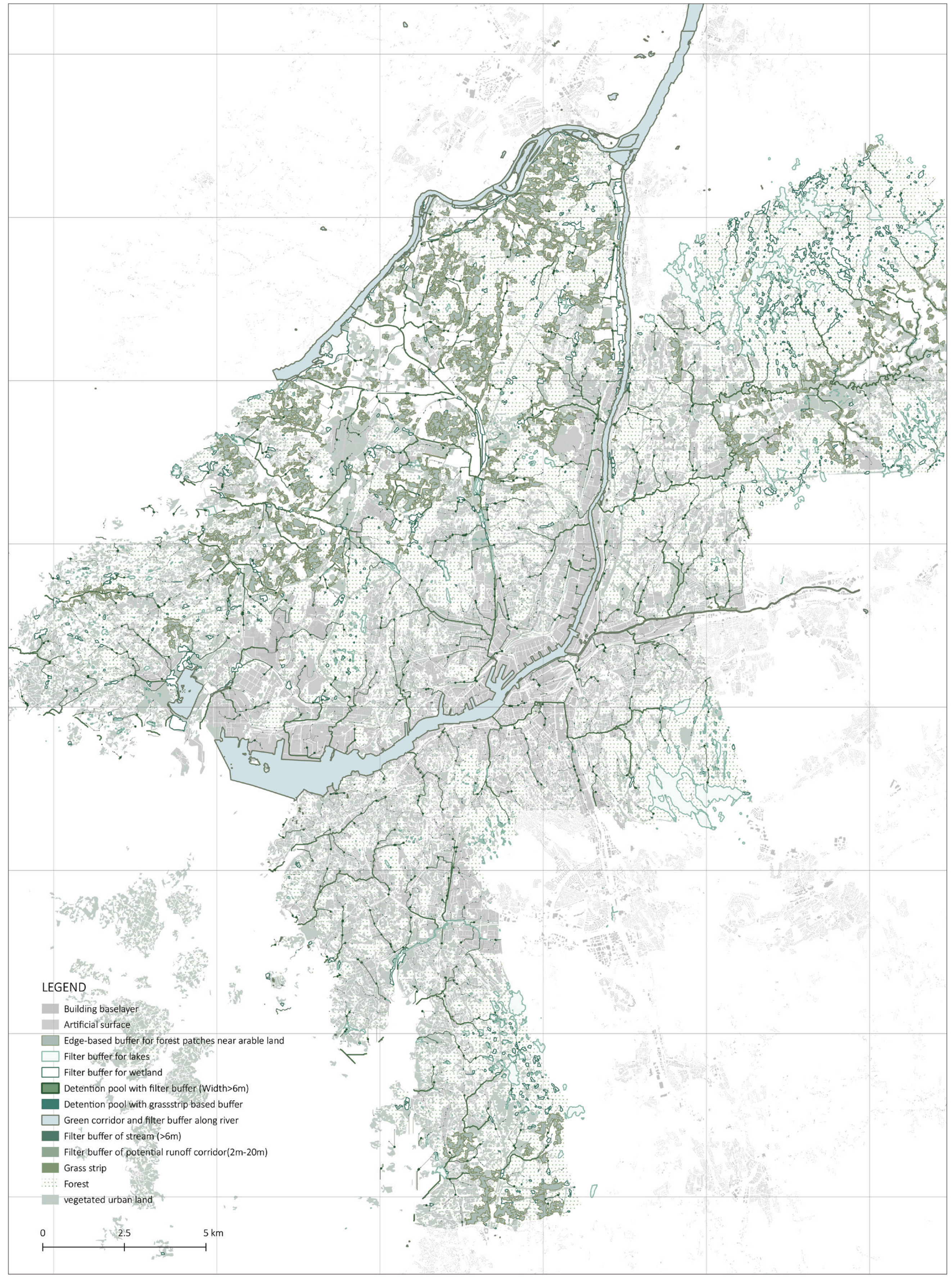


Figure 158: Supporting system2-(Vision of future's green system)



URBAN (CIRCULAR) FOOD SYSTEM

Figure 159: Supporting system3-(Vision of future's transportation system)

