

# **Closing the loop of human waste: can eco-innovation be the key?**

Findings from the case study of the LooPi urinal

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## **Abstract**

The Circular Economy (CE) primary goal is to be capable of "closing the loops" in processes by changing the idea of resources and waste. Eco-innovation ("the introduction of any new or significantly improved product (good or service), process, organizational change or marketing solution that reduces the use of natural resources (including materials, energy, water, and land)" could be a way to encourage industries to develop more solutions with "closed-loop" systems. Eco-toilets were developed to transform the original wastes and possibly capture some of the nutrients from human waste. An example adopted in the city of Vienna related to an eco-innovation project is the LooPi Urinal. The main objective of the research will be to identify the stages, actors, and barriers to an eco-innovation project such as the LooPi. Also, to understand which are the inputs, activities, and outputs (based on the Theory of Change (ToC)) needed for adopting the CE model in a product like toilets. The data collected for this investigation was obtained from a workshop, policy review and several interviews in the network of LooPi. Five different stages (identifying a need, product design, funding and policy research, prototype development and implementation and market planning) and their actors were identified for the eco-innovation process. The actors were categorized as funding/investors, public authorities, eco-innovators, researchers/designers and clients. Several barriers in each of the stages were identified. The actions and outputs needed for overcoming them were also collected. As for the ToC, the results obtained were categorized in the techno-economic, social and political dimensions. The intended outcome of nutrient and water circularity could become a reality by creating the necessary markets, networks, infrastructure, sustainable supply chain, and policies for supporting and regulating wastewater reuse.

**Keywords:** eco-innovation, eco-toilet, wastewater reuse, circular economy, Vienna

## Executive Summary

### *Problem definition*

CE's primary goal is to be capable of "closing the loops" in processes by changing the idea of resources and waste (Ellen MacArthur Foundation, 2017). If this concept is applied, systems would become more efficient and some problematic wastes from most human activities would be eliminated. Eco-innovation projects can bring new solutions to some of the identified waste streams. An example of this are eco-toilets that focuses especially on water efficiency and the reduction of wastewater produced. One of the eco-toilets main goals is to transform the original wastes and give them another valuable use by recycling water and capturing some of the nutrients from the urine or general human waste (Caspersen & Ganrot, 2018). The LooPi urinal was developed as an eco-innovation project for addressing the wastewater production and searching for a possible solution to the loop that exists for nutrients contained in human urine. The possible impact this type of initiatives has would allow to understand the potential role eco-innovation can have in closing the loop of wastewater stream.

### *Aim and research questions*

The current investigation will focus on one of the eco-innovation projects located in Vienna regarding water resource efficiency. This project is a prototype of a urinal that intends to become part of the city's initiative of the transition towards a circular economy. The main objective of the research will be to identify the stages, actors, and barriers to an eco-innovation project such as the LooPi. Also, to understand which are the inputs, activities, and outputs (based on the Theory of Change) needed for adopting the CE model in a product like toilets and closing the loop of nutrients and wastewater.

Taking the LooPi urinal as an example of an eco-innovation project created to solve the nutrient and wastewater loop the following research aims to answer the following questions:

RQ 1: What is the process for implementing an eco-innovation project for water circularity such as LooPi?

*Sub-question 1.1.:* Which are the different stages of the process of eco-innovation?

*Sub-question 1.2.:* Which are the actors, possibilities and challenges in each stage?

*Sub-question 1.3.:* Which is the role of eco-innovators in the process?

RQ 2: Which are examples of inputs, actions and outputs that could help optimize the implementation process of eco-innovation related to wastewater in Austria?

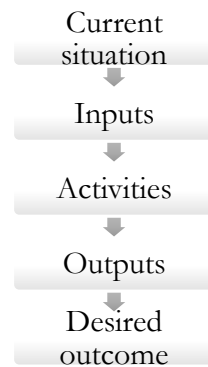
*Sub-question 2.1:* Which techno-economic, social and political criteria need to be considered for closing the wastewater loop?

### *Research design*

This project is structured as an exploratory single-case study of a sustainable urinal in Vienna, Austria. The case study research method can provide useful insights to analyze complex phenomena that involves real-life context and the different factors that might influence the obtained results (Yin, 2009). For this investigation, this type of research design will be applied

in the search of the main possibilities and barriers for the LooPi urinal and an overview of the policies, strategies and programs that apply for this context. The research will obtain the data from a literature review of policies, interviews from the different actors of the networks, and their perspectives with a participation in a workshop.

