CIRCULAR ECONOMY AND ITS GOVERNANCE IN DUTCH AGRI-FOOD GREENHOUSE HORTICULTURE

Overcoming the barriers to implementation

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Abstract

According to the Food and Agricultural Organisation FAO, a third of the global population faces moderate to severe food insecurity. As one of the ways to tackle this existential threat, greenhouse food production is seen as a highly efficient growing method that can help mitigate this problem. The concept of Circular Economy promotes sustainable production and consumption and circularity in the greenhouse sector is important for the perceived food security goals to be attained. As one of the biggest greenhouse food exporters, the Netherlands invests significant resources into greenhouse horticulture. Yet, beyond this achievement in innovations and efficiency, a sufficient systematic understanding of the governance of the circularity in the sector has not been achieved. Although much is known about circularity in individual greenhouses, this circularity is yet to be replicated in the municipalities, provincial regions and countrywide.

This study develops an evaluation framework to understand the contextual governance of the Dutch agrifood greenhouse sector with the goal of assessing the circular practices in the sector, measures to promote them, the stakeholders at different levels, their networks, ambitions, strategies, and resources. This paper asks the following question: *How can the barriers to the implementation of CE practices in the Dutch greenhouse agri-food sector be overcome?*

Empirically, the paper compares approaches implemented by different stakeholders in line with the circular economy principles. Further, contextual governance is evaluated using the Governance assessment tool (GAT) which is a tool that assumes that a governance regime is multi-layered, and multi-actor, considering the different roles, resources, and distribution of power/mechanisms in place. To achieve this, qualitative data from literature, seven semi-structured interviews and observations are used to analyse the state of circularity in the sector and the barriers affecting the full attainment of circularity.

Results show that the Dutch agri-food greenhouse sector is highly efficient and has achieved great levels of sophistication in the greenhouses with high production per square metre. Growers have managed to leverage this to remain competitive in the global market. Some of the service providers in the sector have also incorporated the main principles of CE in their business models. However, the level of circularity is only achieved at a micro level as current legislation does not fully facilitate it on a larger scale/level. Different elements of the governance context were found to be supportive of the transition to circularity while others vary from moderate to restrictive, meaning that they don't fully facilitate it, or they make it very difficult for the stakeholders to implement circular practices.

The results further highlight that while there is increased awareness for the need for sustainable production and consumption, there is still a gap to be bridged in the goals and understanding of circularity in a wider context where politics and economics play a role. Consensus on what circularity means for a region is key in allowing these goals to be achieved. The results inform the need for aligning environmental and economic goals for the attainment of sustainable production and consumption as well as ensuring food security.

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List of Abbreviations

AI	Artificial Intelligence
CE	Circular economy
CIT	Contextual interaction theory
EU	European Union
FAO	Food and Agricultural Organisation
GAT	Governance assessment tool
GHG	Greenhouse gases
LCA	Lifecycle assessment
LED	Light-emitting diode
LTO	Land- en Tuinbouw Organisatie Nederland (the Netherlands Agricultural and Horticultural Association)
MIA	Milieu-investeringsaftrek (Environmental Investment Allowance)
RVO	Rijksdienst voor Ondernemend Nederland (The Netherlands Enterprise Agency)
SIGN	Stichting Innovatie Glastuinbouw (Dutch Foundation for Innovation in Greenhouse Horticulture)
UN	United Nations
UNEP	United Nations Environmental Programme
VAMIL	Willekeurige afschrijving milieu-investeringen (Random Depreciation of Environmental Investments)

1. Introduction

The United Nations, via the Food and Agriculture Organization (FAO) reports that more than 800 million people face hunger and malnutrition worldwide. This figure has recently escalated, mainly because of conflicts, climate change, economic slowdown, and COVID-19 shocks (FAO 2022). It is also reported that about 2.3 billion people, or about 30% of the global population, face moderate to severe food insecurity (FAO 2022). Food security continues to be a challenge with the worldwide population increase, projected to reach 9.7 billion people by the year 2050. The need and demand for more food have driven investments in agriculture, particularly in greenhouse horticulture, to meet global target. However, agriculture and food production systems contribute to one-third of the global greenhouse gas (GHG) emissions, are projected to reach 30 $GtCO_2e$/year by 2050. 39% of these come from the production inputs like fertilisers, while supply chain activities like transport, retail, fuel production, waste management and packaging contribute to 29% of the agricultural emissions (UNEP 2022). Traditionally, this has been practised in linear production and consumption economic models of take-make-use-dispose, leading to waste generation and an unsustainable supply chain (Barros et al. 2020).

Circular economy (CE) thinking continues to gain traction in recent years to address the negative impacts of linear economic models on the environment and social sustainability (Barreiro-Gen and Lozano 2020; Brekke 2021; Gottinger, Ladu, and Quitzow 2020; Kirchherr 2022; Kirchherr, Reike, and Hekkert 2017). The CE focuses on eliminating waste from design and pollution, prolonging the use of materials and products, and restoring the natural environment and its ecological processes (Ellen MacArthur Foundation 2013). A new CE action plan has also been developed by the European Union to promote sustainability and advance the transition towards a more CE, acknowledging the potential of the CE (European Commission 2020a).

In response to the urgent need for more sustainable food systems, international organisations such as the FAO, UNEP, and the Ellen MacArthur Foundation have called for a shift toward circular agriculture practices (Ellen MacArthur Foundation 2013; UNEP 2022). In greenhouse horticulture, CE practices have the potential to reduce waste, conserve resources, and create new economic opportunities (De Boer and Van Ittersum 2018; Swagemakers et al. 2012).

The Netherlands ranks as a top exporter of greenhouse-produced foods (Salinas-Velandia et al. 2022; Vermeulen et al. 2020), and to maintain its status as a worldwide front-runner, innovation in the greenhouse industry is paramount (Hoste, Suh, and Kortstee 2017). CE thinking in agriculture provides that there is a regenerative system for materials, water, and energy. Horticulture as a subfield of agriculture is the vanguard of the CE in agriculture due to the potential for the reuse and recycling of water, energy, and nutrients with a more significant production rate than in open fields (De Boer and Van Ittersum 2018; Salinas-Velandia et al. 2022).

1.1. Problem Statement

Although CE has recently gained increased attention, the adoption and implementation of CE methods in various industries and sectors remain limited, with different barriers and challenges hindering its success (Barbosa Junior et al. 2022; Barreiro-Gen and Lozano 2020; Bocken and Geradts 2020; Geissdoerfer et al. 2022; Gottinger et al. 2020; Hartley, Roosendaal, and Kirchherr 2022; van Keulen and Kirchherr 2021; Mehmood et al. 2021). Barreiro-Gen & Lozano, (2020) found that the

term CE may be loosely used by companies that claim to apply it but have limited interaction with the 4 Rs (reduce, repair, remanufacture/refurbish and recycle/reuse) while some interact with them but not under the framework of CE. Besides this, some are not even aware they are applying it. This points to a gap that needs to be closed between CE theory and implementation.

In the context of the greenhouse horticulture industry, which is a vital cog in the global food system, and faces growing pressure to improve its environmental sustainability, the adoption of CE practices is particularly relevant (De Boer and Van Ittersum 2018; Borrello et al. 2016; Salinas-Velandia et al. 2022; Vermeulen et al. 2020; de Waal and Meingast 2017). Despite this, few studies explore the specific barriers and challenges that limit the application of CE practices in the greenhouse horticulture industry. Vermeulen et al., (2020) studied the comparisons between the Dutch horticultural sector and the space exploration field and found some gaps in which the horticultural practitioners could learn about circularity, waste recycling, and automation.

The Dutch government has been keen to be seen to act in ways that promote sustainability in different sectors, which also involves policies and measures to encourage responsible production and consumption to meet the Paris Agreement goals and in line with the CE plan from the European Commission (European Commission 2020a). Furthermore, the horticulture sector is proactive in setting up measures to ensure competitiveness and efficiency in production (Hoste et al. 2017; Vermeulen et al. 2020). As identified by Bocken & Geradts, (2020), Gottinger et al., (2020), Hartley et al., (2022), Mehmood et al., (2021), and van Keulen & Kirchherr, (2021), CE implementation is widely seen as the future, but its full realisation is yet to materialise. Barreiro-Gen & Lozano, (2020) found that there were gaps in the understanding, awareness, and implementation of the theory of CE. The same may be assumed to be the case in the Dutch agri-food greenhouse business.

1.2. Research Objective

This research aims to analyse the extent of CE implementation in Dutch agri-food greenhouses and explain the governance framework that promotes or limits the application of circularity practices in greenhouses. This research investigates the practices adopted by the greenhouses to increase circularity and the contextual dynamics that influence the implementation of these practices including the governance aspects. The Dutch agri-food greenhouse horticulture is discussed in Chapter 2. The governance context will be analysed using the Governance Assessment Tool (GAT) which is founded on the Contextual Interaction Theory (CIT) (Bressers 2007; Bressers et al. 2016). The GAT and CIT are further described in Chapter 2.

By using the GAT, we can classify the strengths and limitations of existing governance arrangements towards a CE in greenhouse horticulture and develop recommendations for improvement. For instance, the GAT can be used to assess the level of participation and collaboration among stakeholders (which is crucial for CE implementation), the alignment of policies and regulations with CE goals, and the availability of funding and incentives for circular practices. The GAT, however, has only been applied in a few CE studies such as Eneng et al., (2018), aimed at water management in Indonesia, Xue et al., (2019) on urban mining in China, and Nurdiana et al., (2021) which focused on circular cities in Indonesia. By the time of writing this proposal, none addresses greenhouse horticulture.

Therefore, the objectives of this research are to:

1. Distinguish the prevailing understanding, perception, instruments, and methods of CE amongst the companies/farmers, local governments, and national government.

2. Assess the CE governance in the Dutch agrifood greenhouse horticulture sector.
3. Identify the prevailing barriers to the application of CE practices in the greenhouse horticulture sector in the Netherlands.
4. Propose strategies to mitigate these barriers and promote the adoption of CE strategies in the greenhouse horticulture sector in the Netherlands.

1.3. Research Questions

Following the research objectives stated above, the questions this research seeks to answer are formulated as follows:

Main question:
How can the barriers to the implementation of CE practices in the Dutch greenhouse agri-food sector be overcome?

Sub-questions.

1. *How is CE perceived and implemented in Dutch agri-food greenhouse horticulture?*
2. *What measures are observed to promote CE in Dutch agri-food greenhouse horticulture?*
3. *What is the governance context of CE in Dutch agri-food greenhouse horticulture and how supportive is it based on the GAT?*

The first question is aimed at formulating an understanding of what is known about CE and the practices that different greenhouses companies and farmers implement in their businesses. The second question seeks the measures that have been pushed or promoted in the sector for CE implementation. The third question analyses the barriers identified by the practitioners (greenhouse farmers and companies). The fourth question assesses the governance context in the agri-food greenhouse sector using the GAT. To answer the questions, this research will be guided by a theoretical framework that incorporates the understanding of CE, greenhouse horticulture in the Netherlands, and the GAT. This framework is elaborated on in Chapter 2 of this report.

2. Theoretical Framework

This chapter introduces and reviews the main theories and key concepts that will be applied in this research thesis. The general concept of CE is briefly discussed and its relevance to sustainable agriculture is explained. Further, an overview of the Dutch greenhouse horticultural sector is provided while a linkage to potential barriers to CE practices in the sector is introduced. Finally, the GAT which will be used to assess the governance context is explained as well as its application in this research.

2.1. Circular Economy (CE) Concept

The theory of CE has gained traction in many sectors but is interpreted differently across different sectors. According to the description provided by Ellen MacArthur Foundation, (2013), the CE is characterized as an industrial system designed to be restorative and regenerative, which prioritizes maintaining products, components, and materials at their maximum value and utility throughout their lifespan. This approach differentiates between technical and biological cycles, with the aim of achieving optimal resource utilisation. The technical cycle refers to the production, using, and reusing materials without degradation, while the biological cycle refers to the production, use, and recycling of organic materials. With that, the notion of cradle-to-cradle comes to the forefront.

As described by Ellen MacArthur Foundation, (2013), CE is founded on 3 main principles (3R framework) reducing waste, reusing, and recycling. Kirchherr et al., (2017) studied the evolution of the application of CE principles under the 4R framework (Reduction, Reuse, Recycling, and Recovery) and highlighted the differences in their use and interpretation. Barreiro-Gen & Lozano, (2020) and Kirchherr et al., (2017) noted that most of the focus was on reuse and recycling while the dimensions of applications varied based on the motivations for implementation such as economic prosperity, environmental quality, and the application of systems perspective. In their description of the CE, Kirchherr et al., (2017) put forward the notion that this economic model supersedes the 'end-of-life' paradigm by emphasising the reduction, reusing, recycling and recovery of materials throughout the various stages of production, distribution, and consumption, which as well is in line with the idea of cradle-to-cradle. CE thinking, therefore, calls for waste management practices that ensure a regenerative cycle.

Ellen MacArthur Foundation, (2013) illustrated some practical applications of CE in different sectors to achieve responsible production and consumption based on the material and product life cycles for economic, environmental, and social prosperity. Ghisellini et al., (2016) call attention to the fact that for an organisation to achieve CE, the focus should not only be on product design but also on the entire supply chain and utilisation of renewable energy resources, with the consumers playing an equally important role. CE transition has been observed to be top-down in China compared to the bottom-up approach in Europe. The CE is supposed to address the 3 pillars of society, economy, and environment qualities (Brekke 2021; Ellen MacArthur Foundation 2013; European Commission 2020a; van Keulen and Kirchherr 2021). It can help organisations to increase their sustainability performance in the three aspects. However, CE isn’t without criticism. Kirchherr et al., (2017) found that social considerations were largely ignored in many CE understandings with economic considerations being more prominent and while its link to sustainable development was termed as weak. As illustrated by Barreiro-Gen & Lozano, (2020) and Kirchherr et al., (2017), there is a disparity among organisations in the understanding of what CE entails, highlighting the need for awareness and collaborative efforts to make it work.

CE has also been introduced and implemented in agriculture to some degree (De Boer and Van Ittersum 2018; van Keulen and Kirchherr 2021; Rótolo et al. 2022; Salinas-Velandia et al. 2022;

Swagemakers et al. 2012; Vermeulen et al. 2020). Agricultural supply chains have the potential for multiple gains in the application of CE practices with some policy, financial, environmental social, and health drivers playing a crucial role. The Dutch horticultural practitioners already have advanced developments and efforts to make their business more circular (Swagemakers et al. 2012; Vermeulen et al. 2020).

2.2. Greenhouse Horticulture in the Netherlands

The Dutch horticultural industry represents a considerable part of the country's economy, generating significant revenue and creating job opportunities. The Netherlands sits in second place worldwide in the export of vegetables, and the sector has undergone substantial transformation in recent years with an increased focus on sustainability and a CE (Vermeulen et al. 2020).

The Dutch greenhouse horticulture industry is a highly developed and effective sector of the economy known for producing fruits and vegetables of the highest calibre. In fact, according to Hoste et al., (2017), the Netherlands produced more tomatoes per hectare than any other nation in the globe as of 2014. The industry has adopted cutting-edge techniques to achieve sustainability, including integrated pest control, water recycling, renewable energy sources, and intelligent systems for harvesting, sorting, and monitoring (Hoste et al. 2017; Vermeulen et al. 2020).

The sector's dependence on fossil fuels has reduced owing to the adoption of renewable energy sources, such as solar, wind and geothermal power, thereby decreasing carbon emissions (Pekkerieta, Van Henten, and Campen 2015). LED lighting technology has been developed to provide efficient lighting for plants (De Boer and Van Ittersum 2018; Pekkerieta et al. 2015; Vermeulen et al. 2020), which together with improved insulation, results in reduced energy consumption. The use of advanced irrigation systems, such as drip irrigation, has reduced water usage and improved crop yields. Biological control agents have been used to manage pests and diseases, thereby reducing the use of harmful pesticides, and minimizing the environmental impact of greenhouse horticulture (De Boer and Van Ittersum 2018). Additionally, sustainable packaging materials are being developed to reduce plastic waste, such as bioplastics (Pekkerieta et al. 2015).

The greenhouse horticulture sector in the Netherlands has made significant progress toward implementing CE principles. Recycling water, nutrients, and waste products through closed-loop systems have reduced the amount of water used and ensured that valuable nutrients are not lost (De Boer and Van Ittersum 2018). However, despite the numerous advancements, the sector faces several challenges, including the high cost of sustainable technologies and practices. Although energy sufficiency in Dutch horticulture increased by 59% between 1990 and 2016, energy use remains high and continues to take up a significant amount of the running costs of greenhouses (De Boer and Van Ittersum 2018). These barriers are further elaborated Chapter 2.3.

2.3. Barriers to the Implementation of CE Practices in the Netherlands

Several drivers and barriers affect the realisation of CE practices in organisations. Geissdoerfer et al., (2022) identified six categories of barriers to innovation of circularity in business: ***financial, legal, market, technical, organisational, and value chain***. Similar categories have been identified in other literature, under different names but referring to the same elements (Gottinger et al. 2020; Hartley et al. 2022; van Keulen and Kirchherr 2021; Mehmood et al. 2021). In the evaluation of the barriers in the Dutch greenhouse agri-food sector, this categorisation can be applied based on the data collected. A simplified categorisation is given by (Bocken and Geradts 2020) in three categories, that is, *institutional, strategic, and operational,* and can be used to cluster the barriers. As Swagemakers et al., (2012) and Vermeulen et al., (2020) observed, although there have been significant efforts to

make agriculture more sustainable, it is not without challenges and this research attempts to unravel them from the perspective of the stakeholders.

Hartley & Kirchherr, (2023) argue that some emerging methods of CE modelling such as life cycle assessment (LCA), material flow, etc. are nonetheless in the early stages of development and their use in policy decision-making should be approached with caution since these occur in political, social, and technical contexts that are not always straightforward. The contextual interaction theory (CIT) provides a useful structure for studying such complex systems and understanding the interactions between the various stakeholders involved (Bressers 2007; Bressers et al. 2016). According to Bressers (2016), CIT emphasizes the importance of context in shaping the behaviour of actors and the outcomes of governance processes.

2.4. Governance Assessment Tool

CIT is an analytical approach that seeks to explain how actors interact within a specific context and how this interaction can shape their behaviour and decision-making (Bressers 2007, 2009; Bressers et al. 2016). According to CIT, the behaviour and decisions of actors are influenced by three key factors: motivation, cognition, and resources. Motivation refers to the actors' goals, values, and interests. Cognition refers to the actors' beliefs, attitudes, and knowledge. Resources refer to the actors' access to material, financial, and social resources that can enable or constrain their behaviour (Bressers et al. 2016). CIT is particularly useful in analysing complex environmental governance challenges, as it can help identify the interplay between different actors, their motivations, and the resources available to them (Bressers et al. 2016). As is illustrated in Figure 1, these interaction processes are shaped by multifaceted context layers which are the specific context, structural context, and the wider context. The wider context includes the norms, culture, technological developments, and political and economic systems. The structural context concerns the governance dimensions while the specific context refers to the geographical characteristics of the area, previous case decisions, and other circumstances unique to the area (Bressers 2007, 2009; Bressers et al. 2016). By analysing the contexts and identifying the relevant actors and their interests, the CIT framework can help identify the key factors that either enhance or restrict the application of circular systems in Dutch greenhouse horticulture.