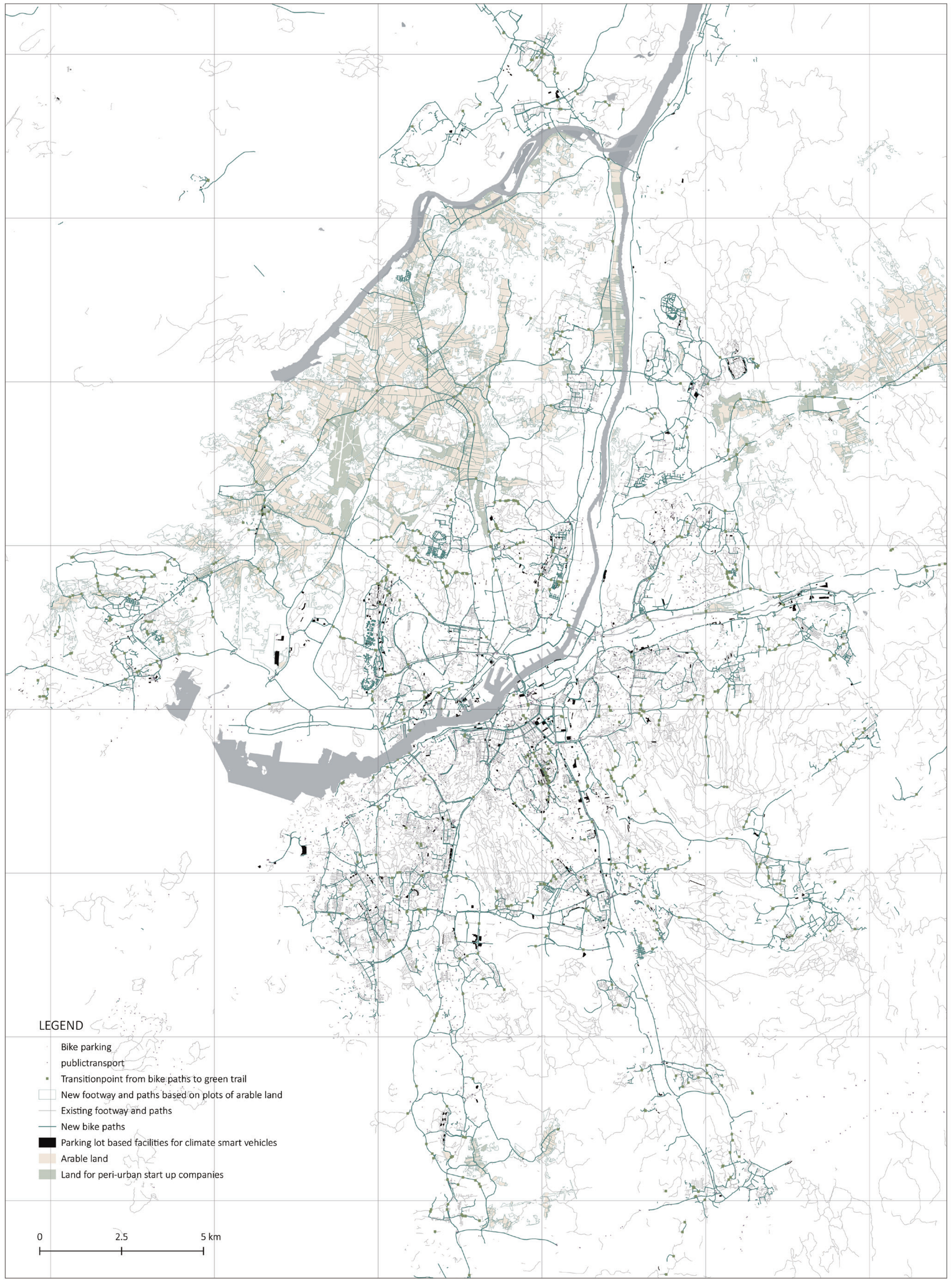
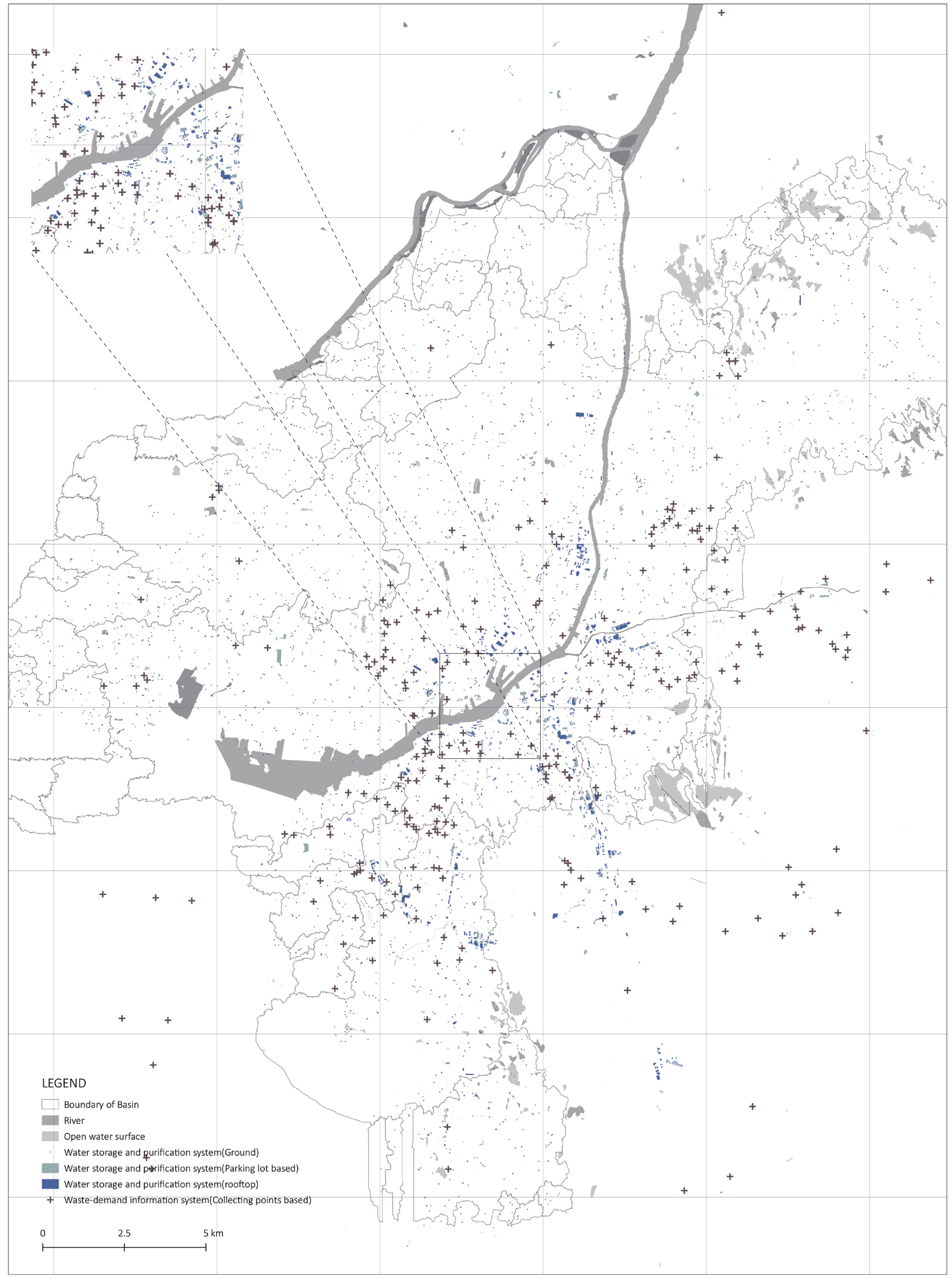


