Exploring the role of business intermediaries to advance circular bioeconomy

- Multi case study on plant-essential nutrient recycling firms and users in Sweden

Urankhaich Batsukh

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Urankhaich Batsukh

Supervisor:	**Per-Anders Langendahl, Swedish University of Agricultural Sciences, Department of Economics**
Assistant supervisor:	Jennifer McConville, Swedish University of Agricultural Sciences, Department of Energy and Technology
Examiner:	Richard Ferguson, Swedish University of Agricultural Sciences, Department of Economics

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Swedish University of Agricultural Sciences

Faculty of Natural Resources and Agricultural Sciences

Department of Economics

Abstract

Nitrogen (N) and phosphorus (P) are key biological nutrients for global crop production and are directly linked to global food security. Despite the enormous agricultural expansion in the past century, excessive use of these elements is causing biochemical imbalances that lead to overstepping the 'planetary boundaries' beyond what the earth can hold. Recycling plant-essential nutrients from wastewater for agricultural purposes is therefore becoming essential to enable the nutrient cycle not only for reducing the impact on the ecosystem but also for enhancing the food security. This study investigates the role of business intermediaries in advancing circular bioeconomy. The empirical context is the implementation of nutrient recycling from wastewater for agricultural applications in Sweden. Since there are many firms specialized, a multi-case study approach was conducted on four business initiatives and three public sectors. Data was collected on the operational context of these firms. The results obtained from the comparative analysis show: (i) there is a diversity in wastewater-as-resource business models where there are mobilizing technology to produce fertilizer and ensuring wastewater-derived fertilizer for agricultural application. (ii) In the context of a circular bioeconomy, business intermediaries work in-between wastewater utilities and agricultural applications. (iii) Three dimensions of expectations were identified: technological availability, resource efficiency, and safe and secure value chain. This study concludes that business intermediaries play three roles in advancing a circular bioeconomy: First, developing technology that enables the recycling of nutrients in wastewater that can be applied in agriculture. Second, business intermediaries develop business models that make nutrient recycling commercially viable and legit. Third, business intermediaries also work to inform actors in the user contexts (wastewater and food sector) about nutrient recycling. Business intermediaries such as those specialized in recycling nutrients from wastewater are important since circular bioeconomy is about converting waste flows into valuable resources. The entrepreneurial process of networking and partnering activities enables market exploration for their technology/product, which is likely to entail enhancement in waste to resource/asset in the system. Their intermediating role of repositioning material flows in waste-as-resource as well as influencing knowledge flows about recycling nutrients are important business processes to advance circular bioeconomy.

Keywords: business model, circular bioeconomy, intermediary, nitrogen, nutrient recycling, phosphorus, sewage sludge, wastewater

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Abbreviations

SLU	Swedish University of Agricultural Sciences
P	Phosphorous
N	Nitrogen
EU	European Union

1. Introduction

Recycling plant-essential nutrients from wastewater for agricultural purposes is one of the focuses of the circular bioeconomy. Business firms have a major responsibility in improving the productivity of resources to retain a higher value which is the focus of this thesis. This chapter provides a problem background, and problem statement, and further illustrates the aim, research questions, and delimitations. The outline of this thesis will be presented at the end of this chapter.

1.1 Problem background

Nitrogen (N) and phosphorus (P) are the key biological nutrients *(henceforth plant-essential nutrients)* for global crop production and are directly linked to global food security (Kahiluoto et al. 2014). Despite the enormous agricultural expansion in the past century, N is mainly used to enhance food production through fertilization; eventually, the large amounts of N polluting regional and global waterways and coastal zones accumulating in the biosphere (Rockström et al. 2009; Steffen et. 2015). Furthermore, 3-5 percent of the world's annual natural gas consumption goes to manufacturing N, which puts it in one of the world's most energy-intensive processes (Smil 2000). P is a finite resource mined for human use, and the P inflow to the oceans causing mass extinctions of marine life. Consequently, both elements are causing biochemical imbalances that lead to overstepping the 'planetary boundaries' beyond what the earth can hold (ibid.). Therefore, limiting P and N inflow from wastewater before releasing it into the environment is vital concern (Kahiluoto et al. 2014). Likewise, it is urgent to make fertilizer for agricultural use with recycled P and N. In addition to that, recycling plant-essential nutrients from wastewater for agricultural purposes is essential to enable the nutrients cycle not only for the reducing the impact to the ecosystem but also for enhancing the food security (ibid.).

Increasing environmental burdens, especially caused by human activities, require a change in production and consumption to achieve sustainable development (WBCSD 2020). The bioeconomy focuses on the use of renewable resources, eventually replacing fossil-based resources (Giampietro 2019). Whereas circular economy focuses on maintaining resource value at its highest level as possible,

ultimately decoupling economic growth from resource depletion and environmental degradation (ibid.). Meanwhile, only circularity or only use of renewable resources will not accomplish sustainable production and consumption by exploiting the exhaustible (non-renewable), depletable resources (renewable), which may cause more waste problems (Carus & Dammer 2018). A key intersection between these two economic models that is defined in the circular bioeconomy concept is enhancing the resource perspective by utilizing the waste streams through recovering and recycling (Giampietro 2019). *Figure 1* shows material flow within the circular bioeconomy in the context of wastewater-as-fertilizer.

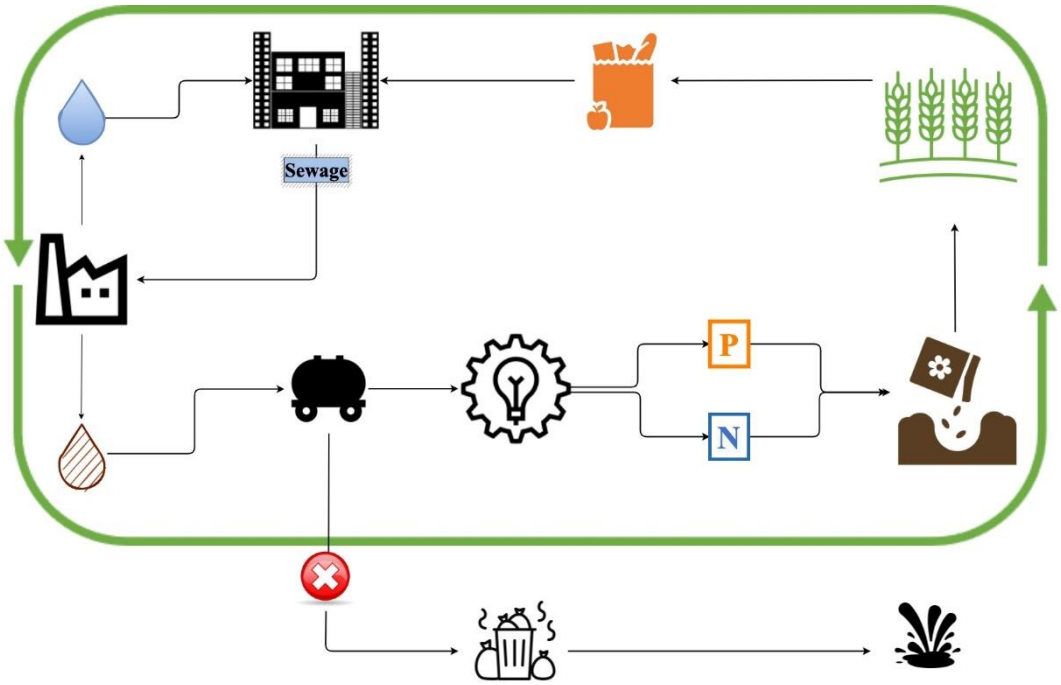


Figure 1. Material flow within the circular bioeconomy in the context of wastewater-as-fertilizer (own illustration).

1.1.1 Empirical problem

Technically, wastewater is considered as a promising alternative and potential in source of plant-essential nutrient (Robles et al. 2020) and furthermore, one of the key areas of the circular bioeconomy (Carus & Dammer 2018). However, the implementation of plant-essential nutrients recycling from wastewater for agricultural application in Sweden today is much contested (Ekman Burgman 2022). From the upstream level, municipal wastewater treatment plants (WWTPs) are designed to remove hazardous materials such as heavy metals, nutrients and organic compounds to protect the environment and human health (Sellberg 2016). Many of the untargeted chemicals and contaminants such as microplastics and

PFAS[1] are released with the effluent discharge (liquid waste) into water which is eventually reach the surrounding environment. Other residuals like heavy metals and other elements end up in the sewage sludge with the nutrients P and N. The requirement for phosphorus reduction is high in Sweden; therefore, most treatment plants use both chemical and biological processes in order to comply with the law. This process is not only averse to the environment and society with chemicals, but also to the economy with high transportation costs and energy use (ibid.).

Traditionally, sewage sludge from wastewater treatment plants, is used directly on the farmland as soil fertilizer because it contains valuable nutrients for the soil (Cohen et al. 2011). But only 34 percent of the total sewage sludge is spread on farmland as a fertilizer in Sweden (Statistiska Centralbyrån 2018; SOU 2020:3). This means that more than 65 percent of sewage sludge is eliminated due to the inclusion of hazardous materials that cannot meet the REVAQ[2] quality standards. Of particular concern is a considerable amount of N and P loss due to quality requirements (SOU 2020:3).

Quality assurance for using sewage sludge on farmland was set from 1994 by Swedish law (SNFS 1994). but higher demand has been established by the REVAQ certification system (Svenskt Vatten 2022). Furthermore, using fertilizer from sewage sludge for food production is prohibited in Sweden (Lantmännen n.d.). In result, depending on the customer demand, farmers decide what they use on their farmland. Yet, farmers are also reluctant to use sewage sludge directly on their farmland because they are concerned about the soil contamination (Ekane et al. 2021). All in all, there is not one answer for the complexity of wastewater-as-resource context where Ekman Burgman (2022:9) argues a holistic view and complexity must be accounted for rather than a solution for all:

> "… splicing the many versions of sewage sludge becomes a persistent conundrum …" (Ekman Burgman 2022:9).

The situation might change under the inquiry on sludge dissemination called 'pollutant-free and circular recovery of phosphorous from sewage sludge' (Regeringskansliet 2018). In 2020, two proposals have been made under the inquiry; the first is a complete ban for spreading sewage sludge on farmland with restricted exceptions, and the second is to allow but with stricter quality requirements (SOU:3 2020). Whatever decision will come, it is obvious that the

[1] PFAS is (per-and polyfluoroalkyl substances) a chemical used for products to be resistant to heat, oil, and water.

[2] REVAQ is a certification system controls hazardous substances of sewage sludge from WWTPs before it uses in agriculture.

regulation will set more stringent quality criteria for waste being created and the waste being utilized.

More importantly, the policy development that it seeks to develop a pollutant-free and circular recovery of phosphorous from sewage sludge', one could also be interpreted as to be techno-centric. It assumes that technological innovation may led to practical application. However, technological innovation does not bring about practical applications on their own (Lüdeke-Freund, 2020). Rather, entrepreneurs are identified as key agents that translate technology into practical application. In such instances, entrepreneurs make use of business models that work as mediating devices between technological developments and their social and economic value creations (ibid.).

In their traditional form, business models are typically used by entrepreneurs to model their strategic approaches for creating, delivering, and capturing value. However, more recently, business models are increasingly used in research for their analytical capacity to support the development and uptake of innovations (Doganova & Eyquem-Renault 2009). In such research, business model is an analytical device for describing firms value propositions to various stakeholders, including how values are created and delivered, and how they capture economic value in return. Thus, business model can be used as analytical device to unpack how firms in the context of wastewater-as-resource construct their value propositions to their stakeholders.

1.1.2 Theoretical problem

Firstly, conceptual frameworks about circular bioeconomy, such as the butterfly diagram by Ellen McArthur or the waste hierarchies, are abstract representations of such developments (Wolf 1988; Van Ewijk & Stegemann 2016; Peter et al. 2022). These abstract representations consist of context-free high-level frameworks and offer very little understanding of the *role of business firms* in advancing circular bioeconomy practices on the ground.

Secondly, the research on waste-as-resource broadly focuses on the role of technology that makes wastewater-as-resource possible (Hultman et al. 2000; Cohen et al 2011; Robles et al. 2020; Ottosen et al. 2022), where the social aspect is reduced to the acceptance (or not) among users of waste-as-resource. There is a paucity of research considering social practices on the ground to advance a circular bioeconomy. Notably, firms that specialized in wastewater-as-resource are regarded as key actors in catalyzing or advancing circular bioeconomy (Salvador et al. 2020, 2021; Brandão et al. 2021; Mehta et al. 2021). Therefore, research is

needed to understand *the function of business firms* in advancing the circular bioeconomy.

Finally, business firms in the field, to be able to convert wastewater-to-resource, coordination between different instuitional actors is needed (Dagerskog & Olsson 2020). Because the waste of the one actor becomes the resource for the other (Puntillo et al. 2020). The link between wastewater and agricultural application that enables nutrient to recycle could be seen as an intermediary practice that works in-between and makes such connections. The practice of intermediation is therefore important for understanding circular bioeconomy. Because they create a link in-between wastewater - and agriculture systems where they operate and create value. Knowledge of such *intermediary relation* is required to understand how to advance a circular bioeconomy further effectively and efficiently. Furthermore, looking at the business model for a circular bioeconomy, the study will shed light on key ethical and sustainability concerns faced by the recovery and recycling business model.