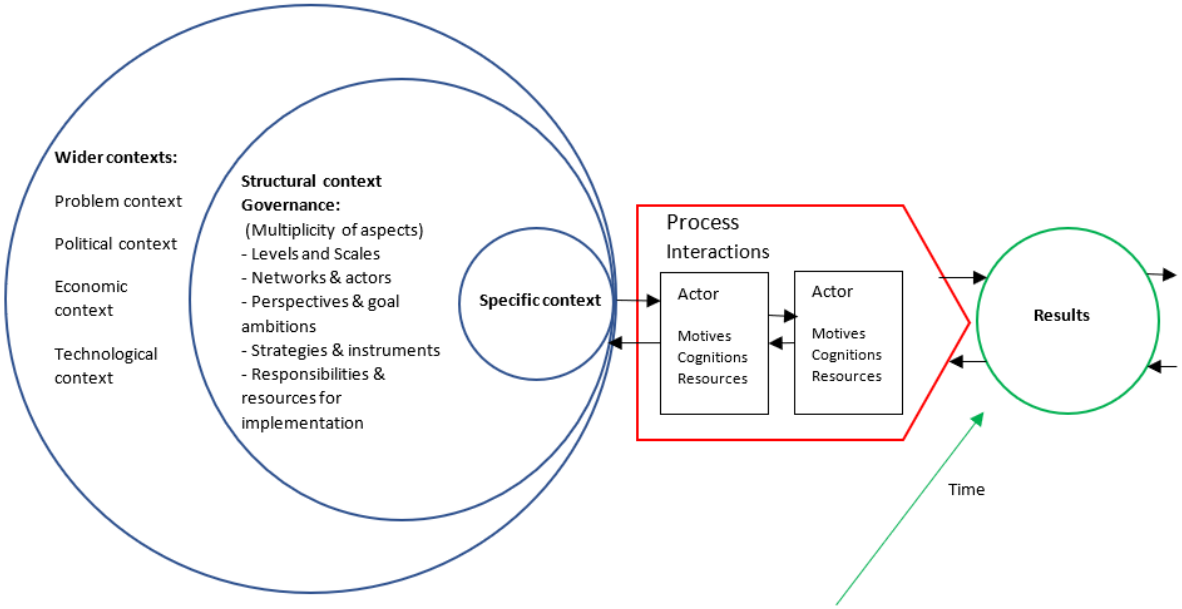

Figure 1: Multi-layered context of interaction process under CIT (Bressers et al. 2016)

Within the CIT, the Governance Assessment Tool (GAT) is a framework for analysing governance structures and processes, including the roles of different actors, the distribution of power and resources, and the coordination mechanisms in place (Bressers et al. 2016). This is done by analysing the five governance dimensions in the structural context which are defined by Bressers (2009), Bressers et al. (2016) and Lordkipanidze, Bressers, & Lulofs (2020) as follows:

a. **Levels and scales:** The governance is assumed to be multi-levelled and on different scales.
b. **Actors and networks:** Governance is assumed to be of a multi-actor nature in the relevant networks.
c. **Problems perspectives and goal ambitions:** Due to the multiple levels and stakeholders, governance assumes there are multiple variations of the actors' problem discernments and objectives.
d. **Strategies and instruments:** Various strategies and policy instruments are assumed to form part of the governance of the multiple actors.
e. **Resources and responsibilities:** The multi-level & multi-actor character of the governance implies multi-resources and responsibilities in implementation.

The effectiveness of these dimensions is then assessed on four quality criteria as follows.

i. Extent: Signifies the degree of completeness in which the five aspects are considered.
ii. Coherence: This is the measure to which the different aspects improve rather than undermine one another.
iii. Flexibility: Signifies the point to which the system elements support and enable adaptive actions and approaches as much as the integrated objectives are served by this adaptiveness
iv. Intensity: This is the point to which the system elements advocate deviations from the status quo or current occurrences

Combining these five governance dimensions with the four quality criteria, the GAT matrix is formed with questions that highlight the level of support or restriction of the governance framework on the application of policies or practices. This matrix and the respective evaluative questions are presented

in Table 1. Although this model was designed to assess the governance in water management, Bressers et al., (2016) recommend its application in matters beyond water management. The evaluation rubric is presented in Table 2.

Table 1: The GAT Matrix (Bressers et al. 2016)

Governance Dimension	*Governance Quality*			
	Extent	**Coherence**	**Flexibility**	**Intensity**
Levels and Scales	Which levels are involved in dealing with the issue? Are there any gaps or missing levels?	Do these levels work together, and trust each other between levels? Is mutual dependence among levels recognised?	Is it possible to move up and down levels (upscaling and downscaling) given the issue at stake?	Is there a strong impact from a certain level toward behavioural change or management reform?
Actors & networks	Are all relevant stakeholders involved? Are any not involved or excluded?	What is the strength of interactions between stakeholders? In what ways are these interactions institutionalised in stable structures? Do the stakeholders have experience working together? Do they trust and respect each other?	Is it possible that new actors are included or even that the lead shifts from one actor to another when there are pragmatic reasons for this? Do the actors share in 'social capital' allowing them to support each other's tasks?	Is there strong pressure from an actor or actor coalition towards behavioural change or management reform?
Problem perspectives & goal ambitions	To what extent are the various problem perspectives taken into account?	To what extent do the various perspectives and goals support each other, or are they in competition or conflict?	Are there opportunities to re-assess goals? Can multiple goals be optimized in package deals?	How different are the goal ambitions from the status quo or business as usual?
Strategies & instruments	What types of instruments are included/excluded in the policy strategy? Are there any excluded types? Are monitoring and enforcement instruments included?	To what extent is the incentive system based on synergy? Are trade-offs and distributional effects considered? Are there any overlaps or conflicts of incentives created by the included policy instruments?	Are there opportunities to combine or make use of different types of instruments? Is there a choice?	What is the implied behavioural deviation from current practice and how strongly do the instruments require and enforce this?
Responsibilities & resources	Are all responsibilities clearly assigned and facilitated with resources?	To what extent do the assigned responsibilities create competence struggles or cooperation within or across institutions? Are they considered legitimate by the main stakeholders?	To what extent can the assigned responsibilities and resources be pooled as long as accountability and transparency are not compromised?	Is the amount of allocated resources sufficient to implement the measures needed for the intended change?

Table 2: GAT evaluation rubric (Casiano Flores, Özerol, and Bressers 2017)

Governance Dimension	*Governance Quality*			
	Extent	**Coherence**	**Flexibility**	**Intensity**
Levels and Scales	**Supportive:** All levels are involved in the implementation **Moderate:** Most levels are involved **Restrictive:** Minority of the levels are involved	**Supportive:** The levels consider they work together trust each other and recognise their dependence **Moderate:** The levels consider few multi-level issues exist, they report some trust issues and recognise their dependence **Restrictive:** The levels consider, most levels are missing, they report some trust issues but recognise their dependence	**Supportive:** It is possible to move up and down levels, depending on the issue in what they could consider a freely manner **Moderate:** It is possible to move up and down levels, depending on the issue, only through the implementation of agreements **Restrictive:** It is not possible to move up and down levels even when there are agreements to do so	**Supportive:** All levels are working to bring behavioural change or management reform **Moderate:** Most levels are working to bring behavioural change or management reform **Restrictive:** The minority of levels are working to bring behavioural change or management reform
Actors & networks	**Supportive:** All the stakeholders feel involved. **Moderate:** Most of stakeholders feel involved. **Restrictive**: Few stakeholders feel involved	**Supportive:** Actors report that their interactions are institutionalised, stable (time working together), and there is trust **Moderate:** Most interactions among actors are institutionalised. Actors report stability and/or trust issues **Restrictive:** Institutions that promote interactions among actors are not operating. Actors report stability and/or trust issues	**Supportive:** The institutional arrangement facilitates the inclusion of new actors, shift leadership and social capital creation **Moderate:** The institutional arrangement facilitates only some of the follows: inclusion of new actors, shift leadership and social capital creation **Restrictive:** The institutional arrangement restricts the inclusion of new actors, shift leadership and social capital creation	**Supportive:** There is a collision of different actors to create a strong impact in behavioural change or management reform **Moderate:** There is a fragmentation of the intensity. There is a minor collision of actors trying to create an impact in behavioural change or management reform. **Restrictive:** There is only one actor or no collision trying to create an impact in behavioural change or management reform
Problem perspectives & goal ambitions	**Supportive:** The actors consider that all perspectives are involved **Moderate:** The actors consider that most of the perspectives are involved	**Supportive:** All the different goals of the actors involved support each other **Moderate:** Most goals of the actors involved support each other	**Supportive:** It is possible to reassess goals during the implementation process **Moderate:** It is possible that some aspects of the goals can be	**Supportive:** The actors consider that the established goals can be achieved with the current policy implementation **Moderate:** The actors

	Restrictive: The actors consider that a minority of the perspectives are involved	**Restrictive**: There is competition among the goals of the actors	reassessed during the implementation process **Restrictive**: It is possible to reassess the goals only, after the implementation process or there is not reassessment	consider that the policy implementation requires some minor changes to achieve the intended goal **Restrictive**: The actors consider that major changes are required to achieve the intended goals
Strategies & instruments	**Supportive:** According to the actors and the law no instruments or strategies are missing **Moderate:** According to the actors and the law some instruments or strategies are missing **Restrictive**: According to the actors and the law an important number of instruments or strategies are missing	**Supportive:** The system allows the creation of synergy among the policy instruments and there are no overlaps or conflicts among the instruments **Moderate:** The system allows the creation of synergy among the policy instruments but some overlaps or conflicts among the instruments are found **Restrictive**: The system does not allow the creation of synergy among the policy instruments and there are overlaps or conflicts among the instruments	**Supportive:** The institutional arrangement provides the opportunity to combine and use different instruments and actors can make choices in a pragmatic manner **Moderate:** The institutional arrangement provides the opportunity to combine and use different instruments if it is stated in the law **Restrictive**: The institutional arrangement provides the opportunity to combine and use different instruments, but the actors do not do it, or they do not have those choices	**Supportive:** The actors report that there is no need of behavioural deviation from current practice and the instruments are being enforced properly **Moderate:** The actors report that there is a minor need of behavioural deviation from current practice and the instruments are facing small issues during enforcement **Restrictive**: The actors report that there is a major need of behavioural deviation from current practice and the instruments are facing important challenges during their implementation
Responsibilities & resources	**Supportive:** Responsibilities are clearly assigned with sufficient resources **Moderate:** Responsibilities are clearly assigned but some have resources **Restrictive**: Responsibilities are clearly assigned but there are insufficient resources	**Supportive:** The institutional arrangement and the actors promote cooperation within and across institutions **Moderate:** The institutional arrangement promotes cooperation within and across institutions. However, actors report some issues. **Restrictive**: The institutional arrangements promote cooperation within and across institutions. However, actors report relevant issues	**Supportive:** It is possible to pool the assigned responsibilities with effective accountability mechanisms in a pragmatic manner **Moderate:** It is possible to pool partially some of the assigned responsibilities with effective accountability mechanisms in a pragmatic manner **Restrictive**: It is not possible to pool the assigned responsibilities with effective accountability mechanisms in a pragmatic manner	**Supportive:** The actors consider there are the enough resources needed for the intended changes **Moderate:** The actors consider there are resources to comply most of the responsibilities to achieve the intended changes **Restrictive**: The actors consider there is a lack of resources to comply the responsibilities to achieve the intended changes

Previous research has identified several barriers to the application of CE practices in various sectors, including the agri-food sector (Barbosa Junior et al. 2022; Bocken and Geradts 2020; Geissdoerfer et al. 2022; Gottinger et al. 2020; Mehmood et al. 2021). Some of the common barriers include a *lack of knowledge and understanding of CE concepts, limited access to financing and technological innovation, regulatory barriers, and organisational inertia* (Barbosa Junior et al. 2022; Bocken and Geradts 2020; Geissdoerfer et al. 2022; Gottinger et al. 2020; Mehmood et al. 2021). However, these barriers can differ based on the specific setting and the actors involved. Thus, CIT and GAT can help identify the contextual factors that shape the actors' behaviour and decision-making regarding CE practices in the Dutch agrifood greenhouse sector.

Application of CIT in this study will involve analysing the motivations, cognitions, and resources of the different stakeholders involved including producers, regulators, and other supply chain stakeholders as explained in Chapter 3.4.2. By doing so, this study aims to provide insights into the factors that enable or constrain the adoption and diffusion of CE practices in Dutch greenhouses.

3. Research Design

Verschuren & Doorewaard, (2010) provide a systematic approach to research design that is meant to help researchers structure their ideas in a piecemeal process which will also be used for this thesis. This research will be conducted in the steps as follows:

3.1. Setting the research objective

Based on the problem statement outlined in section 1.1, the objectives of this research were defined as outlined in section 1.2. To achieve these objectives, the framework as defined in section 3.2 was applied to the research.

3.2. Research Framework

This research will evaluate the state of CE implementation in the Dutch agri-food greenhouses and assess the barriers that hinder it based on the perceptions of stakeholders as well as assessing the CE governance as prescribed by Bressers, (2007) and Bressers et al., (2016) applying the GAT. This research framework was developed based on an analysis of material on the topic of CE, insights from ongoing research at the University of Almeria in Spain and a literature review. The overview of framework is provided in Table 3.

Table 3: Research framework overview

Key concepts	Theories and literature
Circularity Resource efficiency Sustainable agriculture Closed loop systems Greenhouse horticulture Waste management Clean production	Contextual Interaction Theory Governance Assessment Tool Literature on CE Literature on the governance of CE and greenhouse horticulture in the Netherlands

To further define the research process, the framework is presented in form of a schematic visualisation in Figure 2.

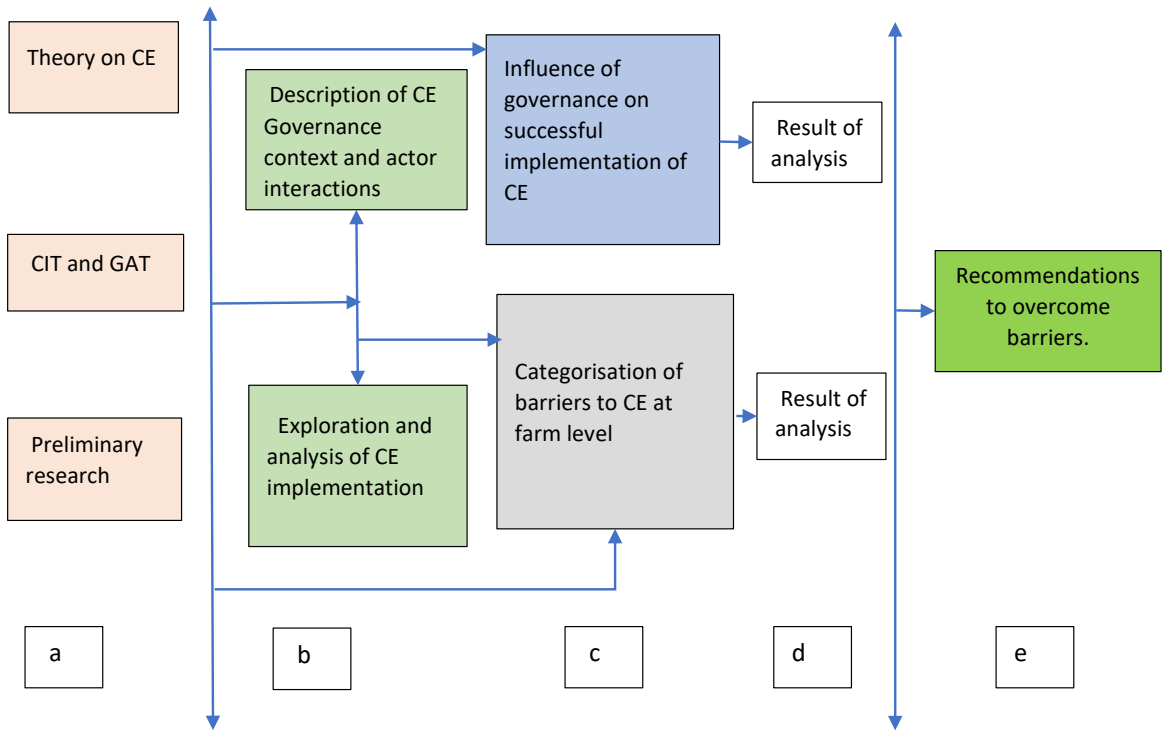

Figure 2: Schematised research framework

3.2.1. Formulation of arguments from the research framework

The steps defined in Figure 2 are explained as follows.

a. Study of the literature on CE, CIT, GAT, and the Dutch greenhouse agrifood sector
b. Collection of data, application of GAT and research on the governance elements of CE in the Netherlands
c. Evaluation of the context of CE governance and implementation barriers at farm level
d. Analysis and comparison of the outcomes and further review of literature
e. Drawing conclusions and drafting recommendations to overcome identified barriers.

3.3. Research Questions

To attain the goal of the research, formulation main research question and the sub-sequent sub-questions was as defined in section 1.3.

3.4. Data Sources and Methods

To answer the research question, data needed was collected through various means such as a literature review, policy papers, a growers' survey, and interviews with different stakeholders. These sources are listed in

Table 5, corresponding to the respective research questions.

3.4.1. Document and Literature Reviews

In this research, different sources of literature were used. Grey literature included documents from government bodies, international organisations, reports, and policy papers. Scientific literature used to develop the theoretical framework was derived from Scopus between February and July 2023 with the following inclusion criteria:

1. To eliminate language barriers, the publication language is English.
2. The source type was limited to “Journal” to ensure credibility through peer review.
3. To eliminate duplicity of research, gain deeper insights on the research topic and ensure credibility and verifiability of sources, the document type was limited to “Article”.
4. The article focuses on the circular economy or circularity in agriculture or horticulture.
5. Since the wider research targets two specific countries, the articles focus the Netherlands or Spain.
6. The article is on all open access.

The initial search strings used were as shown in Table 4.

Table 4: Initial Scopus search strings

Search string	Publications
“Circular ” (All fields) AND “Horticulture” (All fields)	177
“Circular ” (All fields) AND “Greenhouses” (All fields) AND “Horticulture” (Article title, Abstract, Keywords)	39
“Circular economy” (All fields) AND “Horticulture” (Article title, Abstract, Keywords)	35

A quick scan of the abstracts obtained was done to narrow down the results to find the articles relevant to the topics addressing CE implementation, especially in greenhouse horticulture. As outlined by Wohlin, (2014) and illustrated in Figure 3, the snowball technique was applied to extend the literature in an iterative process to yield the references used in Chapters 2, 4, 5 and 0.