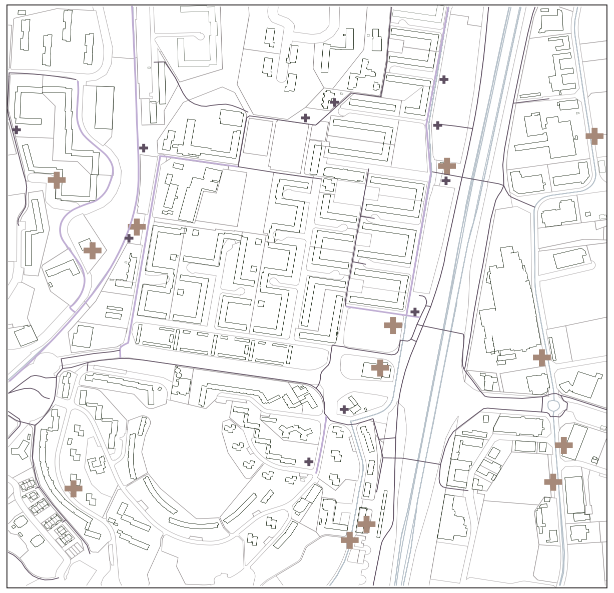
Figure 160: Supporting system4-(Vision of future's resource management facilities)