1.2 Aim and research questions

The aim of this study is to contribute with knowledge of business intermediaries in recycling plant-essential nutrients from wastewater. The empirical context for this study is the implementation of nutrient recycling from wastewater for agricultural applications in Sweden. Since there are many firms specialized in recycling plant-essential nutrients from wastewater, a multi case study approach was conducted guided by the following questions:

- What intermediary roles are developed by firms to recycle plant essential nutrients from wastewater?
- What challenges associated with their business model have they identified, and how do they seek to overcome identified challenges?

1.3 Scope and delimitation

The study phenomenon is the recycling of plant-essential nutrients from wastewater for agricultural purposes. In order to get broader findings for the phenomenon, a multi case study has been chosen to collect data for the phenomenon *(see Figure 2).* The study main focus is on the business firms that are actively working in the field, namely Biototal, C-Green, Easymining, and Ekobalans. The chosen companies are working in different geographical areas in Sweden using different strategies and methods to recycle (recover and cascade) plant-essential nutrients

from wastewater for agricultural purposes. Since these business firms operate in between wastewater management where nutrients are recycled and agriculture where nutrients are applied, the scope of this study also include wastewater utility as Svenskt Vatten (The Swedish Water and Wastewater Association), agricultural application as Lantmännen (Swedish agricultural cooperative) and LRF (The Federation of Swedish Farmers). However, there is a limit concerning the aforementioned cases, this study will not focus on the whole system rather solely on the business actor with its partners (components and links).

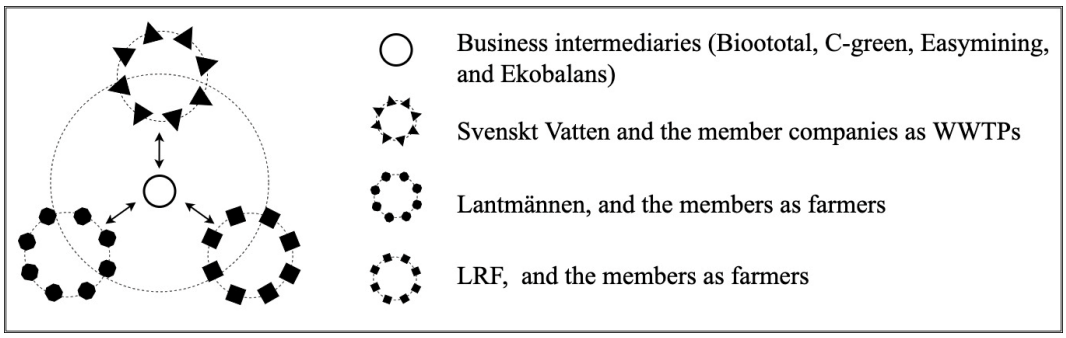
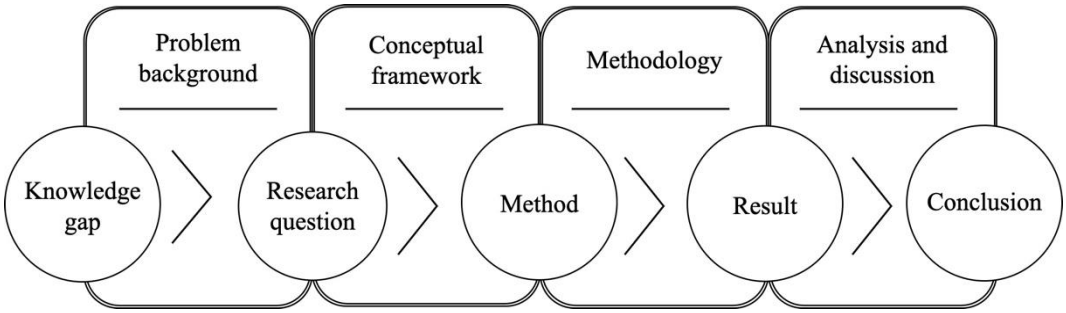


Figure 2. Scope of the study. Own illustration, inspired by Kanda et al. (2020).

In addition, the study is situated in one geographical area in Sweden. The data will be obtained from multiple sources and can be applicable in a glimpse of similar circumstances (Yin 2009). Moreover, the study tries to capture a real-time phenomenon under the chosen conceptual frame rather than a historical or transition perspective, therefore cannot fully capture the whole scenario of plant-essential nutrient recycling from wastewater.

1.4 Research outline

Figure 3. Illustration of the outline of the study



The thesis is organized as follows *(see Figure 3).* After this *chapter 1*, the *chapter 2* starts with the narrative literature review of the business model development in

the context of waste-as-resource through economic framework from linear, circular and circular bioeconomy. Then, the concept of intermediary and business model are reviewed to position the study focus. At the end of the chapter, synthesis of literature review and concepts will be illustrated. *Chapter 3* will present the methodology used for this thesis regarding research design, data collection, data analysis, and quality of the study with ethical consideration. *Chapter 4* presents the multiple case study obtained from interviews and secondary data undertaken during data collection. Following *chapter 4.2.3* includes comparative analysis with discussion of the study. The thesis ends with *chapter 6*, draw a conclusion and further research recommendations.

2. Literature review and conceptual framework

This chapter presents the literature review and the conceptual framework. It follows with literature review of an overview of research on business model in the context of circular bioeconomy. After, concept of intermediary and business model is developed in order to build a foundation for further analysis.

2.1 Literature review

An overview of research on business models in the context of waste-as-resource presented hereafter.

2.1.1 The concept of "waste"

> "Waste, broadly defined, is any nonvalue-added process or physical material occurring in business practices and services" (Perey et al. 2018:632).

In the linear business model, waste is viewed as a burden (Dahlgaard & Mi Dahlgaard-Park 2006). The strategy toward reducing waste was efficient teamwork, quality improvement of the production system, and more control on the quantity of production to minimize cost; thus, it is only at the managerial level. The problem in the linear economy approach is that it transforms the natural resource into waste via a production and consumption system (ibid.). In contrast, these abandoned materials are reconceptualized as a resource by reusing, repairing, refurbishing, and recycling activities, possibly capturing greater values in circular business models (Svatikova et al. 2015). Hence, creating value from waste requires effort from more than one actor (Lüdeke-Freund 2020). The business models emerge in the system around sharing waste-as-resource activity among the actors (Bocken et al. 2016). This underscores the crucial feature of systemic change in value creation (Perey et al. 2018). Recently, the business model for circular bioeconomy puts the waste into more as an asset level, including cascading and recovering activity to regenerate valuable resources (Salvador et al. 2021). Zucchella and Previtali (2019) stressed that only in a more advanced phase of the circular economy can waste be fully

recognized as an asset, capable of obtaining benefits for all the actors in the system *(see Figure 4).*

	Linear economy	Circular economy	Circular bioeconomy
Business model strategies	Reduce waste by managerial configuration	Reusing, repairing, refurbishing, and recycling the waste	Recovering and cascading for utilizing the waste
Realization of waste	Waste as a burden	Waste as a resource for the firm	Waste as resource/asset for the system

Figure 4. The concept of waste from linear economy to circular bioeconomy. Own interpretation according to Puntillo et al. (2020).

2.1.2 Wastewater-as-resource

The complex nature of the wastewater cannot be viewed as only a national agricultural or local environmental issue; it involves diverse actors globally (Peterson et al. 2022). In relation to P recover (interpretation is same to wastewater), Peterson et al. (2022) suggest that a long-term solution must be considered to embrace collaboration between diverse actors and connect management scales to establish a sustainable system approach. Hence, the implication in practice is rather incremental (Callesen et al. 2022). Teece (2010: 183) emphasizes that "technological innovation by itself does not automatically guarantee business or economic success - far from it." Due to the complex nature of the wastewater, it is far to expect wastewater-as- resource/asset; perhaps the business firms can play a role as upgrading the material with technological advancement and their practice. Intermediaries that work in between wastewater and agricultural application are needed to enable wastewater-as-resource *(see Figure 5)*. So, firms or actors situated in such a space can be conceptualized as "Intermediaries", will be explained in the next section.

Figure 5. Conceptualization of business intermediaries in the context of wastewater-as-resource (own illustration).

2.2 Conceptual framework

Business firms can be understood as intermediary actors that make relations in-between those producing waste that contains nutrients (wastewater treatment plants) and those that use nutrients from waste (farmers or food business firms). They perform intermediary roles whereby they are practically linking a waste stream via "technology and practice" to create resources (nutrients) for agricultural application.

2.2.1 Concept of intermediary

> "Intermediaries bridge between actors and their related activities, skills and resources, in situation where direct interaction is difficult due to high transaction costs, information asymmetry or communication problems" (Kanda et al. 2019:3).

Intermediaries can be a process or a specific actor(s) (Kanda et al. 2020). For instance, a recent study proved that multi-actor *(systemic, regime-based, and niche)* intermediaries emerged as a transformative agenda of urban forest strategy in Melbourne (Frantzeskaki & Bush 2021). The study identified first, the *systemic intermediaries* as city councilor of Melbourne during elected year of 2008 to 2020. This city councilor was instrumental in green-focused initiatives and policies, actively involved in global frameworks for biodiversity and climate change, global city networks, and strong collaboration and communication with the local community. The systemic intermediary role and function enabled cooperation between actors in the system to allow successful innovation. The next type of intermediary is *a regime-based intermediary*, identified as Resilient Melbourne, founded by the city of Melbourne (ibid.). The Resilient Melbourne facilitates the networking between different actors, including industries, governmental organizations, business firms, and local governments, by facilitating dialogue for nature-based solution agenda formulation and helping to enable experimentation spaces, consultation. The regime-based intermediary role and function ultimately contributed to launching strategic plan in 2019. The next characteristics of *niche intermediaries* were the researchers collaborating with urban planners, industry representatives, and engineers bridging the organization to enable systemic and process innovations. The feature of the niche intermediaries was to translate knowledge into uptake niche innovations, providing resources and support and disseminating the opportunity to learn. The role and function of all types of intermediaries' orchestrating activities could support collaboration between different actors, policy learning, and eventually strengthened the political support. At the same time, intermediaries' contributions were critical for solutions-oriented governance in the context of complex metropolitan urban forest (ibid.).

The strategies taken by intermediaries' may not often be specified (Klerkx & Leeuwis 2008) because intermediaries usually need to fulfill different demands and gain mutual trust (Kanda et al. 2020). Depending on the resource, motivation and scope, the intermediation role can vary (Kanda et al. 2018). Furthermore, the relation to be successful, intermediaries acquire competence and resources from other actors or organizations and offer desired objectives or create spaces and opportunities (Howells 2006; Kanda et al. 2018).

The earlier connotation of an intermediary usually in business research refers to an agent, broker, and division level as in-between whether in or outside the firm typically related to research and development activities (Morris & Miller 1999; Van Lente et al. 2003). Currently, conceptual understanding of intermediaries' role and functions is viewed as a *catalyst* of systemic innovation and transition types of literature (Kanda et al. 2018, 2019, 2020; Kivimaa et al. 2019), highlighting the importance of conceptual understanding of intermediaries. In the emerging circular economy, Fischer et al. (2021) states that the intermediaries are a novel institutional field because they operate in between different institutional levels or contexts, introducing decent norms and regulations at industry, region, and national level as they are the practitioners or as public and private organizations (ibid.).

Systemic intermediation as dynamic view

Van Lente et al. (2003) emphasizes that systemic intermediaries are essential in the long term in the sense of socio-technical configuration. Systemic intermediaries occur on a systemic or network level (Van Lente et al. 2003; Kivimaa et al. 2019; Kanda et al. 2020). The system by means comprising components and relation between components (Kanda et al. 2020). Components are individual actors within the system such as public authorities, Research and Development, business firms, NGOs, suppliers (ibid.). At a systemic level, intermediary actors are distinguished by their relation in-between different entities, networks, and institutions (Kanda et al. 2020:7). To position the systemic level intermediation three analytical criteria proposed by Kanda et al. (2020:7): functional, relational and appropriation of intermediation benefits *(see*

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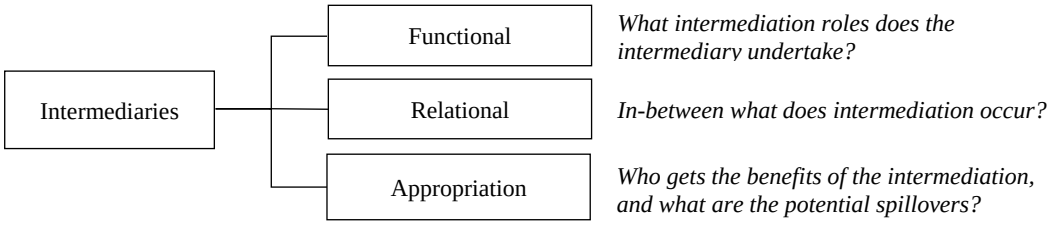

Figure 6. Criteria for characterizing system-level activities of intermediaries (Kanda et al. (2020:7), own illustration)

Intermediaries are often identified by their intermediating *role and function* they undertake. However, the role of intermediaries is not necessarily at a systemic level, it has interchangeably used as function and as role. Thus, it helps to identify the next criteria as *relational*, which postulates in-between what, intermediaries occur. The last criteria, indicates the ability of the intermediary to facilitate systemic change and accounts for who gets the potential benefit (ibid.).