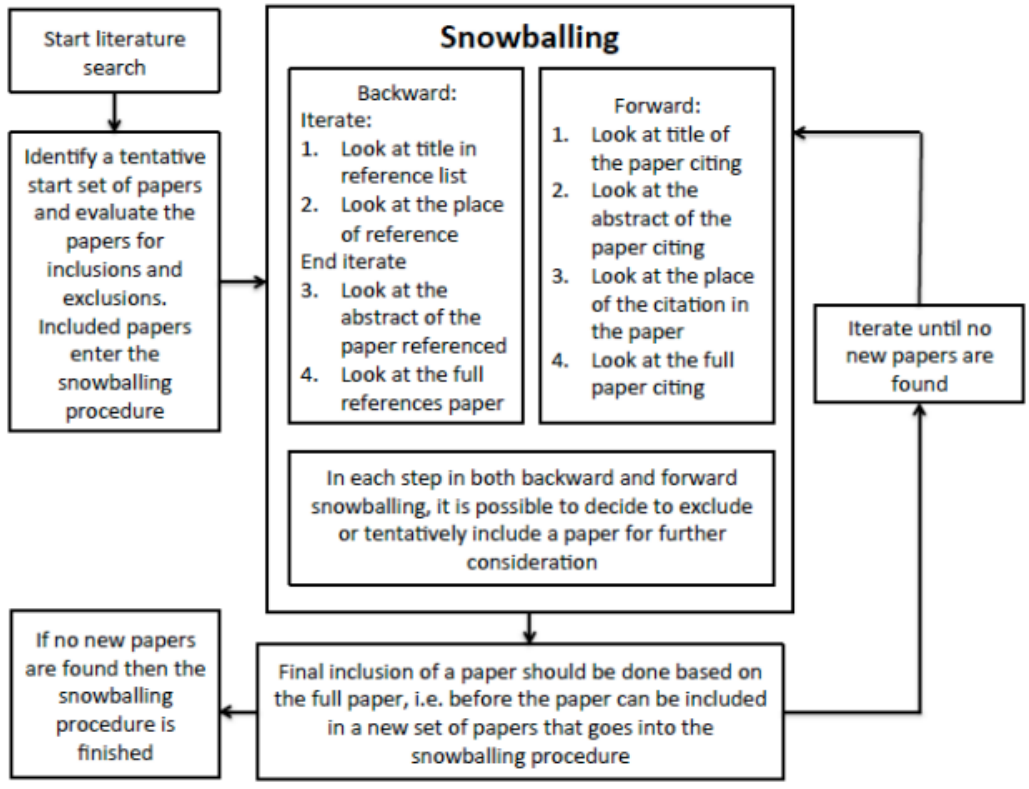

Figure 3: Snowball technique process (Wohlin 2014)

Table 5: Data collection matrix

Research Question	Data and details needed	Data Sources	Access Method
How is CE perceived and implemented in the Dutch agrifood greenhouse sector?	° Definitions, ° Data about the Dutch greenhouse sector, ° CE practices	Secondary Data: Public documents, articles, and reports	Content analysis
		Primary Data: Farmers and greenhouse companies/cooperatives LTO	Survey Interview Content analysis Field observations
What measures are observed to promote CE in the Dutch agrifood greenhouse sector?	° Measures, ° Policy instruments, ° Management strategies	Secondary Data: Public documents, articles, and reports	Content analysis
		Primary Data: Ministry of Agriculture, Nature and Food Quality, Netherlands Enterprise Agency (RVO), Provinces, supply chain actors, suppliers, LTO, and greenhouse growers/companies/cooperatives	Survey Interview Content analysis Field observations
What is the governance context of CE in the Dutch agrifood greenhouse sector and how supportive is it based on the GAT?	° Actors involved. ° Roles played. ° Interaction processes ° The resources, cognitions, and motivations of the actors ° Governance factors	Secondary Data: Policies, public documents, government documents, articles, and reports	Content analysis
		Primary Data: Ministry of Agriculture, Nature and Food Quality, Netherlands Enterprise Agency (RVO), Provinces, supply chain actors, suppliers, LTO, and greenhouse growers/companies/cooperatives	Survey Interview Content analysis Field observations

3.4.2. Survey

A survey with 35 quantitative and qualitative questions was designed based on the CIT model (Bressers 2007; Bressers et al. 2016). This survey was created for comparative research that evaluates CE practices in Spain and the Netherlands. The survey questions are provided in Appendix A. The survey deployment tool used was Qualtrics, which was made available to potential respondents via an anonymous link generated in Qualtrics. Since the two countries are part of the biggest food exporters, not just in Europe but in the world, the survey targets the big greenhouse companies and farmers since they assert a broad influence on the supply chain. The inclusion criteria for data received from the respondents will be as follows:

- The type of growers targeted cultivated either vegetables or fruits since the focus of the research is on food production.

According to the CBS, the total number of greenhouse farms growing vegetables was 1160 as of 2022 (CBS n.d.). The target sample size for this research is thus derived by applying the Slovin formula as follows.

$n = N / (1 + Ne^2)$

where:

- n = sample size
- N = population size = 1160
- e = acceptable margin of error = 5%,

The target sample size for the survey was therefore 298 respondents according to Slovin's formula. A database of potential respondents was set up and operationalised upon approval of the research proposal. The database was expanded by reaching out to research institutions, the Dutch Farmers Organisation (LTO) and farmers cooperatives for potential contacts. This survey was sent out to the respondents primarily via email with an anonymous link generated in Qualtrics.

3.4.3. Interviews

To further gain insights on the governance context, requests for interviews were sent out to different stakeholders in the sector. These stakeholders were picked from the national government bodies, provincial administrations, growers' cooperatives, farmers' organisation, and supply chain actors to provide a wide range of perspective on the state of the sector. The purpose of these interviews was corroborating the outcomes from the literature review and to understand the perception and motivation to promote CE implementation. Respondents were given an interview guide as shown in Appendix 1 which was based on the questions in Table 1 and evaluated based on the rubric in Table 2. The list of interviewees is provided in Table 6. Unstructured interviews were conducted with the respondents and the subsequent content was then used to evaluate the governance context of CE in the sector.

Table 6: List of interviewees

Interviewee	Position	Organisation type	Date	Duration	Code
1	Programme Manager	Farmers'/Growers' Organisation	28-04-2023	02:04 hrs	C1
2	Transition Manager	Province	23-05-2023	01:14 hrs	C2
3	Project leader	Multi-stakeholder horticultural cluster/Agri-business hub	23-05-2023	01:00 hrs	C3
4	Strategic Advisor	Province	26-05-2023	01:10 hrs	C4
5	Sustainability Manager	Growers' Cooperative	16-06-2023	01:05 hrs	C5
6	Advisor	Province	27-06-2023	01:13 hrs	C6
7	Sales Manager	Packaging systems	27-06-2023	01:18 hrs	C7

3.4.4. Field Observations

From 13th to 15th of June 2023, the annual GreenTech horticultural exhibition took place in Amsterdam (Koopmans n.d.). The 2023 event attracted 11,500 visitors and 540 exhibitors from 128 countries around the world. Amongst the visitors were growers, policy makers, investors, researchers, and students. The exhibitors offered different innovations and services such as research and design, knowledge, propagation, greenhouse construction, machinery/equipment, robotics, fertilisers, substrates, plant compounds, vertical farming, and packaging solutions (GreenTech n.d.). This offered an opportunity to make observations relevant for this research. The organisers of the event created a platform through which visitors could locate and interact with exhibitors and set up brief meetings with them to explain their innovations and processes. I went to different stands and spoke to the exhibitors for five to 15 minutes. Data was collected through the discussions with exhibitors, notes on observed innovations and attendance of lectures by experts. The overview of these observations is summarised in Table 7. Further details can be found in Appendix D - Observations.

Table 7: Overview of observations

Observation	Category	Observation period	Code
1	Plant compounds and fertilisers	13th to 15th June 2023	O1
2	Substrates and growing material	13th to 15th June 2023	O2
3	Cultivation Systems	13th to 15th June 2023	O3
4	Packaging materials and systems	13th to 15th June 2023	O4
5	Growing light systems	13th to 15th June 2023	O5
6	Water storage	13th to 15th June 2023	O6
7	Turn-key Greenhouse building services	13th to 15th June 2023	O7

3.4.5. Data protection and privacy

Before the data collection commenced, the research proposal was submitted for ethical assessment and once the ethics approval was given, the survey was distributed to the participants. As per the requirements of the Behavioural Management and Social Sciences (BMS) faculty regulations on ethics and data privacy, consent for participation was sought beforehand and the data of the

respondents was treated with due respect as per the GDPR. All digital data received through Qualtrics was handled as per the privacy regulations set by the University of Twente, BMS, and the GDPR.

3.4.6. Data Analysis

To make observations for the purpose of inferring and drawing conclusions, the data collected was handled in two ways. Firstly, the data collected from the literature review was collated and coded for the categorisation of identifiable barriers and the governance context. The interview responses were transcribed using Amberscript and inductively coded and analysed in Atlas.

3.4.7. Triangulation of data and validation

To ensure the validity of the data collected, different sources were used. This included desk research, exhibition visit, observation, and interviews (semi-structured). The narratives and from the different respondents were cross checked to eliminate bias in the reporting of the findings. The respondents were provided with the same guiding questions to ensure the comparability and possibility to corroborate the data they provided.

3.4.8. Research limitations and process adaptation

Although this research sought to present an insight of the sector, there were limitations to how much could be drawn from it depending on a few factors. Firstly, the number of respondents for the survey in Qualtrics was not guaranteed and as such, alternative data collection methods had to be introduced. After numerous attempts to reach growers for the survey through emails, calls and via their cooperatives, only 10 fully filled in the survey, which was a very low response rate, not enough to do analysis.

In a bid to recruit potential survey respondents, I attended a three-day greenhouse exhibition hoping to meet Dutch growers. However, due to the magnitude of the exhibition, there was an opportunity to collect data through observations and informal conversations/discussions with experts, practitioners, and researchers at the event. This group of respondents provided valuable information on the current practices in the sector and future developments.

The scheduled interviews targeted stakeholders from different levels and groups in the governance hierarchy but some were quick to turn down the request, ignored or declined at the last moment for various reasons. This made it difficult to have a wider view/perspective of the stakeholders in the sector. However, those that are close to the implementation responded and gave their insights.

Lastly, a duration of only three months was available for this research. Therefore, the depth of the research was limited and not all aspects of the sector could be addressed, such as the consumers and retailers' side of the CE topic.

4. Findings

This section describes the outcomes of the research as per the steps described in the previous chapter. Due to the limited number of responses in the survey, the data collected from Qualtrics was not included in the analysis. The target group of the survey was not easily reachable and although efforts were made to spread the survey, only 10 respondents agreed to fill in the survey. In addition to the interviews, data was collected through observations and informal discussions with experts and practitioners at GreenTech 2023 in Amsterdam. The results of the analysis of the data use are presented per research question in the following sections. In section 4.1, the sub question "*How is CE perceived and what practices exist in Dutch agri-food greenhouse horticulture?"* is addressed while Section 4.2 answers the second sub question "*What measures are observed to promote CE in Dutch agri-food greenhouse horticulture*?". Sub question 3 "What is the governance context of CE in the Dutch agrifood greenhouse sector and how supportive is it based on the GAT?" is addressed in Sections 4.3 and 4.4. Section 4.3 provides an overview of the governance context while 4.4 describes the assessment of this context using the Governance Assessment Tool.

4.1. CE perception and practices in Dutch agrifood greenhouse horticulture

The Dutch greenhouse horticulture sector is multi-layered with different actors across different levels involved. Taking the greenhouse as the reference unit, we find that the growers are nested under a cooperative which does the negotiation and collective bargaining for their products in the local and international market. Each grower is linked to a set of suppliers for their horticultural inputs and services. On the other side of the supply chain, there are retailers and service providers for packaging and logistics support. These suppliers and growers are governed by rules and regulations that are set by municipalities, provinces, national government through ministries and the EU. For all these actors, there is an understanding of the need for circularity and sustainable production in the sector. However, this complex relationship between the actors across the different levels comes with some barriers which Kirchherr et al. (2018) argued that there is a causal relationship between cultural barriers and regulatory barriers which then link to market and technological barriers when considering the bottlenecks in circular implementation within the EU.

The Dutch horticultural sector prides itself in proactive and innovative approaches to efficiency and sustainability (De Boer and Van Ittersum 2018; Hoste et al. 2017; Poot 2004; Vermeulen et al. 2020). The concept of circularity is widely accepted as a way forward and is used to guide some applications of technology and materials for different elements of the sector. However, the content of the circularity differs depending on the nature of activity that an actor or region is engaged in (Grafström and Aasma 2021; Kirchherr et al. 2018; Tseng et al. 2019). Considering the 4R principles of reduce, reuse, recycling, redesigning and recovery as defined by (Kirchherr et al. 2023, 2017), different actors focus on a selection of these principles, and few were observed to implement all of them in their business model. As outlined in Figure 4, the definition of the CE principles is based on the cycles of material sourcing, production, and consumption (Kirchherr et al. 2023, 2017). This outlook is adopted in the analysis of the findings.

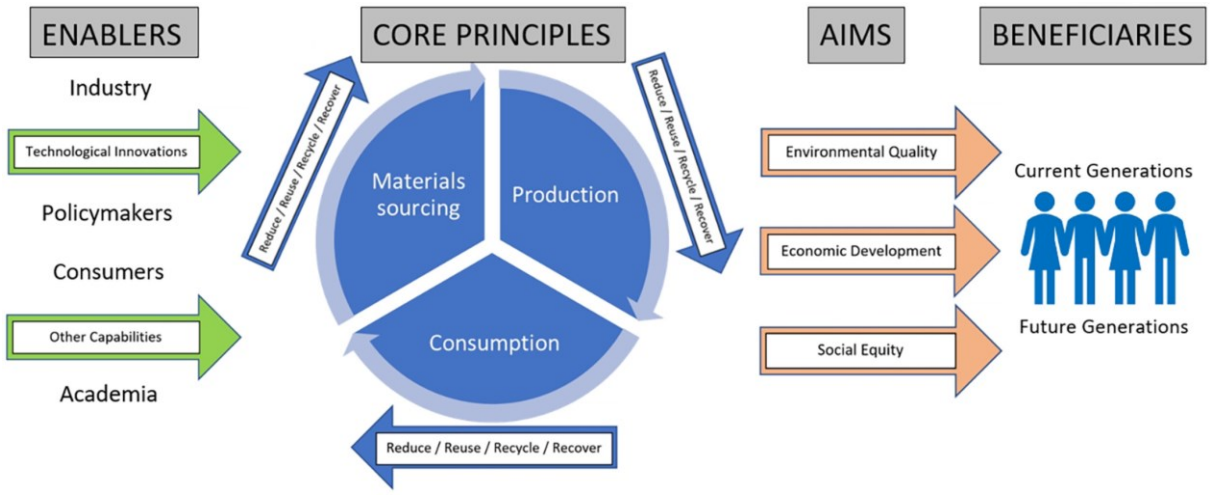

Figure 4: CE Framework (Kirchherr et al. 2023)

Circularity in the sector is observed to happen in silos within different stages of the production and consumption along the supply chain (C1, personal communication, 2023). The level of specialisation in each of the services provided to the greenhouse owners means that the providers focus their energy on making their own processes and products as efficient as possible to meet their clients' demands but that does not equate to them involving other actors whose input or could come from their waste or their waste becoming their input (C1 and C5, personal communication, 2023). The limited focus on material flows is more pronounced in the extraction and construction stages where new material is preferred (C1, personal communication, 2023). This sentiment is corroborated by actors in the packaging and greenhouse building services (O4 and O7, 2023). Along the supply chain, different strategies are implemented relevant to each stakeholder and their line of business. The principles are defined and implemented as follows.

4.1.1. Reduce

This is the principle that aims to ensure that resources are used efficiently while generation of waste and the environmental impact are kept at a minimum. This was observed to be achieved through different practices and technologies implemented in the processes. This includes.

i. Production efficiency- Several techniques are employed to ensure that there is precision in the production and distribution processes. The use of data to make business decisions and optimize growth is reported to help growers save and increase their production, which also boosted their income (De Boer and Van Ittersum 2018; Hoste et al. 2017; Vermeulen et al. 2020). At the GreenTech exhibition (GreenTech n.d.), numerous companies offered advanced technology options for growers in terms of drones, sensors, data solutions and systems to allow them to optimally monitor, predict and use their input such as water, energy, and nutrients in a more targeted way (O3, 2023). Some of these systems are AI powered and are monitored remotely with machine learning algorithms deployed to assist the growers and their system providers make the most informed decisions about their production based on data collected from the crops. This involves installation of high-tech cameras and sensors that can detect variations in light intensity, pests, withering and even air quality amongst others (Ariesen-Verschuur, Verdouw, and Tekinerdogan 2022; De Boer and Van Ittersum 2018; Hoste et al. 2017; Pekkeriet and Van Henten 2011).

ii. Smart Water efficiency – Modern greenhouses are now equipped with smart closed loop water systems such as hydroponics that allow for reduced water consumption (O3 and O7,

2023). This can be applied in different methods of vertical farming. For some growers, drip irrigation is used in the greenhouses. These systems allow for optimal water consumption without loss in production quantities (Ariesen-Verschuur et al. 2022; Pekkeriet and Van Henten 2011; Vermeulen et al. 2020).

iii. Smart energy management – There has been reported growth in the development of energy saving techniques and solutions in the greenhouses (O7, 2023). This has been achieved through the installation of smart systems that monitor the needs of the crop and dose the nutrients, water, or lighting accordingly (Hoste et al. 2017; Pekkeriet and Van Henten 2011; Vermeulen et al. 2020). This minimizes the unnecessary consumption of energy. To further make it even better, more innovation is realized in the use of LED lighting (Bantis et al. 2018; Vermeulen et al. 2020). They are more energy efficient, and some companies have taken it further by customizing the lights to be able to vary the intensity, spectrum of the light system. Some can be operated independently, with the smart system being able to detect the shadow patterns in the greenhouse and match it with the natural light needed per area (O5, 2023). Majority of the greenhouses also use renewable energy sources such as solar and geothermal (De Boer and Van Ittersum 2018; López et al. 2022; Vermeulen et al. 2020). One interesting innovation observed at GreenTech 2023 was that of an LED lighting system that uses water cooling (O5, 2023). The closed water system is incorporated into the LED fixtures such that as it cools the LEDs, it takes up the heat which can be used elsewhere in the greenhouse. At the same time, the cooled LEDs are claimed to have a longer lifespan and efficiency compared to ordinary ones due to the reduced heat exposure (O5, 2023).

4.1.2. Reuse

The purpose of this principle is to ensure that resources and inputs are used through as many cycles as possible such that there is no need for new/virgin input or waste generated.

i. Water – Development of closed loop systems such as hydroponics has made it possible to reuse water (treated or untreated) in the growing of different crops (Baganz et al. 2020; De Boer and Van Ittersum 2018; Casey et al. 2022; Martin, Poulikidou, and Molin 2019). The incorporation of smart systems with sensors that can detect the nutrient levels and water quality allows the growers to keep the water in circulation without the need for draining or introducing excessive amounts of water through irrigation. With the use of data analytics and machine learning algorithms, developers have been able to learn the exact needs of each product and can therefore automate the growing process in a water efficient way (Ariesen-Verschuur et al. 2022; Bantis et al. 2018). Growers are also provided with rainwater harvesting solutions such as water tanks with flexible covers to allow them to use and reuse rainwater in their production activities (O6 and O7, 2023). This in combination with other water saving techniques such as hydroponics and drip irrigation (O3, 2023) greatly reduces net water consumption through reuse. However, besides the developments, it was noted that the collection of transpired water was not considered as a viable option. One builder at GreenTech 2023 said "*The amount of investment needed to achieve that versus the amount of water you would collect does not make economic sense to implement. It is of course an idea that fits the circular thinking, but it is not commercially viable*" (O7, 2023).

ii. By product and nutrients - Growers and researchers have recognized the value of the reuse of by-products of the production processes as well as unused nutrients (Keuter et al. 2021; Rodias et al. 2021; van Tuyll et al. 2022). The growers' cooperative noted that previously there used to be significant amounts of green waste after the harvesting of

fruits and vegetables in the greenhouses (C5, personal communication, 2023). In recent times however, there has been increased valorisation of this waste (C1 and C5, personal communication, 2023). Green waste is increasingly used in compost which can be used in the greenhouse or elsewhere. Further, others use it in their biogas reactors which can also be used for heating (C5, personal communication, 2023). In the Netherlands, there is a company geoFluxus (geoFluxus n.d.), that offers waste management services to companies and government bodies. Their model works by using their platform to analyse each organisation's waste streams and then advising them on how best to utilise it. This platform allows organisations to trade waste since some waste streams are resource streams for other companies. As reported by the growers' cooperative, the use of this platform in the Dutch horticulture sector is in its initial phase and is expected to pick up steam in the coming years through collaboration with the cooperatives and other sectoral stakeholders (C5, personal communication, 2023). As illustrated by van Leeuwen et al. (2018) and van Tuyll et al. (2022), accounting for the flow of raw materials and tracking how they are used in different processes is a key element of figuring out the success factors for true CE.

iii. Equipment – Badji et al. (2022) analysed the strategies in the set up and management of greenhouses. They demonstrated how different considerations take effect in the construction of the glasshouses such as the shape, orientation, and cladding material. The construction of new greenhouses is one that comprises different materials and inputs before they become operational. Noting the different materials commonly used, Badji et al. (2022) highlighted the application of different plastics, glass, polycarbonate, and composite materials in the setup, all of which affected the internal control mechanisms in the greenhouse. As illustrated in Figure 5, many considerations go into the use and purpose of different materials in the greenhouse construction.