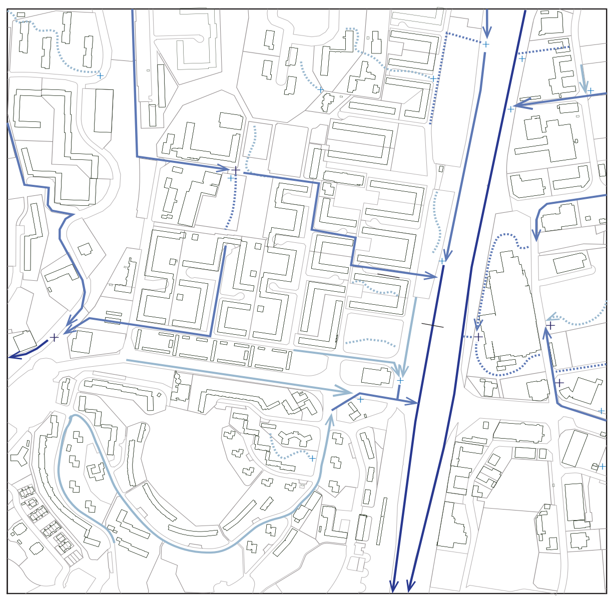
URBAN (CIRCULAR) FOOD SYSTEM

Figure 161: Supporting system at neighbourhood scale 1-(Community garden and district green house)