Market and intermediation process

Market-oriented intermediaries are important in market development (Hyyso et al. 2022). Market development consists of certain 'market segments' (actors, institutions, and networks) that may only develop when the related 'market transactions' (commodifying, communicating, competing) are in a regular form, which is integral to the formation of 'user profiles' (consumer images, use patterns and preference structures) (Dewald & Truffer 2012:402). Primarily, intermediaries are one of the key actors, performing by their knowledge and technologies, they involve in the new market solutions or challenging the existing market structures (Hyyso et al. 2022). Thus, the dynamic of intermediation constitutes of key processes in market formation for more sustainable modes of production and consumption. Although market formation requires credibility (remit), competence, investments of time and resources to act in (ibid.). Hence, business model as an appropriate device led by entrepreneurs, likely to enroll and deploy potential market for sustainable technology/product (Doganova & Eyquem-Renault 2009)

2.2.2 Business model concept

Entrepreneurs develop business models in relation to stakeholders. This is important since market actors must recognize the value proposition. The business model becomes a functional device that enables resource flow from wastewater to agriculture, where they create and deliver values.

Business model as a value creation device

The business model is conceptual rather than the design of an economic model (Teece 2010). The definitions of the business model concept, provided by Zott et al. (2011):

> "… business model as a new unit of analysis, offering a systemic perspective on how to do business, encompassing boundary-spanning activities (performed by a focal firm or others) and focusing on value creation as well as on value capture" (Zott et al. 2011:1037).

To put it simply, the way a firm does business (Zott et al. 2011; Bocken et al. 2016). The finite resource and energy dependency associated with environmental and societal issues have grown in importance in light of ambition to sustainable development. A circular business model is to develop more sustainable production and consumption, starting with the ambition of industrial ecology to become an internal cyclical system (Ayres 1989:23). In result, the perspective of a business model becomes a mechanism to design value proposition, creation, delivery and capture rather than the only value capturing process (Teece 2010; Zott et al. 2011; Bocken et al. 2016).

A business model depicts a company's value creation strategy (Salvador et al. 2020). In terms of extending the resource value, the wastes are turning into new forms of value. In *Figure 7* depicts value proposition, creation & delivery, and value capture of the business model (Bocken et al. 2016). Value proposition is, however, represents a value proposal (product and service offer) to the target customer. Also, it refers competitive advantage of a company that differs from others (ibid.). The value creation and delivery address the company's resources, technologies, and relationship network *(how)* (Bocken et al. 2014). These strategic assets enable the competitive advantage for the company. Finally, value capture represents the income and expenditure that redistributed to the company itself and other parties *(for whom)* (ibid.).

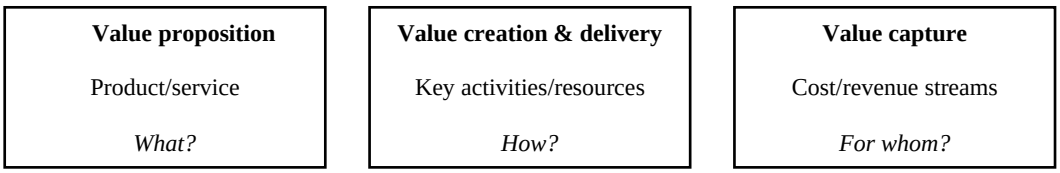

Figure 7. Value boxes, inspired by Bocken et al. (2014) and D'Amato et al. (2020)

Business model for sustainable innovation

> "A business model for sustainability helps describing, analyzing, managing, and communicating (i) a company's sustainable value proposition to its customers, and all other stakeholders, (ii) how it creates and delivers this value, (iii) and how it captures economic value while maintaining or regenerating natural, social, and economic capital beyond its organizational boundaries" (Lüdeke-Freund 2020:669).

Given that business models are embedded in the sociotechnical context, their functions is to create, deliver, and capture the value (Zott et al. 2011), it can be also seen as a device for entrepreneurs. By means business model as a mediating function that execute narrative and a calculation which further allows entrepreneurs

to explore and experiment market and networking (Doganova & Eyquem-Renault 2009). To be successful for their value creation, entrepreneurs align their business models with sustainable technology/product to other actors in the system. Thus, sustainable business models often face barriers when they try to capture value such as complementary assets, resources, or competencies (Teece 2010).

To achieve successful commercialization for the sustainable technology/product, legislation, advanced technology, and marketing channels are most critical (Lüdeke-Freund 2020). *Complementary assets* refer to ability to access special assets or capabilities which is a key to successfully commercialize the innovation. These assets can be sourced from internal or external, also it can be from third-party asset, or specific assets e.g., transportation, warehousing. Cost-disadvantage problems is common in sustainable product, because e.g., virgin resources are cheaper today *(deliberate internalization)*, spatial, cultural, and institutional embeddedness *(discursive ambiguity)*, external cost (risk) when cannot be predicted, borne by innovators *(directional risks)*, (in)ability to solve (non)systemic problem *(methodological constraints)*, and finally, certain spillovers to third parties while innovators carry the external costs (ibid.).

To overcome aforementioned challenges, entrepreneurs design their sustainable business model simultaneously they try to solve societal and environmental problems for various stakeholders (Lüdeke-Freund 2020). To do so, they enter and diffuse their sustainable case on the market by aligning their decision and activities to other related actors. Here, business model is not only product, service, and value chain, but also about designing the business model to enable potential market. It refers business model as *mediating function* (ibid.)

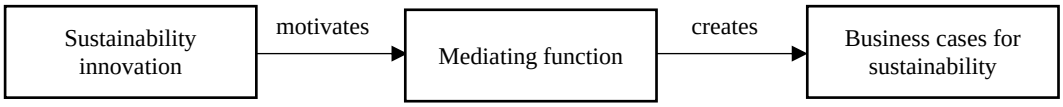

Figure 8. Mediating device ((Lüdeke-Freund 2020), own illustration).

This mediating function framework provides two viewpoints: agency perspective and system perspective (Lüdeke-Freund 2020). Sustainable entrepreneurs as an *agency*, make decisions and acts. They are the one who bring required innovation to the market *(see Figure 8)*. They influence dynamics of the sociotechnical context by their influence and networking within the embedded *system*. The system consists of technical infrastructures, institutions, and other. Entrepreneurs make a new relationship in a wider sociotechnical context such as public policy, investors, and stakeholders. Collectively they contribute to the system change, influence sociotechnical context to move forward to the mutual sustainability goal (ibid.).

2.3 Synthesis

To reach the thesis aim, a literature review was performed, and a conceptual framework developed in this chapter. The synthesis and analytical categories are presented hereafter.

The conceptual framework of the study is summarized in *Figure 9.* This study investigates the role of business intermediaries to advance a circular bioeconomy. The plant-essential nutrient recycling firms are the key focus, which is conceptualized as intermediary actors between wastewater utility and agricultural application. In the context of wastewater-as-resource, business firms are working to facilitate and maintain wastewater-to-resource/asset.

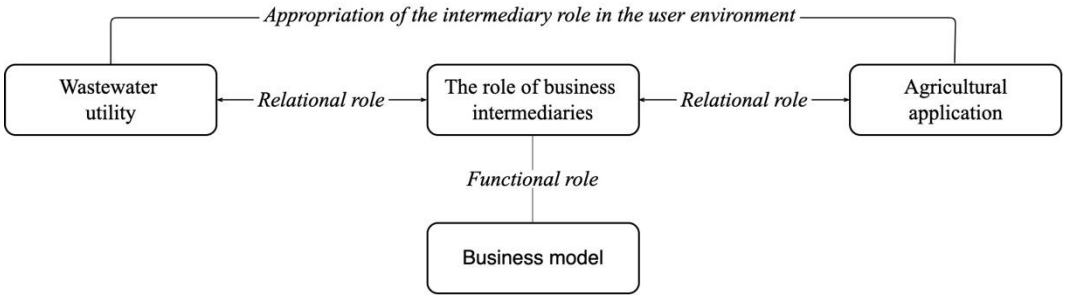

Figure 9. Visualization of the conceptual framework of the study (own illustration).

The concept of intermediary provides a useful account because it draws attention to the relational process. To understand and translate intermediaries' role appropriately, the business model concept was chosen. Business firms propose value to the customer which refers to the functional role of business intermediaries. To be successful in their value creation and delivery, business firms intermediate within or in-between distinct actors which presents the relational role of business intermediaries. Eventually value is distributed and captured by business firms and other actors which refers to *appropriation of the business intermediaries' role in the user environment).* The analytical categories derived from the conceptual framework to answer research question, described below.

Research question 1. What intermediary roles are developed by firms to recycle plant essential nutrients from wastewater?

- **Functional role**. In this category the value proposition of each business model and their target customers will be analyzed.
- **Relational role.** Here value creation and delivery will be analyzed.

- **Appropriation of the value of recycling nutrients in user environment.** In this category, the benefit and challenge of the user environment from business intermediation will be analyzed.

Research question 2. What challenges associated with their business model have they identified, and how do they seek to overcome identified challenges?

- **Mediating function.** In this category, value capture for the company and for other actors will be analyzed.

Moreover, it is important to distinguish between the role and function. Because some studies have used both interchangeably and are often viewed as having the same meaning (Kanda et al. 2020). For this study, the *'function'* is viewed as a business model proposed by entrepreneurs to capture their value. *'Role'* is viewed as a broader aspect as how business intermediaries occur in the system and who gets the benefit of it.

These analytical categories are built to enable analysis on data collection to capture the *business intermediary role in advancing circular bioeconomy* in the context of wastewater-as-resource. The next chapter will describe methodology of the study with data collection and analysis.

3. Methodology

Methodological choices based on ontological and epistemological worldviews are presented and described in this chapter. The chapter starts with the research paradigm, followed by the research design and a discussion of method choice. The case selection, thereafter, accounted for motivating data collection and analysis. The chapter ends by illustrating the assessed quality criteria and the ethical implications of this thesis.

3.1 Research paradigm

The research paradigm comprises three spheres of "epistemology" - the theory of knowledge, "ontology" - the theory of reality, and "axiology" so called methodology - the way to understand the theory (Bell et al. 2018). The term paradigm is described as philosophical 'motivation or intent' for the 'systematic investigation'. In social science, the paradigm is an essential posture of philosophical assumptions for generating valuable knowledge about reality (ibid.).

In this thesis, the *constructivism* worldview assumption as an ontological position to ground approach into practice. Constructivism, or so-called social constructivism ontology, is a perspective that individuals focus on the specific context and its complexity (Creswell & Creswell 2017) and help to identify the socially constructed entities in prevailing discourse. Unlike objectivity, observing on independent organization detached from the externalities, constructivism social actors as externalities that asserts social phenomena, investigating relativism rather than realism (Bell et al. 2018). Social constructivism approach typically seen as qualitative research (Creswell & Creswell 2017).

Epistemological position drives logically from ontology position (Bell et al. 2018). In order to make sense of the world around, the *interpretivist* epistemology position will be the choice to interpret subjectively of human action rather than objectively. In the interpretative stance, researchers might come up with surprising findings due to the 'third interpretation'. It means the second interpretation is based on the participants' perspective about the surroundings, externalities and the third, the interpretation is based on the concept, theories, and literature. Within this respect,

the researchers tend to generate theory from reality instead of beginning from the theory, which entails inductive approach (Mackenzie & Knipe 2006).

The methodology paradigm concerns the way to gain knowledge (Guba & Lincoln 1994). With regard to the ontological position of constructivism, social reality is being investigated from multiple respondents' points of view which are constructed differently (Robson & McCartan, 2016). The methodological analysis is based on similarities and differences (*comparative analysis*) (Ladyman 2007). This requires a method of study that focus on various aspects in different ways to understand holistically and treat human beings as free to act voluntarily. Hence, this investigation can be achieved its goal in some level through nature of socially constructed reality (*naturalistic inquiry paradigm*) from multiple perspective (ibid.). Required information is obtained through practitioners' perception, and experience. Accordingly, semi-structured interviews and pre-existing secondary data are selected to enable triangulation as the principal methods for collecting and analyzing data.

3.2 Qualitative research design

There are two distinctive fundamental approaches: qualitative and quantitative. The difference is that quantitative researchers use numeric measurements while qualitative data is non-numerical (Robson & McCartan 2016; Bell et al. 2018). When researchers do not know what issues arise from the data, the qualitative approach is more useful than testing the hypothesis (Edmondson & McManus 2007). Furthermore, the logic of the discovery process can be characterized as *inductive,* where the phenomenon establishes from the empirical observation (Edmondson & McManus 2007; Creswell & Creswell 2017; Bell et al. 2018).

Moreover, Edmondson and McManus (2007) imply that the maturity of theory strongly influences the research design. So far, the concept of 'Intermediary' is a nascent theory that represents a relatively new phenomenon. It is suggested that context-dependent knowledge provides in-depth understanding when dealing with relatively new phenomena (ibid.). With that said, multi case study methodology with a qualitative approach is fit for this thesis. Furthermore, the *unit of analysis* in this study will start from business models of chosen companies, which then shift to the relation of the companies with other key actors in system more specifically supply and demand side relation. Moreover, the choice of units associated phenomenon are Biototal, C-Green, Easymining, Ekobalans, Latmännen, LRF, and Svenskt Vatten based on multi case study to obtain and analyze the data.