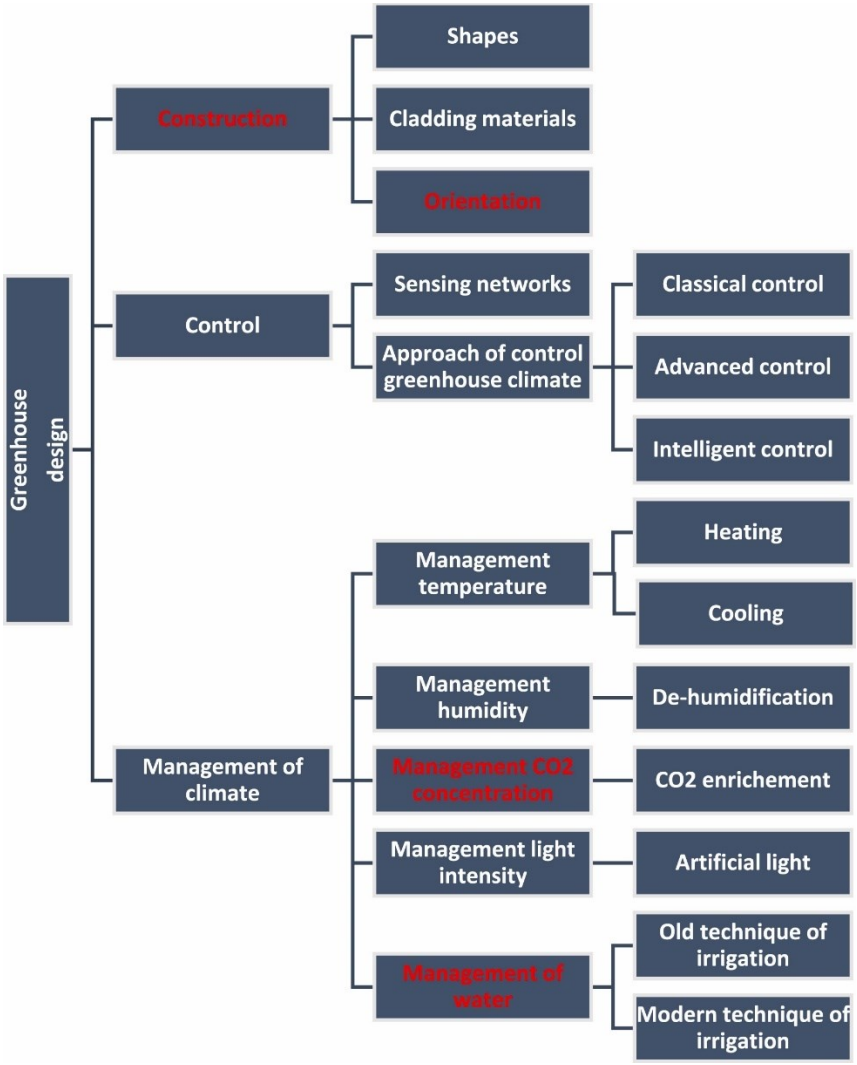

Figure 5: Review of greenhouse design (Badji et al. 2022)

Over time, different parts and components of the greenhouses and their system deteriorate or breakdown (O7, 2023). The choice of what to do with those parts at that point depends on the kind of damage/deterioration and type of material used. Greenhouse builders at GreenTech 2023 indicated some differences between growers and their resources (O7, 2023). Some growers opt for greenhouses made with metal frames and plastic foils while others go for metal frames and glass panels. With the plastic foils, one builder noted that they last a maximum of about 10 years, after which they need to be replaced. Usually, these foils cannot be reused and must be disposed at a waste management facility (O7, 2023). The same was reported for some glass types. There are different varieties, with some of the more expensive ones being more durable and able to withstand high forces and impact. It is common that the glass used in the greenhouses is less brittle compared to that used in housing (O7, 2023). This makes it possible to reuse it. The builders pointed out that when demolishing greenhouses, they take apart the glass and the parts that are still good are reused in a different project while the broken ones are disposed at a waste management facility. For the metallic parts, there is a high reuse rate since most of the parts are standard shaped and sized and because the deterioration of metal under controlled environments such as in the greenhouses is minimal (O7, 2023). Equipment such as sensors, pumps, irrigation systems and other operational installations are usually repaired or refurbished if breakdown occurs where reasonable (O7, 2023).

4.1.3. Recycle

This principle focuses on taking materials considered as waste and reprocessing it into new and usable materials for either the same purpose or different.

i. Packaging – One of the most used packaging materials is plastic, which has also been used to produce many products applicable for daily use (Brizga, Hubacek, and Feng 2020; Tallentire and Steubing 2020). However, this same material poses a threat for environmental sustainability (Tallentire and Steubing 2020). It is a material derived from petrochemical raw material, often nonbiodegradable, and if incorrectly disposed, it creates a wide range of problems for nature and biodiversity (Pazienza and De Lucia 2020). In the horticultural sector, plastics are found in the packaging of inputs as well as the food produced (O4, 2023). Regulation on the types of plastics to be used is still debated, with huge objection to single use plastics (C1, C3 and C7, personal communication, 2023). These are non recyclable, and their continued use only leads to the need for virgin material. The horticultural sector is openly adopting the use of recycled plastic and with the current waste management systems, plastics are separated from other waste for the purpose of recycling (C1, C3 and C7, personal communication, 2023).
   Discussions with packaging companies revealed that the type of material to be used for packaging largely depends on the product it is intended for and the preference of the consumers (C7, personal communication, 2023 and O4, 2023). On one hand, the product-packaging decision is based on the shelf life of a food product while on the other hand, the consumers who are more environmentally aware demand for sustainable packaging or to have no packaging at all for some products. This has an influence in the choices that the retailers have in the packaging of products (C7, personal communication, 2023 and O4, 2023). To enhance the recycling efficiency, it was revealed by one packaging company that they use specially printed codes on the packaging scattered on multiple places to allow their machines to scan and sort the different types of packages based on their material and recyclability (O4, 2023).
   Other packaging materials such as cardboards and paper are collected separately as well and taken to recycling plants. There is ongoing collaboration between waste management companies, municipalities, and grower cooperatives to handle waste (C5, personal communication, 2023).

ii. Circular waste streams (substrates, bioplastics) – An observed emerging or continuing trend is in the use of substrates made from renewable sources (C1, personal communication, 2023 and O2, 2023). This shows a shift from the finite peat resources to alternative materials such as coconut fibre husks. Other such growing media is derived from plant waste making the production more circular and regenerative.
   Interestingly, there is also introduction of biopolymer foam alternatives (O2, 2023). It is not clear what the material used is since the innovators could not disclose it, but they claimed that although made from fossil sources, it was water soluble and inert which made it a good alternative. This material is supposed to be disposed with the rest of the plant waste upon harvesting of the crop (O2, 2023).
   On the flipside, the use of bioplastics is on the rise (O4, 2023). These materials behave like conventional plastics but when they end up in nature, they decompose organically and cause less harm to the environment (Brizga et al. 2020). However, it is also noted that bioplastics are not without environmental harm. The issues of toxicity to

ecosystems are yet to be fully studied (Brizga et al. 2020) and therefore, while there are benefits to their use, it still needs a good level of responsibility in their use.

4.1.4. Recover

Under the Recover concept, valuable materials are extracted from waste streams and put to the best possible use. Resource recovery is accomplished in the Dutch agri-food greenhouse horticulture industry using the following techniques:

i. Energy – The growers' cooperative indicated that a good number of their members utilised anaerobic digestion systems which took organic waste and biomass, such as plant waste, crop by-products, and food waste, to create biogas for energy production (C5, personal communication, 2023). The collected biogas can be fed into the grid or utilised to power greenhouse activities.
Heat energy can also be recovered from the greenhouse and reused elsewhere. Such an example is demonstrated by one growing lights company whose water-cooling solution for their LEDs allowed them to take the heat from the light system and use it to warm the greenhouse or in other cases, for domestic use (O5, 2023). Energy recovery is further enhanced by the implementation of renewable energy sources for instance, solar and geothermal. The growers can get the power needed for their operations and the surplus is fed into the grids (C1 and C5, personal communication, 2023). Further, a collaboration with local industries to have an energy sharing system was reported to be in development with the aim being to use the excess heat and CO_2 from the industries in the greenhouses and neighbouring residential homes/villages (C6, personal communication, 2023).

ii. Nutrients - New methods like membrane filtration or struvite precipitation are used to recover nutrients like nitrogen, phosphorous, and potassium from organic waste streams or wastewater(Keuter et al. 2021; Sonneveld and Voogt 2009). Further, modern greenhouses incorporated closed loop systems and are laden with many sensors that can detect fluctuations in nutrient levels and inform the grower of the needs. The tracking of the resources such as nutrients used and produced in the greenhouse allows for responsible management of inputs and helps to understand the needs (van Tuyll et al. 2022). In the process, the reuse of these recovered nutrients as fertilisers decreases the need for new manufactured fertilisers.
One of the ways as explained by the growers' cooperative is to press the green crop remains to extract the sap that could be used as fertilizer and the fibres/hard waste used as mulch, substrate or as input for building materials (C5, personal communication, 2023). At GreenTech 2023, some exhibitors showcased their organic plant-based fertilisers in which the nutrients were recovered from plant waste streams (O1, 2023). They reported to have a client base that was on a steady increase as EU and national regulations become stricter.

iii. Circular supply chain – Flow of by-products, waste material, and resources is facilitated through partnerships and collaborative networks among greenhouse operators and other stakeholders (C1 and C5, personal communication, 2023). Through systems like geoFluxus, different stakeholders even from other sectors are linked and provided solutions for their waste/input streams . These kinds of collaborations allow the different stakeholders to focus on their core responsibilities while at the same time making the most out of their waste (C5, personal communication, 2023).

4.2. Measures to promote CE

To analyse the CE measures promoted, the multilevel and multi-layered nature of the sector is considered. This can be approached on three levels, macro, meso and micro level as demonstrated by Grafström and Aasma (2021) and Mehmood et al. (2021) in their exploration of the CE barriers. On the macro level, the EU and governmental policies and regulations are considered as well as the industrial associations at national level. On the meso level, consideration is made of the aspects driven by supply chain. This includes the roles of research institutions and innovators, greenhouse clusters and suppliers of inputs. At the micro level, I focused on the role of individual operators, their processes and the influence of the retailers and consumers. To comprehend the sectoral approach to the promotion of CE, it was beneficial to understand who the key stakeholders in the sector are and what their influence is.

4.2.1. EU level.

The European Union has been at the forefront of championing the transition to CE in the region (European Commission 2019, 2020a; Watkins and Meysner 2022). As a regional governing body of 27 member states, the EU develops and implements policies and regulations as well as initiatives to drive CE in the region. Each member state is sovereign and therefore at liberty to adopt the EU directives into national policy and regulations. Many of these CE initiatives are supported through specific thematic areas with the aim of targeting crucial sectors for circularity. The European commission adopted its first CE action plan in 2015 (European Commission n.d.), which laid the foundation for further CE initiatives in the region. In 2019, the European Commission introduced a new strategy dubbed the European Green Deal which defined the intention of the EU to become climate neutral by 2050 (European Commission 2019). This was outlined as a roadmap that came with action plans for attainment of that goal. Key to the CE promotion was the new CE Action Plan presented on 11th March 2020 (European Commission 2020a). This new plan outlined measures and strategies to push the CE agenda in agricultural production and food systems amongst other sectors. The emphasis on reducing waste, increasing resource efficiency and sustainable greenhouse production was a key element of the new action plan. The plan encompasses different aspects of the sector not only in the production but also in the management of processes around waste management and recovery of nutrients. As observed in the operation of greenhouses and the many innovations exhibited during GreenTech 2023, nutrient loops are being utilised and promoted to ensure there is a reduction of fertiliser use and saving on water losses. These deliberate steps highlight the importance that the EU has placed on the role of CE in shaping the future of not only Europe but the global environment.

Further, the EU launched the Farm to Fork Strategy in 2020 (European Commission 2020b), also under the Green Deal. This strategy was adopted to harmonise the EU food production system and make it a benchmark for global sustainable food production. This focused on the supply chain factors as well as the consumer behaviour. For example, there is promotion of healthier diets and sustainable food productions This is linked with other goals such as ensuring food security as well as looking at processing and food distribution. The EU sees this as a possible reality through collaborations and partnerships that foster conducive conditions for sharing not only in the knowledge and skills but also in the prosperity of the region. To facilitate this, there are different incentives and financial accommodations such as the InvestEU Fund and European Regional Development Fund that will help in making the transition to circular and sustainable food production systems for farmers.

Besides the agricultural production systems, the EU announced the strategy for plastics in 2018 (European Commission n.d.) as part of the CE action plan. It is claimed that this was done to reduce the amount of marine litter GHG emissions and the reliance on fossil fuels, mostly imported. The actions around this were aimed at promoting profitability of recycling by having rules about packaging to improve how well the plastics can be recycled which would also increase the demand for recycled plastic. Further, promoting the separation of plastic waste at collection would help support this drive. Other measures include the directives on single use plastics and adoption of measures around bio-composite plastics. The injection of a considerable figure of 100 million for the development of better plastics which would be smarter and easier to recycle, trace and rid off substances that would be toxic of hazardous from the plastics was a clear show if intent from the EU.

Watkins and Meysner (2022) evaluated the policies and actions taken by the EU with regards to CE. They established that the EU recognised the need for legally binding measures as most of the initiatives proposed had not been implemented or adopted. The key areas of focus were on the industrial chemical and textile sectors, while the horticultural sector is not widely mentioned. There is however an acknowledgement of agriculture as a key sector in the drive towards a CE. Interestingly though, the emphasis of measures seemed to be about recycling and recovery while the reduction of waste and reusing are yet to catch up. However, there is an increase of initiatives targeted at the higher waste hierarchy actions of reducing and reusing waste.

4.2.2. National Government

In its vision, the Dutch Government acknowledged the need for a transition from a linear to CE whereby nearly all products used by the Dutch population would be reused multiple times. In its policy, it calls for the design of products to be reusables, easy to repair and reused. To enhance this, the government followed up with the ban on free single use plastic bag with the aim of reducing littering and protecting the environment. By this thinking, the government recognised the need for changes in consumer behaviour for this circular dream to be a reality. It therefore committed to promoting this change by providing a platform for education and conducting campaigns on CE. In 2016, the National Agreement on the CE was submitted to the House of Representatives (Anon 2017). This agreement was a programme that outlined the actions needed to ensure proper, efficient, and smart utilisation of raw materials resources and services to propel the country to be circular by the year 2050. This was followed by the signing of a letter of intent amongst different parties consisting of governmental bodies, public and private sector entities. This formalisation laid a basis for the collaboration between the parties as well as with the government. As part of the deal, different agendas for the transition were identified and mapped out plans to reach milestones until 2030 (Government of the Netherlands 2016).

Functionally, the topic of CE is nested under the ministry of infrastructure and water management and the Ministry of Economic Affairs and Climate Policy (Government of the Netherlands n.d.). The current goals are to ensure that the Dutch economy will be completely circular in 2050 and that by 2030, a 50% reduction on the primary raw material consumption will have been achieved (Government of the Netherlands 2016, n.d.). The government thus collaborates in multistakeholder platforms with governmental, business, and international organisations to drive the agenda of CE globally. The government identified five transitional objectives which were biomass and food, plastics, manufacturing industry, construction, and consumer goods as the priorities across ten cross-cutting themes. The issues of horticulture are addressed in the biomass and food agenda. However, when it comes to greenhouse horticulture, the Ministry of Agriculture, Nature, and Food Quality is responsible for the policies relating to agricultural production (Government of the Netherlands 2016).

As a member of the EU, the Netherlands adopts the EU measures and is a key contributor to the EU political landscape (European Commission of the Regions n.d.). Several stakeholders have been quick to point out that the Netherlands is usually one of the first countries to implement the EU proposed directives and other EU member states look up to what happens to the Dutch scene when new measures are introduced in Europe. In 2021, the Netherlands adapted the new CE action plan into their CE implementation programme. In its report, the Netherlands Environmental Assessment Agency reports that the initial phase of laying the basis for transition is done and clearer goals, responsibility, and ambitions are part of the government strategy in promoting CE (Watkins and Meysner 2022).

The Netherlands Enterprise Agency (RVO) offers a wide range of possibilities for businesses and entrepreneurs to access funds and financial support for their transition to sustainable methods or to support them in investment in environmentally friendly technology. These benefits and can come in the form of subsidies or tax reliefs. Some examples of the available options for the greenhouse sector are the Environmental investment deduction MIA and the Arbitrary depreciation of environmental investment (VAMIL). The former allows entrepreneurs to deduct up to 45% of their environmentally friendly investment costs on top of their regular investment tax deductions while the latter allows them to waive 75% of their investment costs (RVO n.d.). Through the Horizon Europe, funds are availed for projects geared towards research and innovative solutions. Growers, supply chain stakeholders and entrepreneurs who want to contribute to the attainment of the CE goals can make use if the available financial incentives to invest in the betterment of the sector.

4.2.3. Provinces

At the regional level, the provincial governments are responsible for the coordination of the projects within the provinces as well as formulating the regulations about the use of space and the rules about the environmental aspects of the province (European Commission of the Regions n.d.). In this research, I spoke to representatives of three provinces (C2, C4 and C6, personal communication, 2023). There were some distinct similarities in the provinces in the understanding of the topics of CE and sustainable development within the provinces. In all, there was a close collaboration between the provincial administrations and the national government while at the same time maintaining close ties with the different sectoral organisations such as research institutions, the farmers organisation (LTO), the greenhouse organisation (Glastuinbouw Nederland) and the growers' cooperatives (C1 - C6, personal communication, 2023).

The provinces execute many of the initiatives and projects geared towards circularity of the sector. It was observed that there is a clear designation of teams addressing specific issues of CE such as plastics, energy, or biomass provinces (C2, C4 and C6, personal communication, 2023). In one, for example, they are investigating the possibilities of reusing the heat and CO_2 from the industries in the greenhouses and households (C6, personal communication, 2023). There is an ongoing plan for a pilot to connect one village and a nearby greenhouse cluster via a pipeline. With this kind of a project, there are numerous challenges faced in pulling the community and the relevant stakeholders together for there to be social acceptance of the projects as well as potential funding and approval (C6, personal communication, 2023). In the other two, there is a particular interest in the management of plastics used not only the greenhouse sector but also in other sectors (C2 and C4, personal communication, 2023). Besides these aspects, the provinces also focus on other aspects such as substrates, CO_2, water, and energy.

Part of the challenges that the provinces face is in the scoping of the circularity of these aspects. As defined by their representatives, while the greenhouse as a unit might have many circular installations and systems, scaling up to the clusters and regions makes it difficult because the scope

of stakeholders increases and the consolidation of the issues around packaging and other waste streams becomes complicated (C2 and C4, personal communication, 2023). Since each stakeholder tends to focus on their area of expertise and outsources other nonproduction activities to multiple and different providers, it is difficult to bring all to the table and have consensus on what the way forward should be (C1 - C5, personal communication, 2023). The provinces therefore partner with other organisations such as the regional chapters of Glastuinbouw Nederland and Greenport to help address the pressing issues (C1 - C4, personal communication, 2023).

The provinces however coordinate the projects and legislation within their jurisdictions but feel that there should be clearer and stricter directive from the EU (C2 and C4, personal communication, 2023). An example quoted was that of the issue of moving to alternative packaging such as bamboo or paper. These materials purportedly contain coating and additives that made them less sustainable despite them being touted as better alternatives. Their recyclability and biodegradability in the environment were put to question and as such, one of the provinces called their use as knee jerk reactions that don't really solve the problem (C2, personal communication, 2023). The sentiment is that most of the EU regulations are not legally binding or directive for the goals of the provinces (C2, personal communication, 2023). The provinces have regulations that are in line with the EU but would like to have more direction from the EU especially with regards to packaging. The provinces acknowledged the actions of different stakeholders in working towards a CE. However, they noted that the EU was the most significant stakeholder but was hesitant to introduce "biting" legislation regarding the horticultural sector due to the economic significance it holds (C2 and C4, personal communication, 2023). Apparently, there are some stakeholders that lobby the EU in Brussels which slows down the regulation (C2, personal communication, 2023). This challenge was identified as a major bottleneck for the provinces to do their work on circularity. According to the provinces, if the EU legislations are changed or improved, it would be more conducive for entrepreneurs to invest in circular systems and sustainable practices (C2 - C4 and C6, personal communication, 2023).