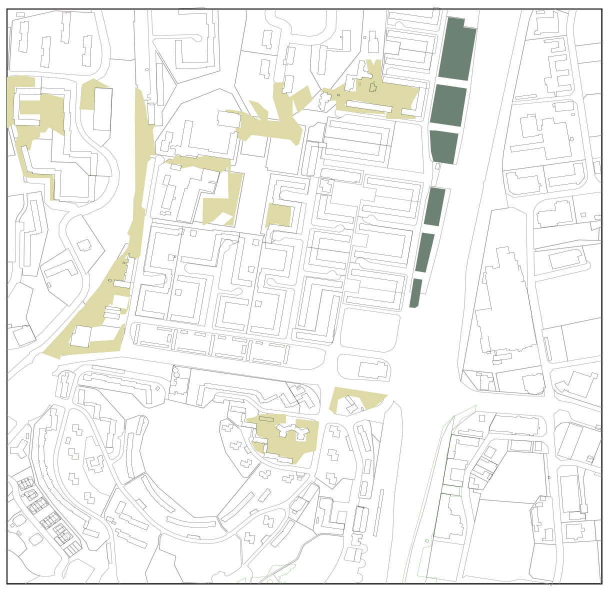
Building and plots



Public transport system **(Cycling+Bus+Tram)**

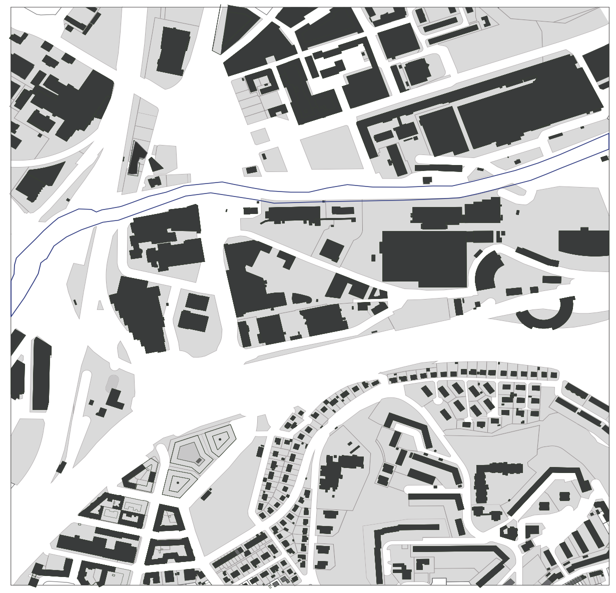


Urban blue and green network

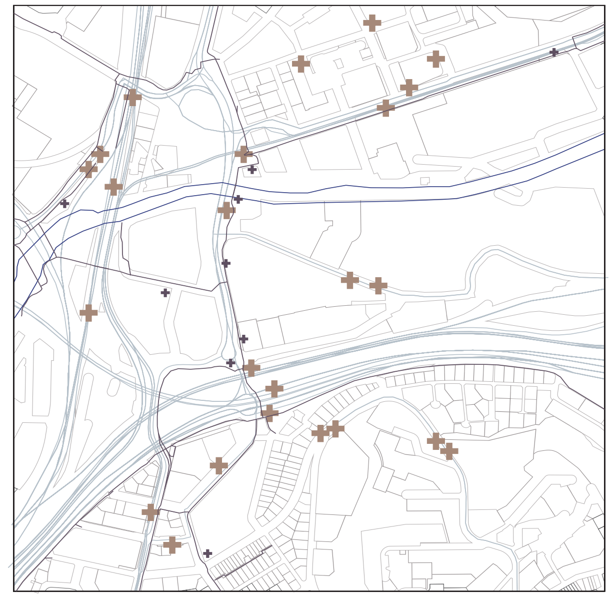


Actors**(community garden)**

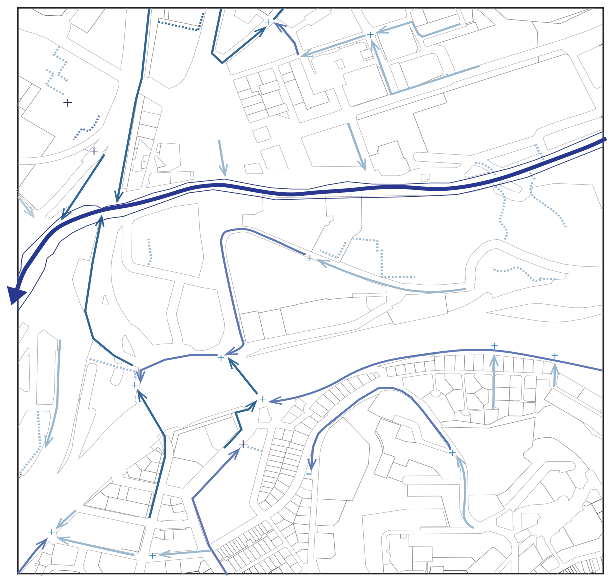
Figure 162: Supporting system-(Roof top fish vegetable symbiosis farm)



Building and plots



Public transport system **(Cycling+Bus+Tram)**

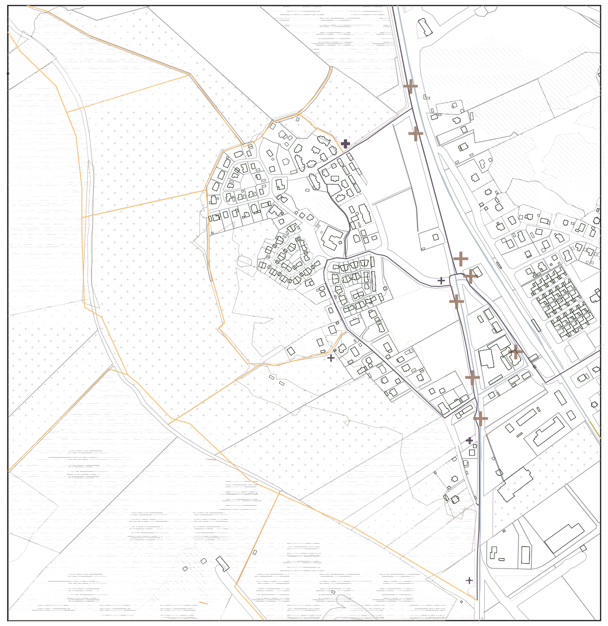


Urban blue and green network

Actors **(Rooftop food production)**

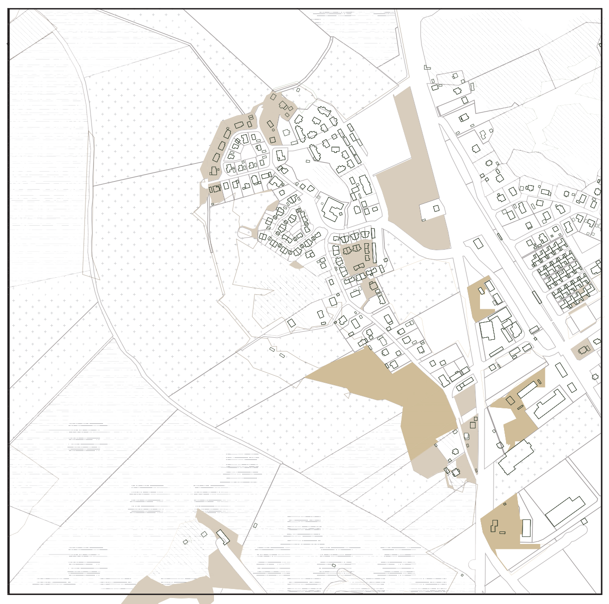
Figure 163: Supporting system -(Existing grazing/monoculture land and suitable peri urban land for start up companies)