3.3 Literature review and conceptual framework

A narrative literature review has been used in this study to get an initial impression of the area. Then conceptual framework was developed to establish the theoretical foundation of the data collection.

3.3.1 Literature review

The literature review is an important step to engage in the existing literature and scholarly debated areas to demonstrate what is known (Bell et al 2018). There are two main ways to conduct literature review: systematic review and narrative review. In business research the systematic review focuses on providing advice for practitioners based on reviewing all available scientific research While, according to Bell et al. (2018) narrative literature review fits when researchers tend to generate understanding of the social phenomena. Because narrative literature allows researchers to modify the boundaries of the matters and carry to the focus (ibid.). In this study, the aim is to gain an understanding of the topic area on wastewater-as-resource business model in a circular bioeconomy, rather than providing advice. Therefore, a narrative literature review has been conducted to get an overview of waste-as-resource business models and how the business model strategy changed over different economic perspectives (linear, circular, and circular bioeconomy).

3.3.2 Conceptual framework

The conceptual framework is a type of manuscript to advance and systematize knowledge by related concepts and empirical study (Rocco & Plakhotnik 2009). The conceptual framework developed in this study is 'intermediary' and 'business model' concepts. This conceptual framework is used as a model guiding the data collection, analysis, and shape of the result. The second duty is what Creswell and Creswell (2017) define as the "endpoint", which is the inductive process of building empirical data to the broader pattern.

However, there are possibilities for choosing other concepts and theories. For instance, stakeholder theory could provide object (e.g., resource, asset) motivated business activity in relation to their stakeholders (Freeman 2016). On the other hand, network theory seeks to uncover diverse patterns between actors in the system and focus on identifying structural importance compared to the intermediary concept (Freeman 2004). Nevertheless, the focus of this study is on advancing a circular bioeconomy that requires an understanding of the relation between different systems, networks, and actors. It highlights the need for waste recycling, and this initiation is not from one side; instead, both sides have a demand to create value from what is considered waste or residual. Therefore, *the concept of intermediary* has been chosen in this study to focus on the relation between actors

rather than solely focusing on the business perspective. Furthermore, the *business model* concept is a complementary part of investigating the function of the business intermediary by value proposition, creation, delivery, and capture. This view enables how entrepreneurs to make use of the business model to align their activities to solve social and environmental problems for various related actors.

3.4 Multi case study and selection of the cases

The use of case study for theory development is prevalent when a relatively new phenomenon is undertaken to study (Yin 2009).

3.4.1 Multi case study

Generally, case studies enable 'extensive and in-depth description of the social phenomenon' (Yin 2009:4). In the business study, the case study design is profoundly used (Bell et al. 2018). According to Flyvberg (2006), a qualitative case study is essential in exploring the phenomena because it contributes to the knowledge through context-specific information and experience. It is specifically suitable when researchers tend to ask exploratory questions, e.g., "how" or "why" in present circumstances (Yin 2009:4). The case study provides an opportunity to use a variety of data for evidence, including interviews, archival data sources, respondent observation, and documentation (Eisenhardt & Graebner 2007). Consequently, researchers will be able to draw results in a broad range of historical, natural, and behavioral matters (Bell et al. 2018).

When the study focuses on the phenomena that constitute different actors, a multi case study is suitable for investigating their unique contexts (Bell et al. 2018). However, there is no broad difference between a single case study and a multi case study; the multi case study has more analytical benefits by strengthening the results (Yin 2009). This study phenomenon is the role of business intermediaries in advancing a circular bioeconomy. This means that business firms are embedded between different actors in terms of their value proposition in the circular bioeconomy context. To advance a circular bioeconomy, the key stakeholders are highly related to the commercialization of sustainable technology and waste-derived fertilizers. Therefore, this study has chosen a multi case study to appeals to more compelling and robust findings for the investigation.

3.4.2 Selection of the cases

Selected cases are presented in *Table 1.* The selection of the cases in this study is based on theoretical sampling, and the special characteristics of the cases were the main principle of selection (Eisenhardt & Graebner, 2007), such as supplier,

retailer, innovator. Further, a snowball sampling was adopted (Bell et al. 2018). Because the study phenomenon presents potential solutions to societal and environmental problems such as water pollution and environmental and societal issues, which is highly relevant for sustainability transitions. Of particular concern is wastewater turned into valuable products such as biofertilizers (diverse potentiality is not accounted for in this study). Therefore, it suggests that wastewater-as-resource could solve some of the sustainability problems. Still, it also demonstrates the complexity of a wastewater system, involving actors from a variety of sectors such as municipality water and wastewater infrastructure, energy, transport, agriculture, sewage, and solid waste management. The plant-essential nutrients recycling business models chosen specific focus in this study because they enable technologies/innovation and upgrading to wastewater-as-resource.

Technically, nutrient recycling can be done before or after incineration; thus, it clarifies several firms actively working in the field in Sweden. Chosen cases are: Biototal, Easymining, Ekobalans, C-Green. However, all four companies are differentiated by their technology/service and location. The pursuit of the firms is to create market opportunities from the wastewater. For a comprehensive understanding of the commercialization process, wastewater and agricultural sectors are selected: Svenskt Vatten from the supply side and Lantmännen and LRF from the customer side.

Table 1. Case organizations' profile

Organizations	**Organization purpose**	**Perspective**
Svenskt Vatten	The Swedish Water and Wastewater Association	Supplier
Biototal	Nutrient recycling firm	Retailer
Easymining	Nutrient recycling firm	Producer
LRF	The Federation of Swedish Farmers	User
C-Green	Nutrient recycling firm	Technology supplier
Lantmännen	Swedish agricultural cooperative	User
Ekobalans	Nutrient recycling firm	Producer

3.5 Data collection and analysis

The data collection from the selected cases and analysis in this study discussed below based on six semi-structured interviews and secondary data.

3.5.1 Data collection

The necessary guidance for data collection is constrained by the naturalistic inquiry strategy, constructivism, and interpretivism paradigm. In naturalistic inquiry, the inquirer should utilize the data collection, as in this study author and the sources can be utilized from both humans and non-humans (Qu & Dumay, 2011). The data collection involves six semi-structured interviews regarding the human source, and secondary data is also collected as the non-human source presented *(see Table 2)*. The semi-structured interview is flexible and allow participants to reveal meaningful information and context-specific description (Qu & Dumay, 2011). Therefore, the author conducted all interviews, approximately 1 hour in duration, using Zoom or Teams.

An interview guide can help the researcher make sure to cover the topic and help with pacing during the interview (Bell et al. 2018). Therefore, an interview guide and agenda have been developed with topic-specific and follow-up questions *(see Appendix 1, 2)*. The interview agenda and topic-specific questions are shared prior to the interview, so participants have been given time to understand the study purpose and prepare the answer. By preparing, participants could have a chance to reveal important information related to the study. However, this preparation could lead to bias where respondents try to influence the result; follow-up questions are thought to reduce bias. The interview agenda used checklists, including anonymity and audio recording of the interview. Thus, all respondents were accepted as not being anonymous in the report and approved the consent letter.

All interviews were audio-recorded, transcribed, and summarized. The result was triangulated with secondary data. Because the author is unfamiliar with the terminology of the sectors, interview transcription, summary, and result were shared with participants to reduce misunderstanding and also to give participants a chance to configure and confirm. The data about Ekobalans is collected from secondary data: company's official website, reports, and regulatory information, and the author justified the selection as it can be most related to the study focus.

Table 2. Respondents and method for data collection

Organizations	**Position**	**Name**	**Interview date**
Svenskt Vatten	Senior environmental advisor	Anders Finnson	12/4

Biototal	Environmental advisor	Bobby Berglund	13/4
Easymining	Product and market developer	Sara Stiernström	20/4
LRF	Sustainability expert	Jens Berggren	22/4
C-Green	Chief technology officer	Peter Axegård	28/4
Lantmännen	Innovation project manager	Pär-Johan Lööf	02/5
Ekobalans			Secondary data

3.5.2 Triangulation

> 'Triangulation is typically a strategy for improving the validity and reliability of research or evaluation of findings' (Golafshani 2003:603).

The triangulation forms the data analysis where data is received from multiple sources, illustrated in *Figure 10.* Each case represents similar (contrast) features to enable triangulation. Triangulation makes it possible to use multiple sources of data which in result access to a range of historical or behavioral information (Farquhar 2012). Yin (2009:115) states triangulation as 'converging lines of enquiry' because it allows converging the multiple sources of data collection. To make triangulation feasible, the question should be formulated and dedicated to getting similar (contrast) data from sources (Farquhar 2012). To gain a broader answer to the research question, data were collected from different perspectives suppliers (Svenskt Vatten), producers (Biototal, C-Green, Easymining, and Ekobalans), and customers (Lantmännen and LRF).

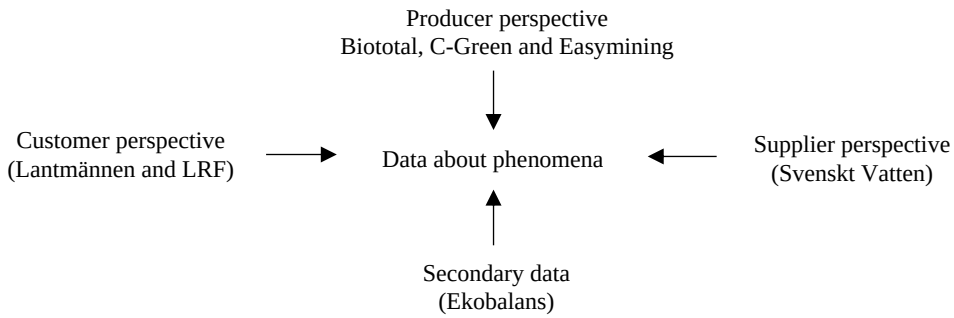

Figure 10. Triangulation of the multiple sources of evidence (own interpretation according to Yin (2009)).

3.5.3 Data analysis

The unit of analysis, themes, and method of analysis is shown in *Table 3.* The *six business models* were identified as the *units of analyses*, and the six participants and secondary data are the *units of observation* in this study. After each interview, transcription, summary and result was prepared by interviewer. Then, codification

is performed to prepare analysis and interpretation. Coding is a crucial step in analysis of qualitative data (Ose 2016). To create more compiled imformation, Excel and Word programs are used for the data codification in accordance with Ose (2016). The interview questions are prepared beforehand based on the conceptual framework, so the coding is divided into four categories based on the interview questions.

In the social sciences, thematic and content analysis is used extensively (Bell et al. 2008), while comparative analysis differs from the others (Fainshmidt et al. 2020). Content and thematic analysis is suitable for in-depth, qualitative study and is based on coded data (ibid.). According to Ragin (1987), when the study focuses on discovering a phenomenon from multiple sources, a comparative analysis suit. A comparative analysis compares similarities and differences between cases, and it helps to identify different roles and emerging patterns from the evidence (ibid.). Ragin (1987:54-55) argues that a comparative analysis can be used to when researcher 'seeks to appreciate complexity'. Furthermore, the selected cases are at different institutional levels concerning companies, associations, federations, and cooperatives. This means a need for multilayer analysis to be able to answer the research question. This study seeks to understand the complexity and find an answer for the phenomenon from multiple sources; therefore, a comparative analysis is carried out. The choice of analysis will depend on the research question for how it can best be answered.

Table 3. Unit of analysis, themes and method for analyses

Unit of analysis	Analytical framework	Themes for analysis	Analysis method
Business models	Functional role	Value proposition	Comparative analysis
	Relational role	Value creation and delivery	
	Appropriation of the value of recycling nutrients in user environment	Benefit and challenge of the user environment	
	Mediating function	Challenge and value capture	

3.6 Quality criteria and ethical consideration

The evaluation of the research quality refers to research rigor which is closely linked to the methodology of this study (Bell et al. 2018). Thus, to speak of quality assurance of a qualitative research relies on the nature of the study. To ensure the rigor, credibility, reliability, confirmability, and transferability have been employed to form the trustworthiness of the study conclusion. Furthermore, the quality of the

study relates to generalizability (Polit &Beck 2010). The broad picture of the small-scale sample refers to generalization. According to Yin (2013), generalization of research results in qualitative case studies is difficult when the number of cases is a few. As Robson and McCartan (2016) imply no replication is exact in practice which means this study cannot claim generalizability. While it can be claimed as applicable in a similar situation (ibid.)

Ensuring *the credibility* of the study is one of the essential criteria for establishing the trustworthiness of the research (Eisenhardt & Graebner 2007). Credibility deals with the compatibility of the findings with reality (Bell et al. 2018). Concerning the sample size, how far represents the total population. Bell et al. (2018) argue that, theoretically, research should be conducted until full saturation of the total population without missing information. However, due to the time limitations of this thesis, six representatives have been interviewed. The respondents are from diverse geographical locations and different sectors; it is argued that a credible sample of the population has been studied. *Transferability* refers to individuals' experiences and provides rich accounts of the context-essential information. It leads to findings as context-specific "thick-descriptions" (Bell et al. 2018:365). With these six semi-structured interviews, which is reasonable to argue this study fulfills the quality of transferability.