4.2.4. Glastuinbouw Nederland

Growers in the Netherlands are brought together by an organisation, Glastuinbouw Nederland, that unites and supports them through lobby efforts at different administrative levels while also promoting dissipation of knowledge within the sector (SIGN 2023). Through their different programmes, they support transition to circular horticulture for instance through the Stichting Innovatie Glastuinbouw (SIGN) which in English, is the Dutch Foundation for Innovation in Greenhouse Horticulture (SIGN 2023). SIGN partners with the Ministry of Agriculture, Nature, and Food Quality to enhance cross sectoral collaboration to work on programs that stimulate innovation and development of methods, models and technologies that support the CE transition. Together with other stakeholders, they investigate and research on how best to utilise the different waste streams as well as optimising the use of inputs such as fertilisers and substrates (C1-C5 personal communication, 2023).

A considerable effort goes towards finding ways of focusing on the principles of CE at the greenhouses and within the clusters. The main thematic areas are around water, energy, inputs, nutrients, and waste streams. SIGN approaches the circularity from three level namely, the greenhouse, the environment and society. Through several pilots and by addressing the issues on different levels, there is a great understanding of the sector and its needs (C1, personal communication, 2023). The placement of the organisation allows them to have a bird's eye view of the sector to identify the gaps and opportunities for making the sector sustainable. The perspective of the organisation is to not only address the technical aspects of CE but also the social aspects such as health, happiness, and wellbeing (C1, personal communication, 2023).

It was revealed that there exists some misalignment between the goals of the governmental bodies and the actions towards circularity and sustainability which makes it difficult for the organisation (C1, personal communication, 2023). While there is a good intention to reach the circular goals, working within specialisations and in isolation is detrimental to ensuring that the goals are achieved (C1, personal communication, 2023). For example, if one ministry makes a commitment to provide subsidies, but the subsidy is to be paid by a different ministry who may not see the justification for the subsidy, it leaves the growers in limbo. For a truly CE to be achieved, the legislations should not be contradictory. Case in point, the legislation of by-products being considered as waste limits the choices that companies have in reusing their own waste as a resource.

Other restrictive legislation identified was the activity "besluit" (decree) whereby companies are only allowed to engage in activities defined in their permits (C1 and C5, personal communication, 2023). This limits the ability of a grower to do waste management or nutrient recovery and recycling in their locations. So, this means many growers need to outsource these activities, which comes with extra cost burdens. These considerations may likely influence choice of growers on whether to consider circularity especially around the management of plastic waste. Glastuinbouw Nederland therefore tries to negotiate this on behalf of its members in collaboration with their cooperatives (C1 and C5, personal communication, 2023). This is done through knowledge sharing, setting goals for all the greenhouses which allows the cooperatives and their members to create common visions and objectives for the future of the sector (C1 and C5, personal communication, 2023).

To stimulate the transition, Glastuinbouw Nederland collaborates with research institutions such as Wageningen University and Research (WUR) that have a specialised focus on agriculture and more so on greenhouse horticulture (C1, personal communication, 2023). WUR conducts extensive research on many social and technical aspects of the horticultural sector and runs experiments at their own facilities (C1, personal communication, 2023). The contribution of these research projects is immense in the sector since new methods and techniques are introduced, bringing about more efficient and sustainable products, processes and even greenhouse equipment. This is important for the sector not just locally but also internationally since the Netherlands exports many products and expertise to the rest of the world (Salinas-Velandia et al. 2022). The GreenTech exhibition provided an opportunity for some of the innovations to be showcased. This collaboration also extends to the growers' cooperatives to which majority of the growers affiliate themselves with (C1 and C5, personal communication, 2023).

4.2.5. Growers' Cooperatives

The interaction with the cooperative highlighted the role that they play in promoting the goals of CE in the sector (C5, personal communication, 2023). As an umbrella body, the cooperatives provide services such as like knowledge services, strategic plan making, knowledge sharing, but also packaging their products, transporting them so that the growers can really focus on the growing and they do most of the other things for them (C5, personal communication, 2023). For example, sustainability wise, they look at what is happening in the market and develop strategies to be 100% fair and circular by 2050. First step is creating the product footprints for all products produced and try to reduce the footprint. Where it is not possible to reduce, they try to compensate. They collaborate with companies that provide sustainable solutions for the problems they might face. They have assigned duties to someone to investigate the waste streams, how they can be recirculated and the most optimum solution (C5, personal communication, 2023).

On the use of plastics and fertilizers, the cooperatives have a say, albeit limited in the way their members operate. The growers are independent companies/entities and therefore can decide how to run their businesses. However, the cooperatives can impose standards that members need to adhere to if they want to keep their membership. The cooperative however, has no legal grounds to enforce or compel the members to implement anything and it is done out of mutual respect (C5, personal communication, 2023).

Money and finances play a huge role in whether members can fully adhere to the standards within the cooperatives since more sustainable options require significant investment. This makes the grower think twice if it is profitable to adopt new methods/processes in the name of sustainability or to slowly implement them (C5, personal communication, 2023). Within the cooperatives, there are initiatives like water coaches who visit the companies to check what could be improved, make improvements plans with the growers and provide advisory on the processes. This allows the cooperative to improve the general performance of their members and having proper comparisons across different grower companies (C5, personal communication, 2023).

The cooperative revealed that the older generation growers are less inclined to change since they are so used to operating in one way and find it difficult to make the switch (C5, personal communication, 2023). So, they try to target the newer generation of growers who are more aware and enthusiastic about sustainability. Some of the companies nested under the cooperatives are family owned and the children of the growers are now getting into the business with more willingness to look at the businesses with a fresh and open perspective to look at all the opportunities as well as sustainable options for their greenhouses. They target them with knowledge sharing and sharing with them all the options and making sure they create future proof businesses (C5, personal communication, 2023).

4.2.6. Suppliers and Service providers

This group of stakeholders play a big role in the transition to a CE. Their involvement in supporting the greenhouse sector is characterised by the involvement in the provision of sustainable solutions for the production and distribution services in the supply chain. These providers are involved in the following ways.

Building of greenhouses:

Different companies provide building and turnkey solutions for the greenhouse growers (O7, 2023). There is a growing awareness amongst the builders in the use of sustainable materials and implementation of the CE principles in their development of greenhouses. The type of materials used in the construction is considered relevant for the greenhouses is important for functional reasons especially in combination with the modernised controlled systems implemented in the sector. Climate controlled greenhouses have become the norm in the sector and a big part of this is in the ability to maintain air quality and temperature which requires materials that are good for insulation. Natural light is also considered a key component of greenhouse production which is the reason why most greenhouses are constructed with transparent and translucent materials. Different builders provided insights on the construction of the structures. The most common materials for the framework were metals such as steel and aluminium. The walls and roofing material are mostly glass and plastic panels or foils. Discussions with construction companies indicated that the choice for which materials and construction type lay with the customers depending on their budget. The consideration for the reuse and recycling of materials has been explored but apparently most customers prefer to have new materials especially for the walls and roofing. The steel and aluminium

parts are usually reused since their deterioration in a controlled environment is limited and because the parts are standardised (O7, 2023).

Inputs:
Different inputs such as fertilisers, seeds, substrates, and pest control are required for production. Much of these inputs are provided in forms of sustainable solutions. In line with EU legislation on the use of fertilisers, manufacturers have adopted the use of biological and organic solutions (O1 and O2, 2023). As observed during GreenTech 2023, growers have the freedom of choice to use substrates that are made from renewable materials such as coconut husks or growing foams instead of peat substrates (O2, 2023). There has been significant development in the extraction of nutrients from green waste and residual waste streams in the greenhouses which is commonly implemented in closed loop systems installed in hydroponic and vertical growing systems (O1 and O3, 2023). The innovative technology applied for the extraction, reuse and recycling of water and nutrients within the greenhouse systems is now a common practice in the sector and suppliers provide customised solutions to growers to meet their specific growing needs (O3, 2023).

Energy solutions:
One of the main challenges for most greenhouse companies and growers in the production cycle is the energy use (C1 and C5, personal communication, 2023). The greenhouse sector has a huge energy demand and forms a considerable part of the national and provincial energy grid systems (C6, personal communication, 2023). Most of the energy demand stems from the fact that most of the production relies on controlled environment systems that require automation of machinery and computers running it 24/7 (C1 and C5, personal communication, 2023). The energy consumption is particularly higher during winter months as the country significantly cools and thus requires the growers to heat their greenhouses. In summer months, it gets too warm and then the greenhouses need cooling. To maintain normal and standard conditions in the greenhouses, growers need solutions to minimise their energy consumption without compromising on their output as well as providing alternatives for the cold winter months (C1, C5 and C6, personal communication, 2023). As such, there are suppliers specialised in the set up of renewable energy systems such as solar, biogas and geothermal (O7, 2023). With these sources, growers can meet their production targets without heavy reliance on the energy grid. This helps them save a great deal on the cost of energy since the energy subsidy received from the government inversely proportional to the global gas prices.

Packaging:
Packaging contributes a considerable amount of waste along the supply chain (Tallentire and Steubing 2020). Different materials such as plastic, paper, and biodegradable material like bamboo or bioplastics find use in the sector and different stakeholders adopt their own policies for their use (C1, C2, C3 and C5, personal communication, 2023). Insights from a packaging systems maker revealed that the choice of which materials to use for some products depends on the type of product to be packaged. While some can be packaged in paper or biological material, others can only be packaged in plastic because on the shelf life (C7, personal communication, 2023).

Other factors considered are the preference of the consumers. The consideration of the consumers' preferences is considered variably by different retailers. In one example, as explained by the packaging system maker (C7, personal communication, 2023), in a bid to reduce the amount of plastic waste, two leading Dutch supermarket chains took two different interpretations to new legislation about reduction of packaging amount. Supermarket A reduced the amount of material per package while Supermarket B eliminated packaging for some products. The result was that while

Supermarket A was able to reduce the amount of packaging, there wasn't a remarkable change in the sales or food waste generated. Supermarket B however noticed that they had more food waste from the products that were no longer packaged. This was attributed to the fact that consumers were able to choose products that were without blemish and left the less perfect ones, leading to those ones left going bad on the shelves.

In the words of packaging companies (O4, 2023 and C7, personal communication, 2023) , there is a fight against plastics that while understandable, is uncalled for. The argument is that plastic is a great and reliable material that has been used for great inventions. However, it is the mismanagement of the material in the waste hierarchy that causes problems, so it is a problem with human behaviour. However, some packaging companies (O4, 2023) take the proactive approach and produce environmentally friendly products such as biodegradable plastics which decompose naturally in nature, causing less harm to the environment. Additionally, their products have numerous scannable codes that contain information about the material, its recyclability, and the type of disposal method appropriate. This means that even in instances where the package material is torn up, there is a high likelihood that the different pieces will have part of the code which makes it easier to sort by machine and handle it appropriately. Although there is awareness from both producers and consumers about the benefits of environmentally friendly product choices, the retailers need to prioritise less on profit and more on doing what is best for the environment (C7, personal communication, 2023). The EU is urged to have more legally binding regulations on the type of materials used in the packaging and the use of plastics should be clear (C1, C2, C3, and C7, personal communication, 2023). For example, the UK has the mono material rule and that simplifies the recycling process (C7, personal communication, 2023).

Having looked at the circular practices in the sector and the different measures being used to promote it, the next step was to assess the governance context in which these practices and measures occur, which is addressed in the next section.

4.3. Governance Dimensions

As previously explained in section 2.4, the effectiveness of a governance regime is determined by the structural context, which contains the multiplicities of governance aspects that influence the interaction processes of stakeholders, driven by their different motives, cognitions, and resources. The governance dimensions as identified by Bressers (2009), Bressers et al. (2016) and Lordkipanidze et al. (2020) are 1. levels and scales 2. Actors and networks 3. Problem perspectives and goal ambitions 4. Strategies and instruments and 5. Resources and responsibilities. These dimensions are elaborated further in the following sections.

4.3.1. Levels and scales

This part of the assessment checks whether the issue of circularity is addressed across all the relevant levels and scales. The topic of CE is one that is relevant globally and has an effect that goes beyond the local context in which it is addressed (De Boer and Van Ittersum 2018; Kirchherr et al. 2023, 2017; van Zanten et al. 2023). Within the EU there are overarching mechanisms that are set up by the member states. The European Commission is active in proposing measures and directives that promote CE (European Commission 2019, 2020a; Watkins and Meysner 2022). The Netherlands, as a member of EU makes use of the EU directives to make national policies through the various ministries (Watkins and Meysner 2022). In relation to the greenhouse horticultural sector, the Ministry of Agriculture, Nature, and Food Quality is responsible for promoting sustainable production in collaboration with The Ministry of Economic Affairs and The Netherlands Enterprise Agency (RVO) (RVO n.d.) to support the transition. Provincially, the Province administrations are involved in making

the regulations, coordination of projects together with growers, their organisations, and cooperatives. Within the provinces, the municipalities within which the greenhouse clusters are located play an important role ensuring the growers and their companies adhere to the rules and regulations within their jurisdictions (C1, C2, C3, C4, C5 and C6, personal communication, 2023). From the EU to the municipalities, there are different stakeholders involved, although with varying interests and influence.

4.3.2. Actors and networks

In this section the multiplicity of actors involved in the CE governance are assessed. To build a clear understanding of the setup, the key stakeholders were identified and mapped in Figure 6. The different stakeholders involved in the issue are found across different the levels (Macro, meso and micro). They interact on different occasions for different matters and have different coalitions and affiliations that allow them to negotiate and deliberate on matters of interest amongst them. It is possible for new actors to be involved although their influence may not be big enough to change the course or direction of the sector. Some of the actors are involved actively while others are involved in a passive way. One such group is the consumers who have a huge influence due to their habits and demands but they are involved in a passive way and sometime not even aware that decisions are made by other actors based on consumer behaviour. The administrative authorities from EU and national level make decisions based on expert knowledge and do not really consult the growers or the consumers before introducing new directives or measures (C1, C2, C3, C4, C5 and C6, personal communication, 2023).

Figure 6: Key stakeholders in the sector

To understand what is expected from these actors in the sector, a summary of their roles is provided in Table 8.

4.3.3. Problem perspectives and goal ambitions

As envisioned by Bressers (2009), Bressers et al. (2016) and Lordkipanidze et al. (2020) this element assumes that there are multiple perspectives and goal ambitions of the different stakeholders. There

is a big push to attain sustainable production and consumption in the world (Brekke 2021; Kirchherr et al. 2023; van Zanten et al. 2023), but what it entails is subject to debate (C1, C2, C3 and C4, personal communication, 2023). The EU in its various directives is focused on pushing the agenda of circularity and sustainable agriculture (European Commission 2020b). The same vision is reflected in the national policies and legislation (Watkins and Meysner 2022). However, the implementation of these policies occurs at more local levels in the provinces and municipalities who face different challenges in their jurisdictions (C1, C2, C3 and C4, personal communication, 2023). As described by the provinces, there is a need for more firm directives from the EU (C2, C4, and C6, personal communication, 2023).

Practitioners within the private sector such as growers and their suppliers are keen to see the sustainability and circularity of the sector, but within the limits of the economic viability of the measures implemented (C1, C5 and C7, personal communication, 2023). As such, although some of the actors may see the sense in incorporating the CE principles into their business, the return on investment is a big consideration on how much they would consider the implementation of CE practices (C1 and C5, personal communication, 2023). Most growers operate family businesses and would therefore want to ensure the longevity of their enterprise to pass on to their children, thus, sustainability of their greenhouses is paramount (C1 and C5, personal communication, 2023). For some actors in the supply chain, the issue of circularity is considered a non crucial matter and is only done at the behest of their clients' needs and demands or because the requirements demand it (C3, C5 personal communication, 2023 and O7, 2023).

4.3.4. Strategies and instruments

Under this dimension, the strategies used by the different actors are considered and analysed. Several policies and measures are proposed or implemented to promote and achieve circularity in the greenhouse horticulture sector in the Netherlands (C1 - C4, personal communication, 2023). The policies and directives issued by the EU are based on a vision drawn by experts and adopted by the national government through the different ministries (C1, personal communication, 2023). The regulatory instruments introduced in the country about the use of fertilisers, plastics and water quality are based on a top-down approach as little consultation occurs with those affected (the growers) (C1 and C5, personal communication, 2023). However, further down the hierarchy, the regulatory measures introduced by the provinces are more consultative in nature since they are formulated together with Glastuinbouw Nederland, the cooperatives and with experts from research institutions (C1 - C6, personal communication, 2023). Besides the regulatory measures, a wide range of incentives at national and provincial level are present. Growers and companies receive subsidies and other financial support to facilitate their investment in sustainable methods and technology (C1 and C5, personal communication, 2023). Despite this, on the different levels, there are awareness campaigns and numerous consultations that occur amongst the stakeholders to ensure there is consensus about the way forward. As revealed by the provinces, they hold regular meetings amongst themselves and together with the national government to chart a common path and to keep up with what is happening in other provinces (C2, C4 and C6, personal communication, 2023).

4.3.5. Responsibilities and resources

This governance element was assessed to evaluate the roles and responsibilities of the actors and determine whether they are clearly assigned. These are summarised in Table 8. The authority of the different actors is clearly defined, and their jurisdictions well marked out. In the simplified hierarchy Figure 6, the EU provides the overarching policies, directives and regulations that are then channelled down to the national government, provinces to the different growers' groups, cooperatives, retailers, and consumers (Watkins and Meysner 2022). The financial resources needed

for the implementation of the circularity are provided via different initiatives from the EU, national government, and provinces. Although these resources are available, they are not enough to make the circularity fully a reality (C1, personal communication, 2023).

Table 8: Stakeholders' roles and responsibilities

Stakeholder	*Roles and responsibility*
European Union	Issues European policies and directives on CE related matters
Dutch government Ministries	Issue and manage the national policies in the respective dockets in line with EU directives. Manage the subsidy programmes. Supervise the provinces
RVO	Provide financial incentives
Provinces	Issue provincial regulations in accordance with the Dutch national law Advise the national government in matters of policy affecting the provinces. Do the spatial planning and determine where greenhouses should be located. They draw up environmental protection plans, laws and regulations that pertain to circularity. Initiate projects with other stakeholders to promote circularity.
Municipalities	Spatial planning and making land use plans within the municipalities. Managing waste management
LTO	Act as a bridge between the ministries, Glastuinbouw Nederland and growers Represents farmers and growers in negotiations with government and EU. Coordinates farmers' activities and programmes nationally
Glastuinbouw Nederland	Unites and supports greenhouse entrepreneurs. Coordinates greenhouse horticultural regions, cooperatives, and groups Initiates programmes and projects for innovation and research
Research Institutions	Provide technical and innovative expertise to the different stakeholders. Collaborate with Glastuinbouw Nederland, provinces and technology service providers to develop, innovate and share technical solutions for circularity. Advise different stakeholders based on their research findings
Cooperatives	Bring together different growers into a group to collaborate and share resources. Facilitation of knowledge exchange, technical expertise, and practices Bargain in the local and international market on behalf of the growers
Growers	Implement specific circular practices in their businesses. Collaborate with suppliers, retailers, and waste management companies to come up with business models that support circularity
Suppliers and service providers	Provide inputs and services to the growers. Assist the growers to reach their circularity goals
Waste management companies	Take up the waste generated by the growers and other supply chain actors. Provide solutions for other stakeholders to upcycle or recycle waste
Retailers	Distribute and sell the products that the growers produce. Collect the data on consumer needs and communicates to the growers. Manage the supply and demand for consumers
Consumers	Set the trends in consumption. Demand for sustainable products

With the governance dimensions outlined in this section, it was then possible to assess them on their qualitative aspects as prescribed using the GAT (Bressers et al. 2016).