Building and plots



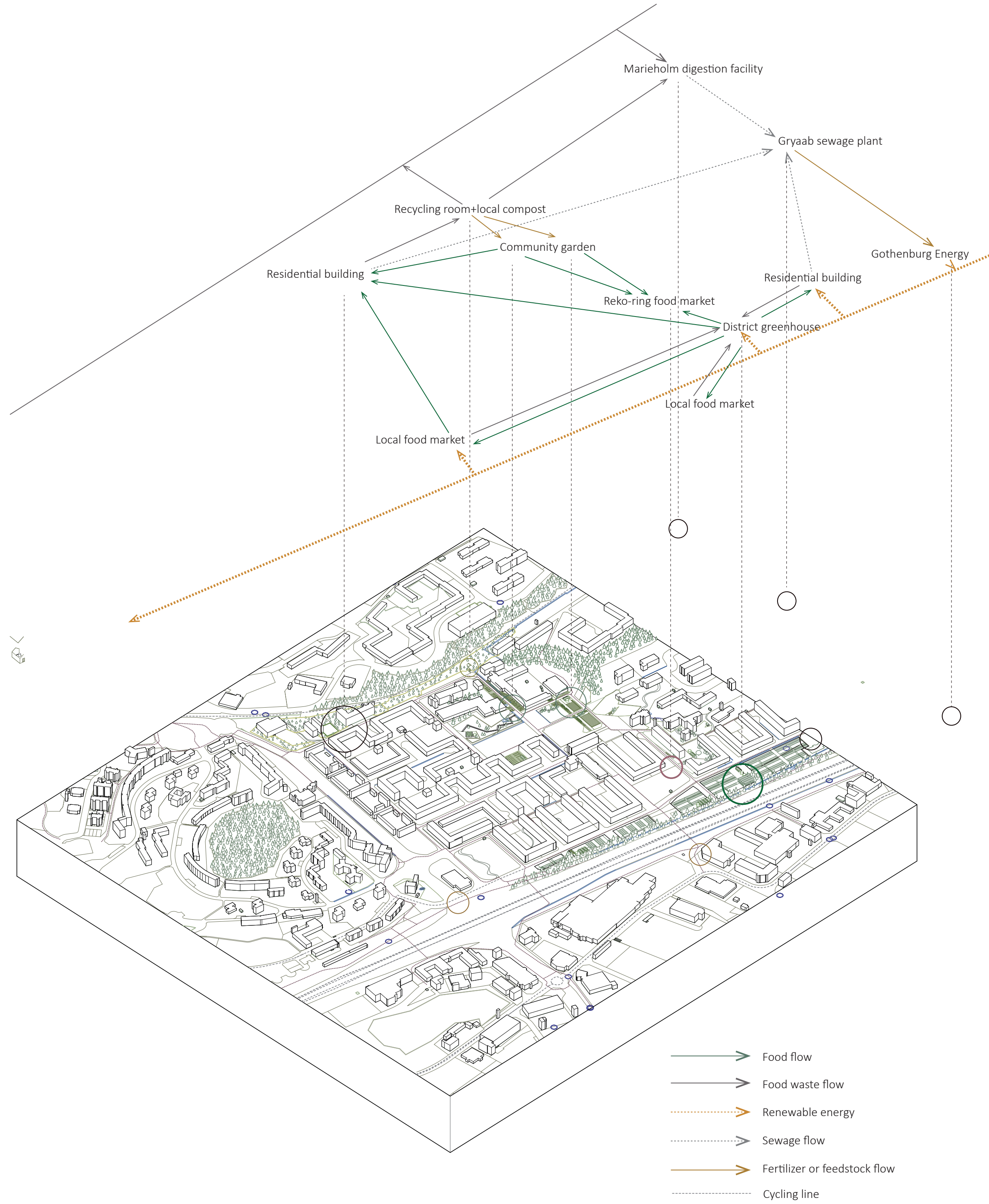
Peri urban ublic transport system **(Cycling+Bus+green trail)**

Periurban blue and green network



Actors **(Land for peri urban start up companies)**

Figure 164: Test of the relationship between actors (zoom-in area A with community garden and district greenhouse)



URBAN (CIRCULAR) FOOD SYSTEM