The concept of *reliability* concerns whether the study results are consistent (Bell et al. 2018). To ensure reliability in the qualitative study, Yin (2009) suggests documenting each step of the procedure as good as possible. In this study, the performed interviews were recorded and summarized. The final result was written based on the interview transcription, summary, and secondary data collection to ensure reliability. Therefore, it is argued that this procedure improves the reliability of the findings (Creswell & Creswell 2017). Since the study area is highly motivated by engineering and chemistry science, findings can be swayed due to the author's inadequate knowledge. To ensure the findings are established appropriately, *confirmability* has been considered (Bell et al. 2018). After the interview, transcription, summary, and result are written by the author and have been sent to the respondents to confirm. This step has two positive effects: first, it ensures the reduction of misunderstandings, and the next is that respondents will review and adjust to the right terminology.

Trustworthiness relies on multiple accounts of social reality (credibility) and consistency of the data (reliability) explained above (Golafshani 2003). Information from both conceptual and real-world has utility in understanding the phenomena, and the quality of the conclusion aligns with the examination of data trustworthiness (ibid.). Furthermore, it is important to build an understanding of a phenomenon

based on a number of studies. The different investigations might offer different results. It is not necessarily implying that the study is untrustworthy. Instead reflects multiple realities (Shenton 2004), the *triangulation* was used to enhance the trustworthiness of the results. This approach is aligned with Dervin (1997)'s view that information retrieval should be the basic principle of research.

Moreover, the trustworthiness also can increase by the researcher's *familiarity* and knowledge of the subject area (Shenton 2004). For this study, the author has participated in a number of webinars organized by the European Feed Manufacturers' Federation (FEFAC) and Ragn-Sells (FEFAC 2022; Easymining 2022), in order to improve the knowledge of the area. Furthermore, most of the peer-reviewed articles were published recently, which can be reasonable to demonstrate that this study is trustworthy. Since the study field is highly motivated by technological terms, the business study in this area is impossible without engineering professionals' advice; results were reviewed by the supervisors to apply two different scientific perspectives and appropriate terminology, which is a valuable factor for trustworthiness.

3.7 Ethical consideration

In social science research, it is important to be aware of the ethical principles and make informed decisions (Bell et al. 2018). In this study, data collection involves people. According to Creswell and Creswell (2017), it is important to protect such personal privacy, create trust, promote the integrity of the study, and eliminate any chance of misconduct. Therefore, any participation has been *voluntary*, and the decision to participate is made upon being informed about the study's general purpose and how data will be used. To create *trust* with the participants, a consent letter and interview agenda were sent before the interview started, and participants were offered to have the possibility to be anonymous in the report. The interview guide is designed to ensure the data collection is treated carefully and not any sensitive information obtains from participants. In line with the *integrity* of the study and participants, General Data Protection Regulation (GDPR) is used to ensure data protection through technological and organizational measures. Finally, all participants have approved the consent letter or emailed their acceptance. The interview transcription, summary, and result are offered to the participants to *confirm* that the information provided in the interview will be used for the study.

4. Multi-case study

The plant-essential nutrients' value chain in terms of case entities' position illustrated in Figure 11. In this chapter, the result of the empirical data collection from multi case study is presented. The data collection has been made on six semi-structured interviews with representatives of the case organizations, and secondary data.

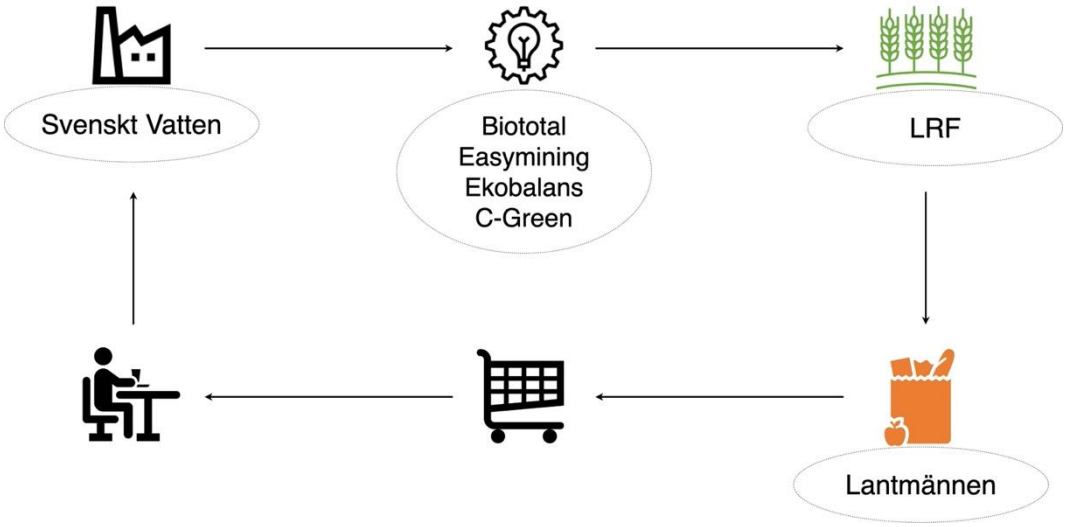

Figure 11. The position of the chosen cases in the value chain (own illustration).

4.1 Plant-essential nutrient recycling firms

This section presents empirical data obtained from nutrient recycling firms Biototal, C-Green, Easymining, and Ekobalans.

4.1.1 Biototal

Biototal is a company that works to get back the nutrients to agriculture and established in 2006, located in Linköping (Biototal n.d). Biototal operates in three different areas: renewable nutrients, circular innovation, and green resource. The *"Renewable nutrient"* is where the company has started (Biototal 2022c). In this area, the company find fields around in Sweden and talk directly to the farmers and

agriculture to use products such as biosolids[3], REVAQ certified biofertilizer[4], liquid biofertilizers[5] from the biogas, and ammonium sulphate[6]. In the area of *"Circular innovation",* the company works with Research and Development projects where they try to reuse resources in different forms of life cycles and develop new products and business areas (Biototal 2022a). For example, projects that investigate aquatic environments, dispersal planning, permits and various certifications regarding biosolids and biofertilizers. Furthermore, the company offers consulting services to both upstream (industries that create wastes) and downstream (municipality WWTPs), it is not only for the product quality but also information about laws and regulations. With consulting services, Biototal helps municipalities and biogas companies to get or maintain certification like REVAQ and SPCR-120. Finally, in the *"Green resource"* area, Biotital works a complete "cover concept", restoring the land to what it once was, for example a meadow or forest (Biototal 2022b). By means, an upper enveloping green layer of vegetation when finishing a landfill or a mining operation where the raw materials are made up of selected by-products and residues that are processed into full-fledged vegetation layers (ibid.).

Biototal is not a producer, instead taking care of fertilizers for agricultural application and coordinating between actors to facilitate resource efficiency. The company creates value by their relation and most importantly they influence the quality of the sewage sludge by their consulting service. By means the Biototal offer services in the whole value chain from WWTPs, companies and farmers, as well as the REVAQ certification system. It helps to get a better product from WWTPs and industries, which in the end creates higher demand from the farmers. The price of circular products such as biosolids with phosphorus and nitrogen is much lower and the product value is renewable. However, farmers are not familiar with the sewage sludge, Biototal provides a much cheaper alternative compared to mineral fertilizers with consultancy. The challenge for Biototal is that between both farmers and WWTPs, the company needs to facilitate possible alternatives for all three parts including their own. Because farmers do not want to pay that much and WWPTs want to get paid as much as possible. Both sides have demand for instance, farmers want only REVAQ sludge.

In 2020, an investigation was made by the government for the wastewater requirements, and it is still uncertain after two years. There are two different products of sewage sludge on the market, one with REVAQ certification and the

[3] *Biosolids* refers to sewage sludge from WWTPs, uses for agricultural application. Biosolids can either be a conventional biosolids or REVAQ-certified biosolids.

[4] *Bio-fertilizer* is a product from the biogas industry used for agricultural application. Bio-fertilizer can be produced from food waste, manure, and other recycling substances.

[5] *Bio-fertilizer* can be divided into two different forms, dewatered or liquid.

[6] *Ammonium sulphate* is a residual product formed by steel production processes

other without REVAQ. If the government changes the regulation for example all the sewage sludge use in agriculture should fulfill REVAQ requirement. It might become hard for many of WWTPs that cannot afford REVAQ due to the quality issue because it takes hard work to have biosolids. Big municipalities can afford it but maybe not small ones. It can also affect Biototal because the company's whole business model is to get the sewage sludge and other waste derived products to where it is useful, like the fields. The environmental consultant of the Biototal explains:

> "It is important (from our point of view) to understand that the products like biosolid and biofertilizers are always compared to the mineral fertilizers. Everything from the prices of nutrients, use of fertilizers (what machine does it take to spread on the fields), storage etc. But the biggest argument for us is that the products are circular and not chemical made."

4.1.2 C-Green

C-Green is founded in 2015 and the headquarters in Solna (C-Green n.d.). The company has strong industrial and financial networks with owners of KIC InnoEnergy, Almi GreenTech, Nordea Bank. C-Green sells industrial plants for converting sewage sludge to a solid product (ibid.). The main activity is to design and build OxyPower HTC plants as well as engineering. To understand how the company builds a plant with consists of a lot of equipment. C-Green manages that through suppliers by building together on-site, which means the different parts of the plant are produced at different workshops and delivered in modules. Therefore, C-Green has the capacity to build a plant in a quite short time from the first part of the plant has been delivered to the site until it is finally constructed and in operation.

C-Green offers a competitive technology because it does not require any external heat, and it is possible to recover nitrogen from the processes as well. The main advantage is the possibility of recovering nutrients with very low emission, with zero cost in heat, and the product is storable (C-Green 2022). Also, when it comes to transportation, the volume is about 20 percent of the sewage sludge with less water and odor are eliminated. The main product, hydrochor, smells more like harder roasted coffee, so it does not have a bad smell. Furthermore, C-Green is a member of Svenskt Vatten. The company provides input to REVAQ certification to make hydrochor from sewage plants in Sweden. For instance, C-Green has been working with Roslagsvatten for almost two years on how to integrate a C-Green plant in their new sewage plant (Christian 2021). This plant will be in operation in 2024 before Roslagsvatten's new sewage plant starts in 2026 and the hydrochor will be used on agriculture (ibid.).

C-Green is supplying equipment to the industries and WWTPs and also takes part in projects partnering and collaborating with others. For instance, the company has built a plant at one of Stora-Enso's mill sites (packaging paper producer) in Heinola, Finland (EIT InnoEnergy 2019). The plant will be handed over to Stora Enso soon. Furthermore, MEWAB (the company that handles waste from different sludge producers, basically converting pulp mills and sewage sludge to soil products) has received funding from Klimatklivet in Sweden for the project to produce hydrochor that will replace peat into soil products, including HTC plant from C-Green (Mewab 2021). Hydrochor is a solid and more stable product for soil products in the future. Then the C-Green is collaborating with Biototal, EcoNova and StoraEnso in terms of handle and use the product hydrochor, this is called 'productization'. Because there are different applications, replacing peat, for instance. Peat is widely used, and it is classified as a fossil in 2021 in Europe because it has been widely used for soil products and energy in Northern Europe, and now that is concerned as scarce. So, there is a lot of research for finding options to peat, which is hydrochor is one of the options. With Easymining and Ragn-Sells, C-Green has got funding for their plant at one of Ragn-Sells waste handling sites. And the long-term plan is to use that technology to recover phosphorus by ash leaching after incineration of hydrochar from sludge.

Although, there is also a challenge because it is a new application using hydrochar from sewage sludge on farmland the C-Green Chief technology officer says:

> "… very few people understand that sludge from pulp mill or sewage plants, is very similar actually. It is basically the same chemistry. In both cases have a lot of bacteria (proteins) that needs to be removed from the sewage plant and precipitation chemicals. So, it's very similar mixture, actually you get the similar results. I think it's more a mental challenge, does it work with the sludge? Of course, it does, it says in chemistry and in C-Greens pilot plant and laboratory, but to convince people is another story."

He also states that the sewage sludge varies from site to site. For instance, C-Green has studied a lot of different sewage sludges and found that there is a big range in contamination in terms of heavy metals. Therefore, it is possible to find everything from very low values below the threshold levels to higher levels that exceed what is allowed. It depends on the location and upstream wastewater suppliers. If you have the industries upstream, it can be a complication. For instance, Roslagsvatten has only households. On the other hand, the legislation might hinder indirectly, says he:

> "If anyone has decided to go for a C-Green plant, then there's no problem from a legal point of view. But environmental permits can take up to two years; that is the same for wind power energy sector. But the biggest concern is the lack of understanding; of how the sludge will be treated in the future and what will be required by the authorities. Today, we have a situation where, for instance, sewage sludge is used on

farmland and if it fulfils certain criteria for heavy metals. But those levels were defined almost 30 years ago. What will update in the case of authorities reduce this number by 50%, or will there be a ban on land applications? That is a big uncertainty."

4.1.3 Easymining

Easymining is an innovation company founded in 2007, head offices are located in Uppsala, Gothenburg, and Berlin (Easymining 2022). In 2014, the company was bought by the Ragn-Sells Group. The Ragn-Sells Group is a privately held corporate group and the biggest waste management company in Sweden (Ragn-Sells 2022). The focus of the Easymining is on chemical recycling for more advanced solutions by developing technology for nutrients and other materials recovering from wastewater. Today, Easymining has almost 40 employees, and its core business is to develop technology and projects to extract nutrients and other materials from wastewater (Easymining 2022). The company holds a number of patents and is building full-scale. Below describes the current project that are in process (ibid.).