4.4. Assessment of the CE Governance Context

Based on the observations and evaluation of the governance context addressed in the previous sections, the governance dimensions were assessed against the quality criteria of extent, coherence, flexibility, and intensity as defined by Bressers (2009), Bressers et al. (2016) and Lordkipanidze, Bressers, & Lulofs (2020). The evaluative questions for the assessment are listed in Table 1 and the evaluation results listed are based on the criteria defined in Table 2.

4.4.1. Extent

Levels and scales: Supportive

From all the interviews, all the relevant levels are observed to be involved in the promotion and implementation of the CE in the horticulture sector. Each of the levels has an objective for circularity with the lead coming from the EU.

Actors: Moderate

Most of the actors feel involved in the transition. The interviews revealed that while the influential stakeholders are involved in the policy making, not all are involved and only come in during the implementation stage. Builders (O7, 2023) and growers (C1 and C5, personal communication, 2023) implement different measures that are driven by policies made in higher levels of governance. However, growers are represented by Glastuinbouw Nederland that tries to negotiate with national government in policy matters (C1, personal communication, 2023).

Problem perspectives and goal ambitions: Moderate

The goals and objectives of circularity in the sector are vastly different across the different stakeholders. It was expressed in the interviews that not all the perspectives are included when policies are introduced (C1, C2, C3, C4, C5 and C7, personal communication, 2023). On one hand, the EU and national government propose adoption of new measures about issues such as plastic but the practicality of that in some applications for the growers and supply chain actors is different. Some believe that the plastics are not a problem but rather the ways of dealing with it (C7, personal communication, 2023 and O4, 2023) while others observe that while there is a push to promote recycling, the chemical and physical process lead to more GHG emissions than use of virgin material (C1, C3 and C7, personal communication, 2023). The general assessment is that there is recognition of the goals but the perspectives on the same goals differ.

Strategies and instruments: Supportive

This was found to be supportive since across the different levels, there are many initiatives in place to promote circularity in the sector. This is seen in the different networks from the EU with the CE action plan and the financial incentives accompanying the initiatives (European Commission 2020b, n.d.-b, n.d.-a; Government of the Netherlands 2016). The national government also came up with a plan to be circular by 2050 and put-up different programmes in place and supported them with empowering the provinces and issuing subsidies (Government of the Netherlands 2016). The provinces, through different programmes and initiatives support the growers and other sectoral actors and collaborate with the national government and Glastuinbouw to promote circularity (C1, C2, C4 and C6, personal communication, 2023). The growers and their cooperatives under the Glastuinbouw Nederland are also active in driving the circularity within their organisations (C1, C3 and C5, personal communication, 2023).

Responsibilities and resources: Moderate

Whilst the responsibilities of the actors are clearly defined in terms of their core functions, it is unclear especially within the cooperatives and greenhouse companies what their circular responsibilities are (C1 and C4, personal communication, 2023). It was noted that in some instances, different actors assume that it is the responsibility of other actors to perform certain functions such as waste management or definition of what waste streams can be resources (C5, personal communication, 2023). This was particularly the case with some growers in cooperatives who perceive water reuse as an important element while others in the same cooperative would perceive it as a nonissue and therefore saw no need to implement (C5, personal communication, 2023).

4.4.2. Coherence

Under this quality, the governance elements are assessed in terms of whether they complement or contradict each other. This is based on how the stakeholders cooperate, share goals, have consensus, or communicate with each other.

Levels and scales: Moderate

Most of the levels perceive that they work together in the promotion of circularity in the sector. However, it was mentioned by different stakeholders that they felt that this cooperation was not always the reality. For example, some informants felt that the decisions made at EU and national levels are made by political appointees who have no connection with the growers based on advice from experts who are not practitioners in the business (C1 - C4, personal communication, 2023). Although this sentiment may be perceived as a negative one, there is a recognition of the mutual dependence of the different levels in making circularity possible in the sector. That is expressed in the way that the cooperatives, provinces and even supply chain actors look up to the national and EU representation to come up with better or more enforceable policies to steer the circularity into reality.

Actors: Moderate

Most of the interactions between the actors are structured through institutions and are sometimes even at regular intervals (C1, C3 and C6, personal communication, 2023). As the structure and hierarchy of the governance is established, there are clear communication channels between the main stakeholders. However, the interviews revealed that some interactions are informal to the extent that they differ from one actor to another. This is true in the case reported by some interviewees about certain actors lobbying EU in Brussels to stall some processes which end up affecting the effectiveness of the stakeholder's work (C2 and C3, personal communication, 2023).

Problem perspectives and goal ambitions: Restrictive

The goals of the actors involved differ according to most of the interviewees' perspectives (C1 - C5, and C7, personal communication, 2023). Whilst the EU and national government are driven by the goal of attaining the goals of the Green Deal and Paris Agreement, some other stakeholders worry about how to do that and whether they can afford to get there . The growers especially are faced with tough times because of the increased cost of energy and the ever-growing demand for food with population growth (C1 and C3 - C6, personal communication, 2023). Small changes in the regulations such as what type of fertiliser or plastic is permissible means that some growers must change so much in their business models and even with the subsidies available, it is still a challenge without a guarantee on the return on investment (C1 and C5, personal communication, 2023). The problem for the growers is defined by all the interviewees as one that is economically driven and the decision of whether they can implement all the CE principles depends on their capabilities. Supply chain actors described their goals as the decision of the consumer or growers and therefore strived to address what they require if it falls within the laws and regulations (C7, personal communication,

2023, O1, O4 and O7, 2023). The research institutions are in this case independent of the goals of other actors as they primarily focus on research to improve every aspect of the sector, that is, helping the sector address the environmental challenges but at the same time improving the efficiency of systems and their profitability (C1, personal communication, 2023). The legislative authorities are primarily driven by their goals for protecting the environment while those in private sector worry about economic considerations (C1, C2, C4 and C5, personal communication, 2023).

Strategies and instruments: Moderate

The systems in place create synergy and allow the policy instruments to work. However, some facilitation of these instruments creates some conflict. For example, RVO helps entrepreneurs to transition to more sustainable modes of production through provision of subsidies. If an organic grower decides to implement circular systems such as hydroponics, they can no longer sell their products as organic due to the requirement that such products have to be grown in soil. Therefore, these kinds of policies beat the purpose and make some growers shy away from the more circular options to keep certain certifications (C1 and C5, personal communication, 2023).

Responsibilities and resources: Supportive

There has been tremendous effort through the different coalitions of actors to bring about cooperation in the sector (C1, C3 and C5, personal communication, 2023). Whilst there may be differences in opinions over what should happen, the institutional establishment allows the dialogue to take place on a good level. The different actors have channels to address the different stakeholders through their representation (C1 - C6, personal communication, 2023). However, the responsibility of the consumer is one that is considered important but is passive since their input is not directly sought but researcher and analysts from the other actors observe consumer habits and make predictions and policies from these observations (C1, C3, C5 and C7, personal communication, 2023) such as is the case previously mentioned about the use of packaging in the supermarkets (C7, personal communication, 2023).

4.4.3. Flexibility

This quality evaluated the extent to which the governance dimensions support and enable and enable adaptive actions.

Levels and scales: Restrictive

The Netherlands is a key stakeholder in the EU (European Commission of the Regions n.d.) and is usually one of the first to adopt any EU measures that are proposed (C1 and C4, personal communication, 2023). These measures are usually absorbed into national policy and therefore gives a target for the provinces to follow (C2, C4 and C6, personal communication, 2023). In the issue of circularity, the national policy is addressed in the provincial level by each province determining their own strategy. However, there is little room for deviation since the provinces all follow the same directives (C2, C4 and C6, personal communication, 2023). Circularity in the sector is still growing but barely goes beyond the cluster level in the municipalities because majority of the implementation is within the greenhouse units (C1 - C6, personal communication, 2023). There are different programmes for the greenhouses and other stakeholders to have a circular metropolis or resource sharing system, but that is still very local and subject to evaluation (C3 and C6, personal communication, 2023). Further, some of the issues that are dealt with for example water quality, are local problems that cannot be dealt with at national or EU level (C4 and C5, personal communication, 2023).

Actors: Supportive

This element was evaluated as supportive since the setup allows for new actors to come in and take part in the CE debate although the direction is not institutionally flexible since policies come from higher in the hierarchy (C1 and C3, personal communication, 2023). The research institutions and tech providers produce different innovations that shape the advancements in the sector thus giving the circularity a new dimension and sometimes a blueprint for new opportunities. Due to the proactive nature of the sectoral entrepreneurs, there are numerous enhancements to the options available for CE such as in the vertical growing systems, LED, nutrient recovery, and hydroponic systems that are introduced, and these groups of stakeholders lead the policy makers in identification of possible solutions to some of the problems with food demand or energy use (C1, C3 and C4, personal communication, 2023). This is evident from the collaboration that brought about the greenhouse units as energy providers. The biggest hurdle for new actors is that of the initial high investment costs involved (C1 and C4, personal communication, 2023).

Problem perspectives and goal ambitions: Moderate

The perspectives and ambitions are considered moderate because on one hand, there are common goals that all agree on such as the need for sustainable production and the urgency to reduce emissions. However, on the other hand, what needs to be sacrificed for that to happen is up for debate. Some of the stakeholders have a financial stake in the sector and their biggest motivation is their livelihoods (C1 and C5, personal communication, 2023) while legislative authorities are driven by the need to protect the environment and ensure the social wellbeing of the population or for political milage (C1, C2 and C4, personal communication, 2023). Whilst all stakeholders will claim to care about the welfare of the society, the stakes are different for them and as revealed by some interviewees, there are lobbyist who move to Brussels to stall progress on certain policies because it affects their profits or interests (C2 and C3, personal communication, 2023). It is therefore the case that on some issues, the goals can be reassessed during implementation but on some, the possibility is limited.

Strategies and instruments: Supportive

The policies and regulations are flexible because it is possible to combine different instruments and the stakeholders can make choices based on what suits them and their business. This is true for example in the cooperatives where they encourage growers to adopt some level of circularity, but the growers are at liberty to choose what to implement and how long they take depending on their financial situation (C5, personal communication, 2023). Those stakeholders that are willing to use the available subsidies can do so at their own convenience. The provinces also use different tactics that fit their needs best, for example, in one, they are trying to set up a system to reuse heat and CO_2 from the industries in the greenhouses and some households while other provinces have a focus on the management of plastics used in the greenhouses (C2 - C4, personal communication, 2023).

Responsibilities and resources: Restrictive

The responsibilities on the different levels are clearly defined on where the policies come from and who implements them. However, due to the nature of CE specific policies not being legally binding, it is not easy to hold different stakeholders accountable (C1 - C4, personal communication, 2023). Some stakeholders believe that the national government subsidy programmes are not streamlined due to the agenda of CE being nested under a different ministry and the subsidy coming from a different one (C1, personal communication, 2023), however, there is consensus that there are several available resources (C1 - C6, personal communication, 2023). The misalignment of ministries in practice apparently makes it difficult for growers to access some of the allocated funds, but the

issue can't be easily addressed because each ministry works in a "silo" (C1, personal communication, 2023).

4.4.4. Intensity

This quality was evaluated as the point to which the system elements advocate deviations from the status quo or current occurrences i.e., adoption and implementation of circularity.

Levels and scales: Supportive

As revealed in all the interviews, the topic of circularity in the sector is addressed on all levels of the governance setup, each with their own approach and strategy. The national government through the ministries has set up policies that are implemented in the provinces. The provinces in turn collaborate with Glastuinbouw Nederland, the cooperatives and other actors to realise the circular.

Actors: Supportive

The stakeholders involved in the CE debate are organised into different coalitions to promote the attainment of circularity in the sector. Growers, being the centre of the implementation plans are organised into cooperatives and are members of Glastuinbouw Nederland and the LTO (C1, C3 and C5, personal communication, 2023). This allows them to be represented in many discussions through their respective representation. Within the provinces, there are other coalitions such as the GreenPorts and different taskforces working on the implementation of CE practices (C2, C3 and C4, personal communication, 2023).

Problem perspectives and goal ambitions: Restrictive

The goals set by the EU for 2030 are far from being achieved and as noted during the interviews, there is less optimism that they will be achieved due to the slow progress in the uptake of proposed measures and their facilitation (C1 - C5 and C7, personal communication, 2023). Some of the issues that come up are related to the lack of uniformity in the EU about how countries implement the EU policies. The interviewees noted that for the goals to be achieved, the member states should act as one since emissions and environmental effects are not limited by boundaries (C1 and C4, personal communication, 2023). Therefore, to pull in the right direction, there are major changes needed in the policies and their enforcement. At national level, there are regulations that prevent the reuse of certain material since it is classified as waste which leads to that resource to have to go elsewhere for different purposes. To ensure circularity, these types of regulations need to be overhauled (C1 and C5, personal communication, 2023).

Strategies and instruments: Restrictive

Although there are numerous policies targeted at regulating the extraction, use, handling and disposal of resources and waste, there is still a big gap in addressing the behavioural change needed. Discussions with the interviewees revealed that the motivations for why certain things happen the are centred on ingrained culture and behaviour with the consideration of livelihood contributing to a great deal of sway in that behaviour (C1 - C3, C5 and C7, personal communication, 2023). For example, it was pointed out that some growers would rather not invest in newer methods because they are used to operating a specific way and because they already make a profit, they do not see the benefit of modern systems which seem expensive without the guarantee of them earning back their investment (C1 and C5, personal communication, 2023).

Responsibilities and resources: Moderate

This element is evaluated as moderate because all the stakeholders interviewed considered that there were enough resources available to comply with most of the expected changes. However,

there is still a gap in the facilitation of the transition which could see some stakeholders fail to survive in the sector (C1 and C5, personal communication, 2023). The rising cost of energy and the general inflation due to economic factors puts huge pressure on the growers and entrepreneurs who are yet to financially recover from the economic turmoil caused by the COVID 19 pandemic. New and modern systems are expensive to install and the entrepreneurs that start the transition can only do it in phases according to their financial ability (C1, C4 and C5, personal communication, 2023).

4.5. Summary of governance assessment

The assessment of the governance of CE in the Dutch greenhouse horticultural sector as outlined in section 4.4 is summarised in Table 9. Each of the governance dimensions is evaluated against the four quality criteria.

Table 9: Summary of assessment, Adapted from, Casiano Flores, Özerol, and Bressers (2017)

Quality / Dimensions	Extent	Coherence	Flexibility	Intensity
Levels and scales	Supportive	Moderate	Restrictive	Supportive
Actors and networks	Moderate	Moderate	Supportive	Supportive
Problem perspectives & goal ambitions	Moderate	Restrictive	Moderate	Restrictive
Strategies & instruments	Supportive	Moderate	Supportive	Restrictive
Responsibilities & resources	Moderate	Supportive	Restrictive	Moderate
Overall assessment	Moderate	Moderate	Moderate	Moderate

5. Discussion

CE as a concept is still growing in the sector and gaining recognition amongst different stakeholders. Across the different levels, the role and significance of circularity is acknowledged for the foreseeable gains in reducing waste or the creation of different value chains for waste. In assessing the perceptions and practices, different stakeholders were interviewed and some of their work observed during the GreenTech 2023 exhibition. What stood out was that there is plenty of specialised innovation around different components of the greenhouse production systems with the main goal being efficiency for production and minimisation of resource use. In my opinion, that is very good for attaining the circularity goals set by the EU and the government. However, several innovators pointed out that their design process was driven by the needs of the grower to help them grow more per square metre with as little input as possible, but the issue of the end-of-life processes for the material and products they offer were not considered. Whilst there is progress being made in the different areas, the pure concept of circular systems would dictate that we think about the 4Rs not as mutually exclusive concepts but as those that should be considered throughout in a system. Outside of the greenhouses, there are other stakeholders also trying to push the agenda of circularity such as the provinces, national government, EU, and the research institutions, but the circularity is observed to have only been achieved at a micro level and with varying applications of the principles. So then, that begs the question, what motivates stakeholders to seek circularity in the sector? As argued in previous research, there are many definitions of what CE entails, but the main concepts revolve around the reduction of waste, reuse, recycling, and recovery of resources from waste (De Boer and Van Ittersum 2018; Kirchherr et al. 2023, 2017; Salinas-Velandia et al. 2022). This was observed to be true in the findings described in 4.1, all with different degrees of accomplishment. The extent to which these practices are implemented differ per stakeholder in the sector and as was revealed in the interviews, the motivations are different.

To understand this, I apply the lessons from the Contextual Interaction Theory, which holds that the extent to which a policy or outcome is effective depends on the cognitions, motivations, and resources (influence) that the actors involved in the interactions possess (Bressers 2004, 2007; Bressers et al. 2016). As revealed in the interviews and at GreenTech 2023, there are differences in the motivations, cognitions, and resources available for the implementation of CE. Different stakeholders understand that there is something called CE, but the content and its application still lacks in the common understanding. For some, it is all about nutrients while for others, water or energy saving is the goal. This is not a problem, but the fragmentation of the understanding causes a rift in the possibility of circularity being applied beyond a specific greenhouse which one interviewee (C1, personal communication, 2023) referred to as working in “silos”. The involvement of multiple stakeholders is great because it brings together different expertise and allows multilevel discussions and knowledge sharing which is beneficial for disseminating the values of CE across the whole sector. The differences in motivations are observed across the actor networks based on the roles they perform. Firstly, the stakeholders agree that there is a climate challenge to be addressed and changes are needed to make the sector sustainable. However, what needs to be sacrificed is subject to debate.

The administrative stakeholders expressed their concern for the sustainability of the sector from an environmental and social perspective whereby they want a transition that supports the improvement of environmental quality and social equity. As such, their policies and regulations are focused mostly on those aspects. The growers, according to their representation at the cooperative and Glastuinbouw Nederland, mostly run family businesses which are passed on to the next generation. They are therefore keen to leave sustainable and healthy businesses for their children. They are

motivated by the ability to have high production per square metre, which implies more profit for the same space, but they also care about their sustainability performance. This pushes them to install all kinds of systems such as growing lights, humidity control, monitoring and recycling of water and nutrients in their greenhouses. In doing so, they invest in systems that allow them to produce in a more environmentally friendly way, but with more financial gains. They are also driven by consumer demands for example, if consumers want to have strawberries all year round, the growers go ahead to produce them because there is market for it.

Supply chain stakeholders cater to the needs of the growers and consumers, so, for them, consumer trends and demands are key for their decision-making which can sometimes lead to detrimental trends. For example, as explained by a packaging company, *"The growers make it possible to have some fruits all year round, that are not naturally available here and when there is a shortage, the same fruits are imported from countries like New Zealand and distributed to the rest of Europe*" (C7, personal communication, 2023). Such practices go against the principles of circularity in the context of there being a regenerative process and considering the amount of GHG emissions associated with it. It is the research institutions that then play an important role in providing research-based insights on best practices as well as developing new innovations for the sector. The knowledge emanating from the institutions is applicable for policy makers, practitioners, and consumers as well. They act as custodians of the scientific knowledge that can be used to advise different policies and decisions which stakeholders would hope is taken in a pragmatic way by the decision makers.

Further, it was observed that majority of the stakeholders want clarity in the policies and strategies from the national government and EU. There is hesitation in the stakeholders' decision-making as they are unsure whether the policies will change or if new legislation comes into effect. This is particularly the case in the issues of fertilisers and plastics. Although there is existing regulation on the plastic use, there is proliferation of many different types of plastics that the process of reuse and recycling becomes too tedious that companies would rather use virgin material. These kinds of sentiments would indicate that there is growing frustration about the matter and majority of those involved in dealing with the matter would want change. As Kirchherr et al. (2018) found, the regulatory barriers underlie the key barriers which are cultural, and market driven. In their findings, the lack of consensus and incoherent laws or regulations exacerbate the key cultural and market barriers. The prices of commodities could then lead to a lack of consumer interest, which makes the companies hesitant due to high investment costs and no guarantee on return on their investments. The main identifiable barriers in the Dutch greenhouse horticulture are institutional barriers, related to policy, enforcement, and coherence of measures as is identified in previous findings (Geissdoerfer et al. 2022; Grafström and Aasma 2021; Kirchherr et al. 2018).