Ash2salt is a plant built at Högbytorp in Stockholm ((Easymining 2022b). The plant will start operating in 2022 with a capacity to recover salt from 130 000 tons of fly ash[7] which is more than one-third of all the Sweden's produced fly ash. The plant is totally owned by Ragn-Sells. But the license is Easymining holds together with Hitachi Zosen Inova. Hitachi Zosen Inova, in partnership with Easymining, holds the patent to build Ash2salt in 12 other countries outside the Nordics. Meanwhile, Ragn-Sells and Easymining are building more plants in the Nordics. Ash2salt plant can solve many problems by recovering salts for many other industrial applications

Project N is demonstration plant, and it aims to demonstrate a totally new way of extracting ammonium from different waste streams (Easymining 2022c). The demonstration plant was funded by EU LIFE with 40 million Swedish crowns, and it has been tested at Högbytorp. The leachate run-off from landfills contains a lot of nitrogen, at least from the old landfills when organic wastes were still allowed on landfills, though it is not the case in Europe today. In March this year, the project has been moved from Högbytorp to Copenhagen, and the site at Biofos, Denmark's biggest water treatment company. WWTPs in Europe, on the one hand, want to have less nitrogen runoff due to eutrophication[8] and increasing regulatory limitations. On the other hand, ammonium sulphate users are more interested in

[7] Fly ash is produced from burning household wastes or other materials and carried into the air.

[8] Eutrophication is an excessive richness of nutrients in a fresh water such as lake due to run-off from the land and it causes a dense growth of plant.

cleaner products. Project N and Ash2salt are both easy to implement in many different countries, which is beneficial in economically and technically.

Ash2phos is a plant for extract phosphorus and can use in many different countries (Easymining 2022a). The first plant will be in Germany together with a German company called Gelsenwasser. The second one is in Helsingborg in Sweden. There will be precipitated calcium phosphate, which can be used directly as a fertilizer or feed phosphate. IN The Ash2phos process up to 95 percent of the materials being produced can be used as products the remaining 5 percent will to be landfilled, which is the heavy metal cake. the technology enables total decontamination because the organic pollutants and microplastics are incinerated and destroyed and the heavy metals separated in the actual Ash2Phos process.

Easymining aims to present a solution for recycling nutrient from sewage sludge where there is need of decontamination. Their technology is not only to solve the wastewater problem but also the product problems by extracting valuable resources from wastewater. For instance, Project N will enable municipality WWTPs to reduce CO2 emission, less release of N into the atmosphere, and less loads of N in the system. Eventually will help municipality WWTPs to have more people connected, and to be a part of the circular value chain where clean products are brought back to the society. Ash2phos on the other hand, is a solution to get back purified phosphorus to society in a safe way.

The challenge regarding chemical recycle is the regulation because it is prohibited to use raw materials from waste to make fertilizer and feed phosphates[9]. To transform to circular economy, the legislation is essential in a sense that changing the practice among farmers and users to start using recycled materials says product and market developer of the Easymining. She also states that the pricing is also a problem because extracting virgin resource is much cheaper than recycling today:

> "We want to push for a circular economy, climate needs circularity. If we are serious about building a sustainable society, we have to start using the materials we already have – over and over again."

4.1.4 Ekobalans

Ekobalans has its origin in plant - nutrient balances in cultivation and nutrient cycle systems research at Lund University since 1990s (Frisk 2012). The core operation of the company began with consulting services in forest fertilization. With the help of loans and money from venture capital companies, Ekobalans developed a process

[9] Inorganic salt which is essential nutrient for animal diet.

for separating nutrients from the substances such as wastewater. These processes can assemble fertilizers entirely based on recycled and decontaminated products like fertilizer with plant-essential nutrients (ibid.).

In 2008, Ekobalans has started its operation as a nutrient recycling company (Finnson & Lind 2021). The company operates in four areas biogas, WWTPs, selling technologies and products as fertilizer (Ekobalans 2022). The main technologies are developed to recycle nutrients from wastewater are: eco:P, eco:N and eco:S respectivel for extracting phosphorus, nitrogen, and remove cadmium.

For instance, digestion or biofertilizer contains 92-98 percent water which makes high transportation cost and storage space most importantly plant-essential nutrients in it (Ekobalans n.d.a). The technologies eco: P and eco: N treats the biofertilizer by dewatering and drying. These technologies are useful in many places for instance small scale farmers that can enable locally produced fertilizers. The advantage is this make easier for the cost and space but also, eventually contribute to the climate impact reduction (ibid.). The technology eco:S is effective way to remove cadmium in the sludge, with special process called “pyrolysis” (Ekobalans n.d.d) and it is a simple and relatively cheap technology. It can recycle almost all the phosphorus from wastewater and more than 75 percent of the nitrogen from the wastewater. Therefore, it can be profitable in small and large scale. According to Ekobalans (n.d.d), the process pyrolysis is a well-known method for converting organic materials into biochar and energy-rich gases. With eco: S can separate 90 percent of the sludge's cadmium content and get phosphorus-rich biochar. Soon, the company will start to sell biochar product that can be used on the farmland (Ekobalans n.d.b). Moreover, depending on the customer, the company has a flexible offer either can sell nutrient extraction plants, take care of the plants under contractual agreement, or own the plants (Ekobalans 2022).

4.2 User environment

Here in this section presents case study of the user environment (LRF, Lantmännen, and Svenskt Vatten).

4.2.1 Lantmännen

Lantmännen is one of Sweden's biggest food industry complex, owned by 19 000 farmers. In the Swedish market, Lantmännen is in the top handle, with a turnover of about 50 billion Swedish crowns (Lantmännen 2022b). The industry works in different sectors: food, agriculture, bioenergy, machinery, and real estate business (Lantmännen 2022a). Furthermore, Lantmännen has different kinds of support

groups that work throughout the whole group, for instance: R&D, human resources, legal affairs, and sustainability. Today, Lantmännen operates in around 20 countries, including the USA, Australia, Poland, Belgium and Germany etc (Lantmännen n.d.a). Because Lantmännen is the biggest food supplier on the market, they are concerning product process at all levels including fertilizer that using in farmland as well as soil health. It is not only because of product process, but also for the farmers best.

To have safe products and keep consumers' trust, Lantmännen sets requirements when they buy crops from farmers. In the contractual agreement between two sides, clearly states if the sewage sludge is not allowed to be used as fertilizer on the farmland (Lantmännen n.d.b). Sewage sludge is not the only consideration but also other chemicals like straw shortening products and use roundup before preharvest sprays. This restriction varies depending on the market where the products will be sold. For example, it is accepted to use sewage sludge on bioenergy products. Whereas it is not allowed in the Swedish food market. If the product goes to the international market for exporting, that is different case. Because there is not any restriction from foreign customers such as large warehouses and traders. Hence, from the Lantmännen's perspective the use of sewage sludge on farmland is more practical than ethical aspect.

In Sweden, some soils contained high levels of cadmium. Therefore, it is required to have decisions with care of soil when to use fertilizer. For instance, mineral PK fertilizer is much safer because information is clear on what is in the fertilizer with a specific amount of cadmium. But when it comes to sewage sludge, the system is uncontrollable, and it could differ over time which is impossible to know what is in it. Also, there is no guarantee that products are safe. However, there are different kinds of certification systems, Lantmännen consider they are still not enough to control this systemic problem and some unwanted substances. The biggest hinder to use sewage sludge-as-fertilizer is that water treatment plants use aluminium to take the wastewater out. Because aluminium and iron-binding the phosphorus hardly to not make phosphorus-free in the water which eventually effects phosphorus solubility for crops. Therefore, when using sewage sludge as fertilizer, it will not have the effect that one could assume.

For that reason, Lantmännen is more interested in finding out system that could select cleaner product and willing to support. Therefore, Lantmännen cooperating with plant-essential nutrient recycling companies such as Ragn-Sells and Easymining. Lantmännen has been following and supporting Easymining for many years from when it was a research project. Now Lantmännen try to take to the market together with Ragn-Sells. For example, Easymining technology (Ash2phos), will get different kind of materials ammonium phosphate,

diammonium phosphate, and they are water soluble. It is important for the food sector to enable safe and secure product value chain.

In future sustainable agriculture, nutrient recovering, and recycling technologies are necessary. It is important to find out systems that works well with *effective* and nutrition point of view that are *safe*. Safe is both heavy metals but also other unknown components from industry, health care products, microplastics. Good thing with burning because destroy all the hazardous substances and concentrate them in the ash. Then clean up the nitrogen and fraction with unwanted substances that could go to disposal.

Today's regulation is not strict; if sewage sludge has just low levels of heavy metals such as copper or cadmium, it is allowed to use that for agriculture by the law. The only thing is that farmers need to be aware of the standard that every five years should use 110 kilos of phosphorus per hectare. But the rules say nothing about sufficiency and quality, where Lantmännen's R&D project manager emphasis:

> I think the system, regulators in Sweden, they are not focus on the right thing because if it could have more concrete rules that system should bring for example phosphorus back into the system on a clean and efficient way, then it would more speed up the research and development for new efficient systems. The main part of sewage sludge today goes just untreated out to the fields and that's not a good system. But that's how the regulations today.

This is problematic when it comes to developing a new system. The restrictions are the documents. Lantmännen looking at the documents, if there are other restrictions in new levels, it could be of products or market shift. Right now, mineral fertilizer price has become very high due to the Russia and Ukrainian war, which is heavily effects to the farming economy. On the other hand, the Paris agreement that focuses on sustainability in a different way which makes fossil-free fertilizers and systems with low climate impacts are attractive for all investors, customers, and producers. That could also change the priority of agricultural sectors as fossil-free products. Things are changing.

4.2.2 LRF

The Federation of Swedish Farmers – LRF – is a broad tent organization consisting of approximately 140 000 individual members and almost 70 000 industries and enterprises in the forestry and farming community in Sweden (LRF 2021). Most of the members have forest and agricultural land, including agri-cooperatives such as Arla and Lantmännen. The federation has many different encompassing activities often divided into different types and places: dairy farmers, pig farmers, other crop producers or virtual gardens, and greenhouses in separate organizations (LRF

2018a). Throughout their activities, LRF focuses on creating appropriate condition for the sustainable industries, ideally, social life and enterprise in rural areas (LRF 2018b). Thus, LRF is a political lobby organization, involving in politics on how to improve the conditions, for instance wastewater management.

LRF does not have formal collaboration with the nutrient recycling companies. Through their engagement in REVAQ steering group, LRF collaborates with Svenskt Vatten, involving in discussions about opportunities and how to increase REVAQ's requirements for the content of the heavy metals as such (Svenskt Vatten 2022). On the other hand, the federation does not control or tell the members what to do but tries to be more constructive and navigate to a more sustainable solution. Therefore, LRF does not control what members use on their farmland such as fertilizer. In general, many of the farming operations in Sweden do not have farming as their only activity or might not even be their biggest economic activity; they work, have a farm, and produce grains or meat. Also, some of them in the other parts of society running enterprise activities such as day-care or healthcare. For that reason, the bigger farmers might use REVAQ-certified sewage sludge or other waste-derived fertilizer on their farmland, but it is not a significant amount.

LRF's biggest concern is the system that benefits all. However, the market is still not ready to use more recycled nutrients for agricultural applications today. The sustainability expert of LRF highlights that 'behaviour' is the main challenge, among others to trnasformation. He implies:

> "… behavior change is always hard part to reach, we need consumers maybe to accept. But right now, if you use a recycled nutrient, food industry would not take your crops. I mean they can go to some parts. To accept the situation where the bread actually been made from cereal to have been watered with sewage sludge or the strawberries have been irrigated with recycled water. Then the quality should be controlled, not held of hazard; not in the short term of hygiene purposes but also in the long term contains of persistent organic compounds. So, the acceptance and safety are very important to overcome this challenge."

4.2.3 Svenskt Vatten

Svenskt Vatten (SV) is the association for all Swedish water and wastewater companies (Svenskt Vatten 2017). By the Swedish law, water and wastewater have to be owned by the municipalities. However, Svenskt Vatten membership is voluntary based, all municipality WWTPs are a member of Svenskt Vatten. The main activity for the members is providing education, training, seminars, and events. Furthermore, Svenskt Vatten helps members with technical guidelines and lobbying or advocacy work in Sweden and the EU parliament in Brussels (ibid.). The association has a representative in the EU parliament in Brussel from

November 2021 because wastewater and chemicals are becoming essential in European legislation making for a circular economy (Svenskt Vatten 2021a).

Swedish legislation for wastewater management is from 1994, which is not enough and strict to control hazardous. Therefore, REVAQ is initiated by Svenskt Vatten and established in 2008 together with Swedish farmers LRF and the Swedish Food industry. To have confidence in the system, Svenskt Vatten operates REVAQ together with the LRF, and the Swedish food industry, to set their requirements. Swedish municipalities are the owner of the Svenskt Vatten, which means members own the systems. Today, REVAQ is one of the most challenging certifications in the Scandinavian countries and is still being developed.