In assessing the governance context, what stood out the most was the restrictiveness of the flexibility of the levels and scales, coherence and intensity of the problem perspectives and goals, intensity of the strategies and the flexibility of the responsibilities and resources. As explained in 4.3, the challenges of these elements are mostly driven by the differences in the motivations, cognitions, and resources of the stakeholders to address the problems of circularity. Whilst there is an awareness of the environmental and social benefits, the considerations for the economic aspects tend to define how well and seriously the issue is taken up. Different entrepreneurs weigh up the options but until they are guaranteed of the returns on investments, they are hesitant to take any risks especially in times when the cost of living is high, and the energy prices are on the rise. This uncertainty in the profitability is because of the lack of clarity on how the policies change, which fits the narrative explained by Kirchherr et al. (2018).

The main research question of this research seeks to overcome the identified barriers to CE realisation in Dutch greenhouse horticulture. This question was drafted in a prescriptive manner and considerable efforts went into the identification of the prevailing barriers. However, based on the evidence available, the extent to which prescriptive recommendations is limited. Some of the barriers identified relate to stakeholders who did not participate in the research such as government bodies and consumers. Insights from their perspectives on the topics addressed would provide a more comprehensive set of recommendations. As such, the answer to the main research question is given from an evaluative perspective as explained in section 6.5.

6. Conclusion and recommendations

6.1. Conclusions

The purpose of this research was to explore the different circular practices implemented in the Dutch agrifood greenhouse horticulture sector and to evaluate the contextual governance of CE in the sector. The research entailed discussions with different stakeholders, a visit to a three-day exhibition in Amsterdam and literature review. Through the activities, the cognitions, motivations, and resources of the stakeholders were considered in the analysis of how the transition to a CE in the sector is governed. This research was guided by the question "*How can the barriers to the implementation of CE practices in the Dutch greenhouse agri-food sector be overcome?"* This was meant to be answered by analysing three fundamental sub questions. First, was to understand how the concept of CE is perceived and implemented in the sector. Second was to analyse the measures currently in place to promote CE in the sector and lastly, to assess the governance context and how it supports or inhibits the CE in the sector. The sub questions were addressed as follows:

1. *How is CE perceived and implemented in Dutch agri-food greenhouse horticulture?*

The concept of circularity is widely embraced within the sector across several levels for its potential benefits in reducing the amount of waste, increasing the value of waste streams and prospective cost saving it brings. However, in accordance with the interviewees' opinions, the definition of what is truly circular remains a challenge since circularity in a greenhouse does not equate to circularity in a municipality, province, or country. As discussed with relevant stakeholders and reported by De Boer and Van Ittersum (2018), Hoste et al. (2017), Lansink and Bezlepkin (2003), Poot (2004) and Vermeulen et al. (2020), it is possible to conclude that the greenhouse sector has achieved considerable levels of the four main principles of reduce, reuse, recycle and recover waste within the greenhouses by implementing smart systems and modern technologies in the growing and production processes. However, now, according to Glastuinbouw Nederland, there is an observed silo mentality in the system where innovation and development is done in individual capacities of stakeholders but not enough collaboration to pool the efforts together has been achieved at cluster, municipal or provincial levels, as corroborated by Glastuinbouw Nederland, cooperative and the provinces. The different stakeholders are observed to make efforts to consolidate their understanding of what a circular region or sector should look like which most likely involve collaboration with other sectors. With this understanding, the next step was to understand what is being done to promote CE in the sector.

2. *What measures are observed to promote CE in Dutch agri-food greenhouse horticulture?*

The agenda of the CE concept is one that has international acclaim in different sectors (Geissdoerfer et al. 2022; Grafström and Aasma 2021; Hartley et al. 2022; van Keulen and Kirchherr 2021; Kirchherr et al. 2018). To evaluate the promotion of CE in the greenhouse sector, the influence of stakeholders at different levels was considered. The hierarchical structure of the horticulture sector is such that the EU guides the regional policy which is adopted by national governments (European Commission of the Regions n.d.; Kirchherr et al. 2018). The European Commission introduced different policies and directives such as the CE Action Plan, Plastic Strategy and Farm to Fork to promote the concepts of sustainable production and consumption, which is also taken up by the Dutch government through the different ministries (European Commission 2019, 2020b, n.d.-b, n.d.-a). The transition to a CE is facilitated at national level through subsidies and programmes in collaboration with other stakeholders from the private and public sector (Government of the Netherlands 2016). The

programmes, as discussed with stakeholders in the interviews are mostly initiated in the provinces with the help of Glastuinbouw Nederland, growers' cooperatives and research institutions.

Each of the stakeholders has a vision for their own contribution to the CE debate and they leverage their expertise to promote the different principles. The primary goal of the growers as reported by Glastuinbouw Nederland and the cooperative, is to maximise their production sustainably and thus seek the help of different suppliers to provide them with the most efficient inputs and systems. The research institutions provide the theoretical and practical expertise that growers and their suppliers can adopt to improve their operations. Growers come together through the cooperatives that market their products and negotiate on their behalf in local and international markets. The cooperative reported that they also facilitate knowledge exchange amongst the growers and part of this is to also promote responsible action from the growers. The interviewees highlighted that through the collaboration between the different stakeholders, there are several platforms at EU, national, provincial, and municipal level that the issues of circularity are discussed and negotiated, not just within the greenhouse sector but also with other sectors such as energy and infrastructure, to find ways to utilise resource and waste streams. To understand how well these measures work and to what extent they work or fail to achieve their goals, it was also important to evaluate the governance elements as defined in the third sub question.

3. *What is the governance context of CE in Dutch agrifood greenhouse horticulture and how supportive is it based on the GAT?*

As argued by (Bressers (2007), (2009), Bressers et al. 2016, and Casiano Flores et al. (2017), the effectiveness of a governance regime can be assessed through the application of the governance assessment tool as described in section 2.4. This is founded on the Contextual Interaction Theory which accounts for the cognitions, motivations, and resources of stakeholders in the quest for effective governance. The evaluative questions of the assessment matrix were posed to the interviewees as a guide for the interview and through the conversations, the governance elements and their qualities were discussed. The interviewees expressed their views on the state of the sector, actors involved, and the policy instruments used among other things. These insights therefore built the score as per the evaluation criteria follows:

The **levels and scales** are supportive in their extent and intensity, moderate in their coherence but restrictive n their flexibility. All the levels are reported to be involved in addressing CE and most stakeholders feel they work well together. However, some of them such as growers, cooperatives and supply chain stakeholders feel left out in the decision-making process at EU and national levels. The provinces are also not involved in the EU legislation process. The interviewees revealed that it is difficult to address issues across all the levels since some are dealt with at a local level and have no place in the provincial or national debate let alone EU level.

The **actors and their networks** are moderate in their extent and coherence and supportive in their flexibility and intensity. It was observed that while most actors interviewed feel involved in a structured way, not all are involved when the decisions of policy are made. The actors and their networks reported to work well together although there are those that were reported by the interviewees to have different agendas and are not willing to see the change, so they lobby to keep the status quo. However, they indicated that it is possible for new actors to take part in the CE plans and there are many organisations and networks to which they can join to make their mark.

The **problem perspectives and goal ambitions** are moderate in their extent and flexibility but restrictive in their coherence and intensity. While most actors reported to be involved have an objective for achieving circularity, their motivations vary widely based on their core business. This

element sees the most restrictive qualities especially due to the clash of efficiency vs profit vs environmental benefits perspectives. For example, the cooperative reported that within their organisation, there were growers who didn't prioritise the environmental effects because they felt they already operated within a strictly regulated system but there were those in the same organisation that embraced the change and would champion it.

The **strategies and instruments** are supportive in their extent and flexibility while being moderate in coherence and restrictive in their intensity. The interviewees shared that there are many initiatives across the levels that are also flexible in application based on the location and the actors' networks capabilities. However, they are not always in synergy and sometimes prevent the full applicability of CE measures. Further, the interviewees claimed that the strategies applied are not always legally binding in nature and do not address the need for behavioural change. As such, it is ineffective in achieving the desired goals such as circularity by 2030, thus while they are hopeful, they remain sceptical if the goals can be achieved without behavioural change across the sector and in society.

The **responsibilities and resources** are moderate in their extent and intensity, supportive in their coherence but restrictive in their flexibility. The interviewees felt that the responsibilities of the different actors are clearly defined on most levels but since the clarity on what circularity should be is still pending, there are functions that need to be refined through legislation and policy changes. As a result of the lack of enforceable policies, the responsibilities cannot be accounted for, and the resources associated with that may not always be easily accessible.

6.2. Significance of the study

The findings of this study show that the CE in the Dutch agrifood greenhouse horticulture is already being implemented on different levels. The practitioners, driven by their ambition to be as efficient as possible entered into collaborations with innovators, researchers, and other experts to find the most optimal solutions for their business models. As such, there are now some futuristic advancements made in the sector where growers can account for almost every input / resource such as water, nutrients, and energy in their production. Whilst these advancements bring about some positive environmental benefits, there are still some unanswered questions about what this does for the global problems of food security and sustainable production and consumption. While it could be argued that this efficient production is somewhat sustainable, there is a fallacy in how necessary it is. Much of the focus of the advancement of the technology on display at GreenTech 2023 was aimed at helping the growers increase their output per square metre, but the amount of food waste at the end of it is still not addressed. This is while the UN estimates a third of the global population to be facing food insecurity. There would need to be a balance between production and consumption.

Revelations by packaging companies and other respondents in the research about the amount of food waste generated due to overproduction and assumption of the consumers' demands showed that the circularity achieved at the greenhouse does not replicate itself in the rest of the supply chain. To keep the produce longer on the shelves of retailers, packaging, mostly plastic, is needed. This is a big problem which the world is still grappling with as plastic waste continues to be washed into water bodies. So, to answer the question, is circularity in the agrifood greenhouse sector addressing the targets of SDGs 2 and 12? Not completely yet!

The evaluation using the GAT points towards a mismatch in the understanding of the problems, solutions, and distribution of the derived benefits. This is possibly due to a lack of commitment to the enforcement of the EU proposals and their lack of consistency. Different actors look to others to take initiative for the transition while others take proactive steps, but the pace in which the active steps happen is staggered across the levels. The private sector is reported to move faster in innovations

and progressive solutions, and the governments are trying to catch up and therefore can't come up with policies or measures that are easily appealing to those already implementing CE.

6.3. Reflection on effectiveness of GAT in Dutch agrifood greenhouse horticulture

The GAT as a framework provided an avenue for asking some relevant questions to the accessible stakeholders and obtain a wider view of the governance context. The systematic breakdown of the governance elements was beneficial for raising important points of discussion and research about the way the sector operates and who is involved in it. With it, it was possible to address the research questions considerably. However, the wider context, especially the political context may have played a role in the effectiveness of the application of GAT in this research. It proved difficult to triangulate all the facts or perspectives since some key stakeholders did not take part in the research. Representation from the national government through ministries or RVO were unreachable and therefore the perception about their involvement was based on those that interact directly with them. Prior to the start of the research, there had been ongoing heated negotiations between farmers and the government over the issues of emissions reduction in the agricultural sector. As such, the level of cautiousness of the potential respondents was more heightened. This may have led to some respondents shying away from the discussion this research would bring. The GAT focuses on the structural context of a regime, but in this case, the wider context seemed to have a significant influence on the willingness of stakeholders to take part in the research.

Further, it can be argued that the GAT would have been more effective when addressing a more specific element of the circularity topic such as either plastics, nutrient, fertilisers, water, or energy etc. In this research, a broader view was adopted and given the limited amount of time, addressing CE in a general way would leave some room for future questions and research. Since circularity is still a growing phenomenon, addressing it from a broader perspective is just as important since it allows for potential misalignments in the objectives to be addressed and helps link other sustainability topics to the circular objectives. This is because when doing so, different perspectives are considered.

6.4. Limitations

This research was initially designed to incorporate a survey that targeted the views of growers. However, there were difficulties in getting many of the growers to take part in the research. Efforts to reach them through different cooperatives, emails, calls, and one on one conversations did not elicit enough responses as only sixteen of them filled in the survey with only ten being complete. This not being a statistically significant number of responses, it was not viable to make a statistical analysis to include in the analysis. Inclusion of their direct views would have added some weight to the discussion since they are at the centre of the sector and do a great deal in implementing circular practices as well as dealing with the other stakeholders. One potential reason for the low response rate was the length of the survey. It is possible that the growers may have perceived thirty-five questions as too many for them to take their time to fill in.

Further, it was impossible to secure interviews with any representatives from the ministries or RVO. There were views shared by different interviewees about their interactions with the ministries and national government and for the purpose of this research, it would have been ideal to get all sides of the story. The government websites did not contain all the latest information about the planned policies, developments, or updates about some of the ongoing programmes. If this information would have been available from their representation, it would have improved the quality of data available for analysis.

As a student, I found it difficult to elicit the number of responses needed from sectoral stakeholders I initially targeted. Part of it, I realised, was the lack of social capital to engage some of the stakeholders. Comparing that to those that have built that kind of a relationship with the stakeholders, it was not possible to build that trust within the limited timeframe.

This research was about the sector in general. However, not all stakeholders were considered in the research. The role of the consumer was not part of the methodology, but in hindsight, it is a crucial one since the topic of CE also addresses SDG 12 (responsible consumption and production). Although mentioned in passing, part of the transition is tied to consumer habits and trends, and this would add value to the conversation.

6.5. Recommendations

In answering the main research question, "*How can the barriers to the implementation of CE practices in the Dutch greenhouse agri-food sector be overcome?",* attention is given to the main barriers identified in the governance elements. The following restrictive qualities of the governance context need to be addressed.

6.5.1. Future research

One of the main challenges in this research was getting a statistically significant number of responses with the survey. Part of the reasons for the low response rate could be attributed to the length of the survey. It would therefore be recommendable to attempt to break the survey into several parts targeting specific themes rather than an extensive one with many topics addressed. This could make it more accessible to the potential respondents without taking too much time.

Further, it was mentioned by different stakeholders that the consumer played an important role albeit passive in shaping the assumptions of policy makers and decisions of entrepreneurs and retailers. This aspect would one worthwhile to investigate especially given the fact that many consumers have an online presence on social media platforms, so getting their views would be easier compared to the targeted growers who run busy schedules.

6.5.2. Recommendation for practitioners

a. The flexibility of the levels and scales

To address this, there needs to be openness in the sector through the different administrative levels to handle circularity issues across different levels. For example, projects about heat and CO_2 sharing between industries and greenhouses could be pushed by the national government to all provinces so that there can be a cross level resource sharing system.

b. Coherence of problem perspectives and goal ambitions

There needs to be more awareness campaigns to promote the common understanding of what circularity entails for the individual businesses, regions, and country. This is needed to make sure the motivations for the circularity are aligned and synergetic. The motivation for profit should not be perceived as the most important factor for adoption of circular measures and rather the

environmental and social benefits should be promoted, and the entrepreneurs better supported to mitigate the deficit.

c. Intensity of problem perspectives and goal ambitions

The lack of uniformity in the adoption of CE measures proposed at EU level and the contradictory policies should be resolved. Where the government wishes to regulate certain waste streams, there should be a re-evaluation of whether businesses can be allowed to handle their waste as a resource. Since this was identified as a major issue, the provinces or municipalities should be given the mandate to license organisations that wish to recycle or reuse by-products and waste without the current restrictions if it does not cause a threat to the environment or pose a health hazard.

d. Intensity of the strategies and instruments

Major behavioural changes are needed to achieve CE goals. This can only be achieved if there is awareness about what it entails, benefits and the dangers of maintaining the status quo. The cooperatives should be empowered to run pilot projects, hold workshops and seminars to educate their members. In these, supply chain actors such as packaging companies and retailers should be involved so that the efforts are widespread across the sector.

e. Flexibility of responsibilities and resources.

Punitive measures are needed to compel entrepreneurs to comply with requirements to invest in circularity. Now, measure seem more like suggestions and until they are made enforceable, they will only be implemented if there is economic advantage emanating from it. This means that there is responsibility and accountability placed on actors with proper coordination mechanisms in place to ensure practical transition.

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Appendix A – Survey questions

You are being invited to participate in a research study called "Strategic tool for the evaluation of sustainability in greenhouse horticulture: a case study for the Netherlands and Spain". This study is being performed by Isaac Ngirubiu, M. Laura Franco and Ana Batlles from the Faculty of Behavioural, Management and Social Sciences at the University of Twente, and by Luis J. Belmonte and José A. Plaza, from the Faculty of Economics and Business at the University of Almería.

The purpose of this research study is to identify and analyse good environmental practices and their impact on companies' performance, focusing on the agri-food sector of both countries, The Netherlands and Spain, and will take approximately 20 minutes to complete. The data will be used to gather information from various organizations to obtain a sufficiently representative sample of greenhouse vegetable production. Your participation in this study is entirely voluntary.

We believe there are no known risks associated with this research study; however, as with any online related activity there is always a certain danger of a breach. To the best of our ability, your answers in this study will remain confidential. We will minimize any risks since the answers will be sent to the main investigator's email alone, without the need for mediators during the survey process. In addition, at no time will information related to identity be requested, such as name, telephone number or other data that may locate the organization surveyed. Finally, the data will be processed quantitatively through a statistical program, thus in no case will external agents know the variable to which each number is associated.

Study contact details for further information:
Isaac Ngirubiu, i.i.ngirubiu@student.utwente.nl
Ana Batlles de la Fuente, a.batllesdelafuente@utwente.nl

Strategic tool for the evaluation of sustainability in greenhouse horticulture: a case study for the Netherlands and Spain

A.- CONTEXT

1. **Geographic location of the greenhouse**

Country:
City/Town:

2. **Total wintering area (m2):**

3. **Type of greenhouse cultivation.**
   - **a)** Flowers
   - **b)** Vegetables (including tomatoes and the like)
   - **c)** Fruits (stone fruits, shrubs...)
   - **d)** Other, please specify

4. **How long have you been producing the same type of crop?**

5. **How many crops are there in the greenhouse per year (cycles per year)?**
   - **a)** 1
   - **b)** 2
   - **c)** 3
   - **d)** 4
   - **e)** 5
   - **f)** Other, please specify

6. **What type of greenhouse cover do you have? *Choose the most representative, focused on the production of vegetables**
   - **a)** Plastic
   - **b)** Polycarbonate
   - **c)** Glass
   - **d)** Other, please specify

7. **What type of greenhouse do you have? *Choose the most representative, focused on the production of vegetables:**
   - **a)** Flat or arbor type
   - **b)** Scrape and fake
   - **c)** Asymmetric
   - **d)** Multitunnel/ double layer
   - **e)** Gothic type tunnel
   - **f)** Venlo
   - **g)** Covered with mesh
   - **h)** Other, please specify

8. **What vegetables did you produce in the previous season? *If the variety is known, indicate it, for example: cherry tomato and California pepper. If the variety is not known, simply indicate the vegetable, for example: tomato and cucumber.**

9. **What variety of vegetables do you currently produce? *In case you have produced the same vegetables as in the previous season, write the same answer as before.**

10. **Greenhouse's year of construction:**

11. **Do you have organic crops?**
    - **a)** Yes
    - **b)** No

12. **In terms of climate management, your greenhouse is:**
    a) Passive (temperature is controlled by closing or opening zenithal and/or lateral windows).
    b) Active (forced heating systems or other systems that artificially improve environmental conditions are used, such as CO_2 injection to improve photosynthesis, etc.)
    c) Combination of both processes

13. **Evaluate from 1 to 5 the degree of the following statements**

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
Do you consider that the country's characteristics/resources encourage you to implement sustainable action plans?					
Are the company's mission/vision and/or objectives aligned with the implementation of new sustainable practices?					