From the resource point of view, all the sewage sludge from wastewater is produced by the ten million inhabitants in Sweden. More than 36 percent of this sewage sludge is used to agriculture with or without REVAQ quality assurance. The remaining more than 60 percent is used for landscaping and land reclamation. In terms of sustainability concern, this is problematic. For example, the use of sewage sludge in green areas along highways may not be sustainable in the long run. Therefore, new technologies can be used on sewage sludge that cannot fulfill REVAQ requirements. Nevertheless, the market is quite extensive for the companies because REVAQ is only for the finest sludge. For instance, Uppsala has strict control over connected industries, metals, and hygienic requirements. Today, a little more than five million swedes are connected to REVAQ certified WWTPs. On the technology development, the senior environmental advisor of Svenskt Vatten implies:

> "Today we have the legislation, and it is possible to use sludge on agricultural land but, REVAQ has higher demands than the legislation and is also getting little bit tougher each year and maybe water companies will not have the right sludge quality in 5-10 years. So therefore, look into other technologies at the same time, so there is a lot of interest, especially for all the wastewater companies and water companies in northern Sweden […] there is a lot of interest in this part of the country to find a new technology and maybe technologies from where you can work in a small scale like Ekobalans or C-green where you don't have to have big mono-incinerator. But in south of Sweden, there is a lot of interest from the bigger cities to follow the development of Easymining incinerators."

The companies have important role in converting sewage sludge to agricultural product, and also helps to restrict chemicals by their technologies. At the same time, it is essential to develop infrastructure. New development in wastewater treatment plants in Sweden on its way. For example, a project in the city of Helsinborg called H+ and water and wastewater company (Helsingborgs stad 2021). This is the system that separates the black water from toilet in one pipe, and gray water from

shower and dishwasher in another pipe to have cleaner resource in the end. This project can enable less chemicals in the sludge, easy to keep in good quality, and also good way to not load or the stress the wastewater treatment plant where there is separated systems. There are few other plants as well such as Stockholm, Visby, and Gotland. Perhaps there will be more in Swedish cities in the future. The senior environmental advisor of Svenskt Vatten emphasis:

> "It is always good to have several competitors on the arena. We would like to see more companies which is better for the technology development and for our members, so we will see quicker development and also lower prices for our members. If there is only one provider, they could take whatever prices so that will be more expensive for our members and therefore the water and wastewater tariff for you and for me would be more expensive."

Hence one could see a mixture between treatment plant delivering high quality sludge to the agriculture land and new technologies that will be able to share to work together with.

The strategy of the Svenskt Vatten is to *not to use* sewage sludge on agriculture land outside REVAQ certified WWTPs (Svenskt Vatten 2022). Sewage sludge can be used directly on the agricultural land with REVAQ. If that is not possible due to lack of agricultural field, long-distance, or low quality, *recover* the nutrient as possible such as phosphorus, nitrogen, and the carbon. The next stage is to *reuse* at least the organic matter for landscaping. If it is not a solution, at least use in *energy* making for incineration. The final solution is going to *waste* side, but that is most of the case not possible in Sweden.

Svenskt Vatten works closely with the companies Easymining, Ekobalans, C-green and other smaller companies, try to support in a way which will be the best for both sustainable circular economy and for the members of Svenskt Vatten. To this extent, Svenskt Vatten organize 'speed-dating' (meeting) to let companies meet the members or help them with the contacts. Also, representatives from Svenskt Vatten are involved in many projects from nutrient recycling companies by reference groups such as Project N from Easymining, development project by C-green and Biototal.

In 2018, the Swedish government assigned delegation for the circular economy to form an expert group on sustainable and circular water and wastewater services. Together with SLU professor Håkan Jönsson, managers from the water and wastewater, and nutrient recycling firms Easymining, Ekobalans and C-Green, published a report in 2021 (Svenskt Vatten 2021b). The report was about the new legislation needed to transform the wastewater treatment plant into a resource treatment plant. The main focus of this report was not only on nutrient recycling,

but also on reusing treated wastewater in a changing climate in agriculture and industries.

The challenges in WWTPs today, associated with the chemicals like PFAS used in society (Svenskt Vatten 2022). It is a growing problem for the environment and human health as it is polluting the drinking water. There are about five to seven thousand different PFAS for organic and widely used, e.g., firefighting foam, outdoor clothing to be water repellent, cosmetics, and liquids for the dishwasher. It is essential to restrict the use of chemicals to reduce environmental and societal burdens. While it is concerned at last on the EU agenda. The retailers have an essential role to be ahead of a slow legislation and voluntary phase out all PFAS from all their consumer products.

5. Analysis and discussion

This chapter presents a comparative analysis and identifies differences and similarities between the cases, answer the research question and finally discusses the results of the findings.

5.1 Comparative analysis

This section presents the comparative analysis and identifies differences and similarities in the business model between selected cases Biototal, C-Green, Easymining, Ekobalans and user environments as Lantmännen, LRF, and Svenskt Vatten. Analysis combines the business model concept with the concept of intermediaries. Value proposition represents the functional role of business intermediaries as in the value the firm produces to its target customer. Value creation and delivery represents the relational role of the business intermediary as in the practices deployed to create and deliver value to its target customers. Value capturing represents the appropriation of value by the customers and for the firms.

5.1.1 Functional role

The business model's value proposition related to its target customers is analyzed in *Table 4*. This analysis focuses on understand functional role of the business intermediaries in the context of wastewater-as-resource. Two types of target customers were identified: farmers and WWTPs. Biototal is a company that focuses on agricultural applications, and therefore the target customer is farmers. It must be also noted that Biototal also offers consulting services to WWTPs and other waste producing industries. But the main target of this service is to get better quality fertilizer for agricultural application, therefore here presented as farmers. In comparison, C-Green is a technology and engineering company focusing on mobilizing technologies for WWTPs and other related projects. Meantime, both Easymining and Ekobalans share a number of characteristics. Both companies have nutrient recycling technologies, focusing on both WWTPs and farmers. A significant difference in their technology is that Easymining's technology is a full-scale plant that extracts nutrients from wastewater after incineration. In contrast,

Ekobalans technologies work on large and small scales, and wastewater does not need to be incinerated.

Table 4. Business model functional role performed by selected firms.

Firms	Value proposition What?	Target customers
Biototal (2006)	Maintaining and facilitating waste-derived fertilizer for agricultural application.	Farmers
C-Green (2015)	Design and build OxyPower HTC plants as well as engineering equipment for waste treatment plants and industries.	WWTP
Easymining (2007)	Chemical recycling for more advanced solution by developing technology for extracting nutrients and other materials from wastewater.	WWTP and farmers
Ekobalans (2008)	Developing technologies and system solutions to enable nutrient recycling of plant nutrients and carbon.	WWTP and farmers

5.1.2 Relational role

The business models' value creation, delivery, and key activities are analyzed in *Table 5*. All case companies are here to create value from wastewater, and their activities are associated with value creation and delivery, varied though. Four types of key activities have been identified: *consulting*, *selling*, *developing and partnering*, and *networking*.

1. *Consulting activity.* Biototal's priority area is agricultural application. Therefore, the company is giving consultancy to WWTPs on how sewage sludge can be better treated and assisting in getting REVAQ certification. Biototal also guides farmers on how to use the sewage sludge-as-fertilizer or other waste-derived fertilizers. Similarly, Ekobalans also offers consulting service to farmers and WWTPs, but it is dedicated to their technology and products.
2. *Selling activity.* Two different products that the business models create value from: plants and equipment for wastewater utilities and waste-derived fertilizer for agricultural applications. C-Green and Ekobalans are *selling* plants and equipment to WWTPs. The difference is that C-Green does not own the plant, and Ekobalans is with flexible management such as owning, managing under contractual agreement and selling. On the other hand, Easymining focuses on the full-scale plant projects. For the agricultural applications, Biototal and Ekobalans selling fertilizers derived from wastewater to the farmers. The difference is that Biototal sells fertilizers from different industries such as biogas products, biofertilizers, and biosolid from nutrient recycling firms, biogas industries as such. In comparison, Ekobalans sells their fertilizer extracted from wastewater by

their technologies. Additionally, Easymining has test fertilizers from their demonstration plants which are not selling yet on the market.

3. *Developing and partnering activity.* Easymining develops several projects such as Ash2phos, Ash2salt to build full-scale plants, and other companies are partnering in different types of development projects. For instance, the project in the Roslagsvatten, C-Green as a technology supplier, integrating their HTC plant in the new wastewater treatment system. While Biototal is partnering in agricultural applications, which means that the company will sell the fertilizer from wastewater to the farmers in the future. On the other hand, Ekobalans installs their technologies eco:N and eco:P in the Reco Lab in Helsinborg. Overall, these projects are mainly dedicated to WWTPs to manage wastewater better and are funded by different foundations and investors, e.g., EU life, and RISE.
4. *Networking activity.* There are numbers of networks that representatives from various companies and organizations could join, discuss and relate their work. The networks are committed to providing information, round table discussions, and developing different goals such as innovation, circular economy, etc. Some of the identified networks were 'Delegation för circular ekonomi' (Svenskt Vatten 2021), CIRCLA (Rise 2022a), and 'Näringsplattformen' (Rise 2022b).

Table 5. Relational role in terms of value creation & delivery.

Firms	Value creation	Value delivery	Key activities
Biototal	Communicating with actors such as REVAQ, WWTPs and other industries in the upstream wastewater to create better quality sewage sludge and also waste derived fertilizers.	Selling fertilizer to the farmers and giving consultancy to the WWTPs to get quality certification.	Consulting, selling, and partnering
C-Green	Mobilizing technology from technology developers that can be applied to recycle nutrients from wastewater.	Equipment and recycling plants are delivered to Water utility	Selling, partnering, and networking
Easymining	Developing full-scale plant-essential nutrient recycling plant projects.	Building full-scale plants for WWTPs.	Project developing, networking, and partnering
Ekobalans	Building and selling plant-essential nutrient recycling technologies, and plants to the WWTPs. Also selling recycled fertilizers to the farmers.	Selling, managing, and owning nutrient recycling from wastewater plants, and technologies to the WWTPs. Also selling	Selling, partnering, and networking

		wastewater derived fertilizers.	

5.1.3 Appropriation of the value of recycling nutrients in user environment

The appropriation of the value recycling nutrients in user environment is analyzed by their benefit and challenges in *Table 6.* The challenges are also differing between these actors. All three organizations were different opinion toward nutrient recycling companies due to their value chain position. Benefit for example for the Svenskt Vatten (representing the WWTPs) is to reduce environmental and societal impacts by limiting hazardous substances before to reach environment. For the food industry Lantmännen, enabling more secure alternative fertilizer that can enable food value chain safer. The benefit for the LRF (representing farmers) on the other hand, farmers will have more confidence for the system to use wastewater derived fertilizer. From the user perspective, farmers are currently facing challenges with high fertilizer prices because of war between Russia and Ukraine. Therefore, recycled nutrients can be an alternative that might be cheaper, most importantly renewable and get market acceptance such as food industries. Besides food market is today limited by regulation to use waste derived fertilizer further analyzed.

Table 6. Appropriation of the intermediary role in user environments.

Entities	**Benefit to working with nutrient recycling firms**	**Challenges to solve**
Svenskt Vatten (WWTPs)	- Reduce CO2 emission - less environmental (P and N inflow) and societal impact. - More people be connected to REVAQ certified WWTPs. - WWTPs could be part of value chain. - Enable transformation of WWTPs to resource treatment plant.	- It is getting harder to fulfill REVAQ quality assurance. - It is challenging to manage wastewater. - Budget is inadequate. - Costly to change infrastructure. - Legislation is not strict enough to prevent major hazardous materials from upstream level.
	To enable transformation of wastewater treatment plant to resource treatment plant.	
Lantmännen (Food industry)	- More fertilizer availability. - Secure and safe product value chain. - Market acceptance.	- It is prohibited to use sludge-as-fertilizer in Swedish food market by the law. - Mineral fertilizer price is increasing. - Regulations do not focus on the clean and efficient system that can bring back nutrients to the society.

	To have secure product value chain and sustainable agriculture.	
LRF (Farmers)	- Farmers will have more confidence in using waste-derived fertilizer on their farmland. - Using recycled fertilizer can be cheaper than mineral fertilizer.	- Farmers need to follow food industry requirements to sell their crops. - Today's farms mostly depended on mineral fertilizer.
	To have confidence for the system and get access to the market.	

Challenges faced by business models and value capture for the firms and key stakeholders presented in *Table 7.* The challenges faced by user environment and business firms, were varied. For the wastewater utilities to solving issues related chemicals already used in society, is a challenge. Because these chemicals ended up in the sewage sludge which is farmers and food industries concerning its contaminants. While the common challenge expressed by business firms were regulation. For C-Greeen and Biototal expressed that the regulation makes uncertainty for their future. For the Biototal, the company assists on use of sewage sludge with REVAQ and without REVAQ assurance to farmers and also land covering projects. While for Easymining, marketing is limited because waste-derived fertilizer is prohibited to use for food production. The next challenge expressed by respondents were pricing. Because producing wastewater derived fertilizer costly and it makes less competitive on the market.

Value capture for the firms is for the firms are the resource related as wastewater is undervalued and other value is projects that can be fully recognized as future value for the firms. While for the customers there are three types of value captured: first it is related to technologies for the WWTPs. The next it is related to resource efficiency which makes possible to reuse nutrients. Third it is related to safety of the food value chain that can enhance the market for the farmers and also reduce societal tension.

Table 7. Business model as mediating function, the value capturing process

Firms	**Identified challenges**	**Value capture** **For whom?**
Biototal (2006)	- The product is undervalued by buyers (farmers), while economic interest from WWTPs. - Uncertainty regarding future change in regulation.	- *For the company*: low transactional costs, income from new unvalued products in the society - *For others:* additional incomes for the WWTPs and other waste producing industries, offering cheaper product than mineral fertilizer on the market.

C-Green (2015)	- A relatively new application that society, in general, is not knowledgeable. - Uncertainty regarding future change in regulation.	- *For the company:* lower cost from installment of the technology; not need big investments. - *For others:* cheaper than alternatives which makes economically feasible for WWTPs and industries.
Easymining (2007)	- Pricing is a challenge because mineral fertilizer is easier and cheaper business today. - Legislation barrier makes harder to reach market.	- *For the company:* large-scale projects are developing and new market exploration and promising future income. - *For others:* additional incomes for other partners in the project and wider product selection. It will reduce transportation cost (fly ash compared to sewage sludge).
Ekobalans (2008)	- Legislation barrier makes harder to reach market.	- *For the company:* partnering projects; lower cost; not need big investments; good quality products. - *For others:* lower cost concerning transportation and storage; locally produced biofertilizer; additional income; wider selection.

5.1.4 Summary of analysis and research findings

The summary of analysis presented in Table 8 and it enables to answer the research questions.

Research question 1: What intermediary roles are developed by firms to recycle plant essential nutrients from wastewater?

Functional role: However, there are diversity in business models regarding their value proposition, the comparative analysis shows two distinct features: (i) mobilizing technology for plant-essential nutrient recycling from wastewater to produce fertilizer and (ii) ensuring wastewater-derived fertilizer for agricultural application.

Relational role: In the context of a circular bioeconomy, business intermediaries work in-between wastewater utilities (waste producers) and agricultural applications (resource users) in terms of value creation and deliver.

Appropriation of the value of recycling nutrients in user environment: Three dimensional appropriations from the key actors aligned by business models. It means the beneficiary of the business intermediaries' value of recycling nutrients

from wastewater: technology availability, resource efficiency, and value chain safety.

Research question 2. What challenges associated with their business model have they identified, and how do they seek to overcome identified challenges?

Mediating function: This comparative analysis shows that the challenge associated with the business firms in the context of wastewater-to-resource is the regulation and pricing. Because it limits commercialization of the wastewater derived fertilizer. To overcome this challenges, different recycling technologies and different commercialization activities are developed but it is still not the only way to advance circular bioeconomy. Therefore, developing projects, partnering with other actors and networking activities deemed to overcome associated challenges.

Table 8. Summary of analysis

Firms	**Functional role of business intermediaries**	**Relational role of business intermediaries**	**Appropriation of value by firm and its customers intermediaries' role in user environment**
Biototal	Waste-derived fertilizer for agricultural application	Consulting, selling, and partnering	For the firms value captured by resource and project. For the customers value captured by technology availability, resource efficiency, and safe and secure value chain.
C-Green	Mobilizing technology development for WWTPs and other projects	Selling, partnering, and networking	
Easymining	Bringing large-scale technology and clean products for agricultural application	Project developing, networking, and partnering	
Ekobalans	Bringing feasible technology to WWTPs and recovered nutrients for agricultural application	Selling, partnering, and networking	

5.2 Discussion

The present study was designed to investigate the role of business intermediaries in advancing a circular bioeconomy—particularly focusing on the implementation of plant-essential nutrient recycling from wastewater for agricultural applications in Sweden. To gather broad understanding, multi-case study was undertaken on plant-essential nutrient recycling firms that are actively working in the field namely

Biototal, C-Green, EasyMining, Ekobalans, and their key stakeholders, Svenskt Vatten, Lantmännen, and LRF. Regarding the functional role of business intermediaries, the target customers were identified as WWTPs and farmers. The results indicate that the plant-essential nutrient recycling firms have shared features (e.g., ensuring fossil-free fertilizers for agriculture) and specific features depending on their sustainable technology/fertilizer – (e.g., solving big city level wastewater management or farm-level management).

Regarding the functional role of the business firms, the target customers identified in this study were WWTPs and farmers. The comparative analysis confirms two distinct features of business models in this context: *mobilizing* the technology for plant-essential nutrient recycling from wastewater to produce fertilizer and *ensuring* wastewater-derived fertilizer for agricultural application. About the relational role, in terms of value creation and delivery, these firms operate in-between wastewater utilities (wastewater products) and agricultural applications (food sectors and farmers). Further, the appropriation of the value of recycling nutrients in the user environment is identified as technological availability, resource efficiency, and a safe and secure value chain. The result shows the common challenge for all these business firms is regulation. Furthermore, the pricing is also a challenge in competing with a traditional business model.

Moreover, the result shows that the difference between cases lies not only in technological or product aspects but also in their activities in relation to value creation and delivery. As such, there are not only business firms are intermediating but also other intermediary actors (e.g., Lantmännen, LRF, Svenskt Vatten, RISE) and their partnership is critical to exploring the market for sustainable products/technology. Because in a circular bioeconomy, waste of the one actor becomes the resource of the other actor (Puntillo et al. 2020). In this regard, business firms are embedded within the different institutional actors, which requires entrepreneurs to align their business model in relation to other actors (Doganova & Eyquem-Renault 2009). This result also in line with Lüdeke-Freund (2020) that stresses the relevance of partnership and network in order to create and deliver value from waste. Given that the policy context is in flux, this knowledge relationship might form a new different relation between wastewater system and agriculture system. These alliances may enable more value creation but also shape the direction of appropriate implementation of a circular bioeconomy.

The complex nature of wastewater is not only a national agricultural or local environmental issue; it involves diverse actors globally (Peterson et al. 2022). Business intermediaries' role is pivotal concerning their technological advancement and entrepreneurial processes. This study result also shows that the wastewater-as-resource business models support advantage in geographical

presence, meaning that the human and economic activities link between urban and rural environments. This is important in the process of wastewater becoming a resource/asset by a change in coordination and management mechanisms of the wastewater-as-resource.

6. Conclusion and future recommendation

This paper has sought to give insights into the practice of wastewater to resource activities related to business firms in advancing a circular bioeconomy. In the context of wastewater-as-resource, the function of the business model is to maintain and facilitate the agricultural use of wastewater-as-resource through technology and knowledge. In the circular bioeconomy, these business firms are intermediating in-between wastewater utilities (waste producers) and agricultural applications (resource users). Therefore, business intermediaries not only play key roles in terms of "mediating" material flows to advance circular bioeconomy in this context; they are also mediating knowledge flows through collaborations with key actors (such as food industries, wastewater utilities, and farmers) and through network activities – where learning about the value of recycling nutrients occurs among actors on the market and in policy making.

In conclusion, business intermediaries can play three roles in advancing a circular bioeconomy:

1. By developing technology and that enables the recycling of plant-essential nutrients in wastewater that can be applied in agriculture.
2. Business intermediaries develop business models that make plant-essential nutrient recycling commercially viable and legit.
3. Business intermediaries also work to inform actors in the user contexts (wastewater utilities and food sector) about nutrient recycling.

Furthermore, business intermediaries such as those specialized in recycling nutrients from wastewater are important since a circular bioeconomy is about converting waste flows into valuable resources/assets. Therefore, entrepreneurial process of networking and partnering activities enables market exploration for their technology/product, which is likely to entail enhancement in wastewater to resource/asset in the system. Finally, business firms' intermediating role of repositioning material flows in waste-as-resource as well as influencing knowledge flows about recycling nutrients are important business processes to advance circular bioeconomy.

6.1 Critical reflection and limitation

In this study, the data collection is mainly relied on semi-structured interviews concerning respondents who may answer the question of what the researcher wanted to hear (Creswell & Creswell, 2017). As such, there might be filled platitude data which is not necessary for this study. To counter this author attended several

webinars, and secondary data collections have been adapted to enable triangulation. Secondly, these companies are not all nutrient recycling companies in Sweden, and there are other companies not included in this study, such as Ragn-sells and MEWAB. Third, this study only investigated the plant-essential nutrient recycling initiatives in wastewater systems in Sweden, which means findings might not be generalized to other sectors or countries but can be claimed as applicable in similar situations. Finally, the data were not collected from actor constituencies such as farmers, WWTPs, and food industries.

6.2 Future research recommendation

In response to limitations, future research should be carried out the perception of farmers, wastewater utilities, and food industries to obtain context-specific knowledge of the wastewater-to-resource process. Further, studies regarding the role of intermediaries at systemic-level, regime-based, and niche levels would be worthwhile. Regarding this study only explored the role of nutrient recycling firms in advancing a circular bioeconomy. A similar study on other sectors to understand emerging patterns of waste-to-resource initiatives for advancing a circular bioeconomy could be fruitful area.

6.3 Implication

Notwithstanding the relatively limited sample, this study offers valuable insights into the practice of business model that works for nutrient recycling from wastewater for agricultural applications. The knowledge about recycling nutrients from wastewater is mainly produced in natural and engineering research disciplines. This study contributes knowledge about business practices in this context. In line with Kivimaa et al. (2019), this contribution is relevant because, in the context of wastewater-as-resource, the role of business intermediaries is to support different systems, which promotes the transition to sustainability. This orchestrating intermediaries' activities strategically engage in systemic and non-systemic activities (Kanda et al. 2020), to enable resources such as funding. This contribution thus clarifies the intermediation role and objectives in comparison to the business model or innovation study in general.

This study has implications for policy making by highlighting the challenges associated with the implementation of a circular bioeconomy. Business firms that adopt circular principles in their operations they need credibility to remit, resource to act, and competences to compete with traditional business models. Therefore, regulatory frameworks should be designed to support these business models

adequately by laws, regulations, and economic incentives with possible financial support. It can also be suggested that a key policy priority should be to plan for the long-term care of different intermediaries' potentials and their roles and functions appropriately counted to enable the transition to a low carbon economy.

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Appendix 1 – Interview Guide

The interview will be held three sections: introduction, topic-specific, and follow up questions. Agenda for interview has been sent prior to the interview, so checklists regarding permission for record and anonymity as well as consent letter has been already decided by respondents *(see Appendix 2)*. Furthermore, only topic-specific questions have been provided to the respondents. Follow up questions will be used if interviewee think need to ask.

Introduction

- Thanks for the interview opportunity and readiness to talk
- Introduction of interviewer (SLU, Master Thesis, Topic)
- Explanation of Thesis Topic and Aim:
- Method: Multiple case study on nutrient recycling firms in Sweden, by interviewing actors from the organization.

Short presentation of respondent

- Who are you?
- What is your role in the organization?

Producers – Biototal, C-Green, and Easymining	
Topic-specific questions: 1. What kind of products/services does your company provide? 2. Could you describe your value creation and delivery (supplier and customer) process? 3. What is the main challenge and advantage of the circular bioeconomy business model? And why? 4. Final thoughts regarding the role of business firms in advancing a circular bioeconomy?	Follow up questions: - What does your company do differently in manufacturing processes and/or other operations? - Where will your company be in 5 to 10 years and what business opportunities and challenges do you foresee arising from the circular bioeconomy? - Is the Swedish legislative, political system in favor, or does it hinder these kinds of the process?
Supplier – Svenskt Vatten	
Topic-specific questions 1. What is your organization role in recycling nutrients from wastewater? 2. Are you (cooperating with others to enable recycling of nutrients from wastewater? 3. What impacts does nutrient recycling practice have on your organization? (positive, negative) 4. What is the future of recycling nutrients from wastewater and key challenges to overcome?	Follow up questions: - How do municipalities manage their wastewater today? - What more alternatives can you see the municipalities have concerning nutrients recycling possibilities? - How do you foresee the future wastewater management arising from the circular bioeconomy? - Which challenge/opportunity do you see for nutrient recycling?

	- Final thoughts regarding the role of business firms in advancing circular bioeconomy?
Users - LRF and Lantmännen	
Topic-specific questions 1. Do your members as farmers use nutrients that are recycled from wastewater? 2. How is your relationship with nutrient recycling from wastewater companies? 3. How do you see the future nutrient-cycle in agriculture? (opportunities/hinders) 4. Final thoughts regarding the role of business firms to advancing circular bioeconomy?	Follow up questions: - How do farmers manage fertilizer in their farming today, and how do you think about the future? - How do you foresee the future agri-food system arising from the circular bioeconomy? - Which challenge/opportunity do you see regarding nutrient recycling?

Appendix 2 – Interview Agenda

The project title:

> "The role of business intermediaries to advance circular bioeconomy – Multiple case study on plant-essential nutrients recycling firms, in Sweden."

Project aim:

> The study investigates the role and function of firms in the context of recycling plant-essential nutrients from wastewater for agricultural application as fertilizer.

The interview will start with the introductory section (project information and your role in your organization), topic-specific (question number 1-3, below), and exploratory (question number 4, below).

Topic-specific questions:

……..

Checklists:

- ☐ Would you like to be anonymous in the final project report?
- ☐ Do you agree with the audio recording in the interview?

After the interview, a transcription and summary of the interview will be sent to you to confirmation. So, you will have a chance to adjust the text and add some thoughts.

Thank you, and I hope we will have a fruitful discussion during the interview.

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