Are you reluctant to introduce new laws focused on innovative sustainable practices?					
Do natural demographic changes in the surrounding context influence the need to introduce sustainable practices in the organization?					

Participant's details:

14. General information about the respondent:

Age

Years of experience in the sector Current job position

15. Gender:

a) Male

b) Female

c) Prefer not to say

16. Have you had previous jobs related to the agricultural sector?

Yes

No

17. Is farming your main source of income?

Yes

No

18. What is your highest level of education?

a) Secondary education or below

b) Vocational training

c) Bachelor's Degree

d) Master's Degree

e) PhD

f) Other, please specify

19. Could you indicate your specific area of study? *Example: agricultural engineering

20. Evaluate, according to importance, the following planning criteria in the management of the farm:

	Not important at all	Slightly important	Moderately important	Very important	Extremely important
Maximize profit					
Minimize water consumption					
Minimize economic risk					
Minimize energy consumption					
Minimize occupational risks					
Minimize waste generation					
Maximize the reuse of waste					
Minimize the environmental impact of cultivation					

21. Motivations that lead to the introduction of sustainable processes in the organization:

	Not important	Slightly important	Moderately important	Very important	Extremely important
Subsidies					
A desire to help future generations and/or reduce pollution as a personal motivation					

Religious values that advocate respect and care for everything around us					
Pressure from stakeholders (consumers, local agents, activist groups…)					
Competing companies advocating more sustainable practices					
Will to innovate					
Reputation and image					
Reduction of risks (illegalities, taxes...) that translate into cost reduction					
Association with other neighboring organizations that facilitate the objective					
Consultants that advise what needs to be done					

22. Check the corresponding box according to the resources that the company has in relation to greenhouse production:

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
Do you have a great investment capacity to make changes in infrastructure?					
Do you have innovative machinery adapted to market requirements?					
Do you have technological resources to allocate to the sustainable field?					
Do you have a high degree of coordination and collaboration among workers?					
Do you have the right to be invited to agreements or negotiations, in the field of sustainability, together with other companies?					

Regarding financial aspects:

What percentage of campaign expenses do you finance in the short term?	0-20%	21%-40%	41%-60%	61%-80%	81%-100

23. Sustainably strategic models in the organization as regards greenhouses:

Do you have an annual sustainability plan, or do you include sustainability goals in your strategic plan?	Yes	No
Is there a model whose purpose is to promote sustainable production?	Yes	No
Is there a specific strategic plan on the actions to be carried out to achieve the objectives?	Yes	No
Is introducing or improving Circular Economy in the company part of the mission of the proposed strategic model?	Yes	No
Is this the first time that a plan of a sustainable nature has been introduced in the organization?	Yes	No
Do you evaluate the satisfaction obtained from achieving sustainability goals on a yearly basis?	Yes	No

Regarding sustainability strategic models:
What are the objectives to be achieved?
What is the time period that has been established to achieve them?

24. Check the appropriate option for the following questions:

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
Do you consider that you have a high level of knowledge about circular economy and sustainability?					
Do you have a high level of knowledge about action plans, alternatives or financing necessary for sustainable production?					
Are you interested both at an organizational and social level in sustainable aspects? Ex: reading journals, articles with scientific information or reports on a daily basis.					
Do you understand the need to introduce sustainable practices?					
Do you consider that information filtered from outside influence the motivations of the company as regards sustainable practices?					
Do you consider that sustainability is given great importance by the entities that make up the organization? Ex: talks, training, presentation of updated information					
Do you prioritize your daily concerns over these sustainable strategic issues?					

25. Do you know the difference between biodegradable and compostable plastics?

a) Yes
b) No

26. From among the following options, mark with a cross those supplies for which you believethere are biodegradable alternatives

Plastic covers
Greenhouse band mesh
Mesh to cover the ventilation hole
Double roof plastics
Irrigation pipes
Solarization plastic
Crop mulch
Fertilizer product packaging
Containers of bio-stimulant products
Phytosanitary product containers
Field boxes
Trellising raffias
Staking Clips

27. If you belong to an organization/cooperative, are the strategies supervised by it or arethey decided at an individual level?

a) They are supervised by the organization
b) They are not supervised by the organization
c) I do not belong to an organization/cooperative
d) Other, please specify

28. Indicate the approximate percentage

	0%-19%	20%-39%	40%-59%	60%-79%	80%-99%
In what percentage do you manage your plant waste?					
What percentage of your vegetable waste do you send to a specialized waste manager?					
In what percentage do you manage your plastic waste?					

Evaluate from 1 to 5 the degree of implementation of the following sustainable practices:

	Not considering	Planning to consider	Considering at the moment	Initiating implementation	Implementing successfully
Do you have alternatives to herbicides and insecticides?					
Is there machinery that respectsthe environment? (Electric tractors and others)					
Are there actions focused on					

energy saving?					
Are there activities designed to minimize water e?					
Do you carry out any activities aimed at preventing soil erosion?					
Are there facilities that allow for the use of renewable energy (wind, solar, biomass...) as an alternative?					
Are part of the residues from agricultural practices burned?					
Is anaerobic digestion introduced as a waste management process?					

To what degree have these practices influence the following choices?

	Not at all	A little bit	To some degree	Relatively significant	Significant
Have greenhouses gas emissions decreased?					
Has water consumption decreased?					
Has energy consumption decreased?					
Has the use of hazardous materials decreased?					
Has waste generation decreased?					

Evaluate from 1 to 5 the degree to which sustainable practices have influenced the following options:

	Not at all	A little bit	To some degree	Relatively significant	Significant
Sales expansion					
Market share expansion					
Increased profit margin					
Cost reduction in the long term					

Annual net salary:

Annual net revenues	12000<X>24000	24000<X>36000	36000<X>60000	60000<X	NA

29. Staff in the greenhouse:

- Number of permanent workers:
- Number of temporary workers/season labors/short-terms workers:
- Number of family workers:
- Total employees dedicated to greenhouse vegetable production:

Answer in relation to the reward within the organization:

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
In the organization employees receive benefits linked to their performance					
Employees receive bonuses for outstanding performance					
All employees receive effective feedback on their performance					

Workers earn bonuses based on organizational performance					

FUTURE PERSPECTIVES

The next 6 questions are the last in the survey. In this section we would like to know any comment, opinion, or information you wish to provide on the subject. If you don't want to add anything, please skip these questions and finish the questionnaire.

30. Do you truly think that sustainability is important?

a) Yes
b) Maybe
c) No

31. Do you think your children will work in this sector in the future?

a) Yes
b) Maybe
c) No

32. Indicate help, resources, alternatives, or options that you would need to implement or improve CE in your company.

33. What action plans do you think should be considered to progress in the sustainable field?

34. Regulations that you are aware of that are currently impacting greenhouse horticulture and that affect your way of producing and/or marketing.

35. Introduce any technological innovation that has positively influenced CE or the sustainability of the company and that you wish to share. Indicate the year in which you incorporated it.

Appendix B – Interview guide

You are being invited to participate in a research thesis that is titled "Circular economy and its governance in the Dutch agri-food greenhouse sector". This research is for my master's in environmental and Energy Management thesis and is also a collaboration with ongoing research at the University of Almeria in Spain. The purpose of the research study project is to identify and analyse good environmental practices and their impact on companies' performance, focusing on the agri-food sector of both countries, The Netherlands and Spain. In my thesis, I will be assessing the governance elements that support or inhibit the application of circular economy practices in the agri-food greenhouse sector. The questions that follow are designed to analyse the governance context and its elements. The purpose of these questions is to **guide the conversation** so that we can discuss the state of the sector and hopefully identify solutions for the betterment of the sector.

Research definition of Circular Economy (CE)

1. How would you define circular economy in the greenhouse sector?

Levels and scales

2. Are all relevant levels (EU, national, provincial, municipal/local) involved in dealing with the circular economy in the greenhouse sector? Are there any important gaps or missing levels you can identify?
3. Do these levels work together and trust each other between levels? To what degree is mutual dependence among levels recognised?
4. Is it possible to move up and down levels (upscaling and downscaling) given the issue at stake?
5. Is there a strong impact from a certain level toward behavioural change or management reform?

Actors and networks

6. Are all relevant stakeholders involved? Are any not involved or even excluded?
7. To what extent do the stakeholders work together? Do they trust and respect each other?
8. Is it possible that new actors are included or even that the lead shifts from one actor to another when there are pragmatic reasons for this? Do the actors share in 'social capital' allowing them to support each other's tasks?
9. Is there strong pressure from an actor or actor coalition towards behavioural change or management reform about CE?

Problem perspectives & goal ambitions

10. To what extent are the various problem perspectives taken into account?

11. To what extent do the various perspectives and goals support each other, or are they in competition or conflict?
12. Are there opportunities to re-assess goals? Can multiple goals be optimized in package deals?
13. How different are the goal ambitions from the status quo or business as usual?

Strategies & instruments

14. What types of instruments are included/excluded in the policy strategy? Are there any excluded types? Are monitoring and enforcement instruments included?
15. To what extent is the incentive system based on synergy? Are trade-offs and distributional effects considered? Are there any overlaps or conflicts of incentives created by the included policy instruments?
16. Are there opportunities to combine or make use of different types of instruments? Is there a choice?
17. What is the implied behavioural deviation from current practice and how strongly do the instruments require and enforce this?

Responsibilities & resources

18. Are all responsibilities clearly assigned and facilitated with resources?
19. To what extent do the assigned responsibilities create competence struggles or cooperation within or across institutions? Are they considered legitimate by the main stakeholders?
20. To what extent can the assigned responsibilities and resources be pooled as long as accountability and transparency are not compromised?
21. Is the amount of allocated resources sufficient to implement the measures needed for the intended change?

Thank you for taking part in the research.

Isaac I. Ngirubiu

Student at the University of Twente

Appendix C - Consent form sample

Informed Consent form for the research:
"Circular economy and its governance in the Dutch agri-food greenhouse sector."

Researcher: Isaac I. Ngirubiu

Supervisors: Dr. Laura Franco-Garcia and Dr. Steven McGreevy

Research objective

As the world population continues to rise, so does the demand for food. The United Nations estimates that 2.3 billion or one third of the global population faces moderate to severe food insecurity. This is a problem that is further exacerbated by the challenges to food production because of climate change. Intensification in agricultural production has led to a contribution of 30% of global greenhouse gas emissions. The greenhouse horticulture sector, however, has seen many developments to improve efficiency and reduce emissions. Circular economy concept is touted as one of the pathways to transition to sustainable consumption and production which remains an important component of sustainable development. The Netherlands, being the biggest exporter of greenhouse produced foods in the world plays an important role in setting the pace for the global greenhouse food production regarding sustainability. While the developments and innovations in the sector are well documented, few empirical studies have been done on the governance of the circular economy in the sector in the Netherlands.

The aim of this research is to evaluate the circular practices currently implemented in the sector and assess the contextual governance of circular economy in the Dutch agrifood greenhouse sector in the Netherlands. The governance will be evaluated using the Governance Assessment Tool (GAT) which is a framework for analysing governance structures and processes, including the roles of different actors, the distribution of power and resources, and the coordination mechanisms in place. The GAT is based on the Contextual Interaction Theory, which considers that the context shapes the behaviours of actors and outcomes of governance processes. This research therefore tries to map out this context, the interactions and the actors involved in achieving circularity in the sector.

*Please note that this research has undergone a rigorous ethical review process and has been

approved by the BMS Ethics Committee (Ethics Committee of the University of Twente).

This committee ensures that the research is conducted in an ethical and responsible manner,

with participant rights and well-being as the highest priority.

Informed Consent form for the research:
"Circular economy and its governance in the Dutch agri-food greenhouse sector."

Please tick the appropriate boxes	Yes	No
Taking part in the study		
1. I have read and understood the study information dated [___/___/2023], or it has been read to me. I have been able to ask questions about the study, which have been answered to my satisfaction.	○	○
2. I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time without having to give a reason.	○	○
3. I understand that participating in the study involves a video/audio-recorded interview accompanied by taking notes during the interview, which will be transcribed. The recording will be destroyed after transcription and anonymisation of my details.	○	○
Consent to be Audio/Video Recorded		
4. I agree to be audio/video recorded and transcribed	○	○
5. I consent to notes being taken of the proceedings and interview content.	○	○
Use of the information in the study		
6. I understand that the information I provide will be used for the thesis report and publication related to the research project.	○	○
7. I understand that personal information collected about me that can identify me will be handled confidentially, not be shared, and shall be anonymised for use.	○	○
8. I agree that my information can be quoted in research outputs	○	○
Future use and reuse of the information by others		
I give permission for the anonymised transcript I provide to be archived in the University of Twente repository to be used for future research and learning.	○	○

Signatures

_____	_____	_____
Name of participant	Signature	Date

I have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

Isaac Ngirubiu	_____	_____
Researcher's name	Signature	Date

Study contact details for further information:
Isaac Ngirubiu, i.i.ngirubiu@student.utwente.nl
Dr. Laura Franco-Garcia m.l.francogarcia@utwente.nl

Contact Information for Questions about Your Rights as a Research Participant

If you have questions about your rights as a research participant, or wish to obtain information, ask questions, or discuss any concerns about this study with someone other than the researcher(s), please contact the Secretary of the Ethics Committee Information & Computer Science: ethicscommittee-CIS@utwente.nl

Appendix D - Observations

1. Plant compounds and fertilisers

Several companies producing organic plant-based fertilisers. Products come from recovered nutrients out of plant waste streams. Their process is fully organic and tries to reduce/eliminate environmental damage because of their product or production processes.

Their work is done within the regulations provided in the law within their sub sector of fertiliser production. However, the regulations that apply to growers on what chemical and products they can use do not affect them since they are regulated by the government.

The EU gives guidelines to the member states and then the national governments give the national policy. This forms part of the regulations that the provinces and municipalities use, and they comply with all these regulations.

Their focus is on the production of organic fertilisers and other aspects such as plastic waste management and packaging are not part of your business model. The plastic/packaging waste is dealt with by their clients through their own waste management systems or programmes.

In their line of business, the biggest influence comes from the client/customer. Because they already operate within the rules and regulations available, they try to adhere to the needs of the client and make what works for their plants and systems. They can customise products at the request of the clients based on what they grow and the type of growing system they use. Their products are optimally used in the closed loop vertical and hydroponic systems, allowing the growers to monitor their use and give the plants what they need to grow.

2. Substrates and growing materials

There are different alternatives being provided for substrates and growing media. Most are utilising organic material obtained from sources such as plant fibres, coconut husks, bamboo, and other compressed plant residues in place of peat.

Interesting alternative from one exhibitor with a biopolymer foam product. They say it is made from bio-fossil sources but is soluble in water, so as the crop grows, the material dissolves in the water and the residual plant can be removed without extra handling to remove the foam.

Most if not all the exhibitors in this category have stayed away from using peat as a substrate. They recognise the dangers of continued peat harvesting.

3. Cultivation systems

Different types of growing systems are on display. Solutions offered include vertical farming, different closed loop hydroponic systems which are some used in vertical farming setups. These systems are equipped with sensors to monitor the air/water quality, light intensity, level of required nutrients and the presence of diseases or pests. With some, there have been demonstration of the use of AI, cameras, and robots to target specific plants or areas in the greenhouse. Light systems are incorporated in the setup such that they can vary the light intensity in different areas depending on the needs of each section of plants. Using closed systems helps them to reduce the amount of water and nutrients used per production cycle. These systems are also customisable per grower and their specific needs.

4. Packaging systems and products

There are producers of plastic packaging and films. Printing of the packages as well as coding the packaging material for easy identification during recycling or reuse after disposal. The special codes are placed at different locations on the package so that even if the packaging is ripped, sections of the code are scannable for the separation and sorting based on the material type and recyclability. However, there is uncertainty about the amount of recycling that is sustainable due to the emissions that the recycling process produces. It is sometimes better to use virgin material than to recycle certain plastics. This aspect of material flow is mostly ignored since there seems to be fascination about recycling being the only solution.

Some of the products includes biodegradable plastics which are harmless to the environment and reduce the need for recycling, whose process leads to extra GHG emissions.

One is a leader in the packaging industry and constantly innovates to ensure its products are of high quality and meet the needs of the consumer as well as those of the environment

They claim that consumers and retailers have a huge influence on the packaging trends for which materials to use or for the type of packaging.

Plastic use increasing due to demographic changes – smaller families leading to the need for smaller portions or food products. Sometimes the portion sizes reduce but the price remains the same for the product.

Different strategies for different retailers with some opting for reduction in the weight of packaging while others entirely get rid of the packaging for certain products.

Argument that the shelf life of products is higher with the packaging as opposed to without. Also to do with consumer mentality that they don't want their food touched by others.

Retailers argue that there was an observed increase in food waste due to the total removal of packaging. Consumers only pick the good or best product, and a lot of the not so good ones spend more time on the shelves until they are thrown away.

5. Growing light systems

All modern greenhouses are observed to have lighting systems that mostly consist of LED lights that are programmable to produce different light intensities as per the needs of the grower. Some are combined with smart systems that can detect the variation in natural light in different sections of the greenhouse to provide varied light intensity such that the production per square meter on each section is relatively the same throughout the greenhouse.

Standout system was observed to incorporate water cooling. As the LEDs are used, water cools them and dissipates the heat. The heat is carried away in tubes for reuse in other sections of the greenhouse for heating. They can also connect the tubes to domestic users for heating houses or swimming pools as is already shown in one of their successful projects. This system shows it is possible to combine different uses and still benefit from the fact that the cooled lights are observed to have a longer lifespan after testing by the exhibitor.

6. Water storage

A few water storage builders showcased their ability to build tanks and ponds that were able to hold large water reserves for the growers to use in different conditions from wet to arid areas. To prevent water loss through evaporation, some have corrugated sheet roof coverings while others have flexible covers made from special plastic material reinforced with woven material. These storage systems can capture rainwater as well as be filled with water pumped from surface or other water sources. The foundations of these storages vary from concrete bases to geotextile and plastic covers. Most of the hard materials can be reused for other projects but are difficult to recycle. The consideration of whether the plastic used can be recycled is not yet part of the design considerations of the builders.

7. Turn-key greenhouse building services

Several construction companies were present to showcase their different turnkey solutions for those interested in owning a greenhouse. They offer design and building services which also cover installation of all structural and technological equipment. They collaborate with different suppliers for specialised services such as lights, growing systems, energy, computers etc. They do all the procurement on behalf of the investor and deliver a fully functions greenhouse to a grower.

Discussion with a few of them show that the end of life for materials not really their concern. They focus on delivering what a grower needs and when the different parts of the greenhouse get damaged or reach their end of life, it is up to the user to determine what to do with it. They consider some circular thinking in the processes about glass and metal since these materials are easily reusable without recycling. Since some parts are of a standardised size and quality, they can reuse them for different projects where necessary.

One demonstrated the use of a polycarbonate material in place of glass. The material was claimed to be less brittle than glass and able to withstand high forces. However, this material is not recyclable, and the builder did not know what happens to it at the end of life or after damage. The material is dumped at a waste management facility and the rest is not subject to any of their policies.

The builders claimed that the EU has much power, but not uniform rules and regulations come from it. They further pointed to weak upstream regulation and strong downstream rules which affect how well the policies work. Such an example given was with the water quality requirements. Apparently since Germany has more relaxed policies than the Netherlands, the industrial and agricultural effluents from Germany come to the Netherlands but the Netherlands has strict regulation, so even with a strong stance, the water quality is already affected before anything can be done. The coherence in the strictness in the region should therefore be checked.

Water is a big problem for the sector because there is always a discussion of where to dispose the wastewater. Sewer or open water? There is a price for sewer discharging and some are ready to pay it because it is easier, but others find alternative ways and eventually there is leakage into surface water.

One builder said that there are subsidies available for implementation of circular systems and practices. The subsidy might be enough but not being used in the right way, for example, there is focus on the wrong priorities such as too much on LED and forget about the rest of the stuff. There is no standard requirement of what should be installed or prioritised so everyone does what they think is best but if it is not uniform, progress might be difficult to see.