The principal framework for this research is based on the Theory of Change considering eco-innovation initiatives as a way to change the current situation of the linear economy into a more closed loop economy. The potential use of this model for the present investigation will allow an understanding of how the current situation with eco-toilets could be improved in Vienna and even how this could be applied to other contexts considering that some of the factors might be similar in different locations.



*Visual representation of Theory of Change and its main components*

*Source: based on Mattos et.al, 2022*

For the case of the role of eco-innovators, two concepts were selected for understanding their role in society, especially in the transition towards a circular economy. First is the concept of “circular intermediaries”, as they are highly interested in connecting the different stakeholders for their projects to be successful and create proper business models for the markets they want to be part of. Second, eco-innovators are the ones that will need to contact and push forward projects and changes needed in different areas such as techno-economic, social and political by using what has been defined as “boundary work”.

By using this theory and the mentioned concepts, the investigation will research the eco-innovation process in general and intend to understand the role eco-innovators play in the CE transition. By researching their different networks, their influence and power as intermediaries and change starters can also be further understood.

### *Main findings*

Five different stages (identifying a need, product design, funding and policy research, prototype development and implementation and market planning) and their actors were identified for the eco-innovation process. The actors were categorized as funding/investors, public authorities, eco-innovators, researchers/designers and clients. Several barriers in each of the stages were identified. The actions and outputs needed for overcoming them were also collected for further analysis in the ToC model.

As for the ToC, the different inputs, activities and outputs obtained from the interviews and the workshop were categorized in the techno-economic, social and political dimensions. The

intended outcome of nutrient and water circularity could become a reality by creating the necessary markets, networks, infrastructure, sustainable supply chain, and policies for supporting and regulating wastewater reuse.

### *Conclusions and recommendations*

Eco-innovation is considered an important mechanism to reach the needed changes for CE faster and support the systems to perform the same or even better. It represents a major opportunity for the development of industry and society at the European level and worldwide. The successful creation of new products (such as eco-toilets) and the markets derived from eco-innovation could also facilitate the transition for CE in the wastewater. By remarking the multiple benefits in the society, economy, and environment from eco-toilets, they could be further implemented. The possible benefits for users, farmers, technology developers, and several actors are still to be discovered by replicating these initiatives in more places around the world.

Understanding the different stages, the actors present in each of them, and the main barriers present, could make the process easier to follow and allow more and more organizations to join in developing this type of innovation. Eco-innovators also have an important role in taking part in the force rooting for changes and their role as circular intermediaries is connected to their ability to create strong bonds between the actors and stakeholders that are part of the process.

The Theory of Change model obtained from the results of this investigation also allows visualization of an integral model in the techno-economic, social and political dimensions. Identifying some of the needed inputs and activities that lead to specific outputs could trace a roadmap of actions that could lead to closing the wastewater loop for the Austrian context. The intended outcome of nutrient and water circularity could become a reality by creating the needed markets, networks, infrastructure, supply chain, and policies for supporting and regulating wastewater reuse.

As for the case of Austria, there is a clear commitment from the public authorities on financial supporting for eco-innovation and providing aid for eco-innovators to grow by enabling channels and networks through several strategies and programs. It is a fact that changing the existing systems, such as infrastructure and policy framework, can be challenging, but the change needs to start somewhere.



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# 1 Introduction

The European Union (EU) countries have been part of most international agreements in recent years; however, from the 1990s on, they took a significant role in creating and implementing environmental policy treaties and regulations (Vogler & Stephan, 2007). The urge for action induced by the European governments marked the beginning of extensive development in the environmental policy into a more complex system involving different types of policies (mandatory, voluntary, local programs, and others) (Holzinger & Sommerer, 2014). Holzinger *et.al.*, 2008, mention that EU members adopted around 40 policies before the year 2000 related to environmental topics. As part of these environmental policy packages, the European Union also developed the Circular Economy Action Plan (CEAP) in 2015 and released another version in 2020 (European Commission, 2015). One of the main objectives of this plan was to transform the current "linear economy" into a circular economy (CE) by using different strategies. Some of the required actions for this transition are increasing global competitiveness through innovation, developing options for sustainable economic growth, and creating a substantial number of new jobs in sustainable businesses (European Commission, 2015)

The CE's primary goal is to be capable of "closing the loops" in processes by changing the idea of resources and waste (Ellen MacArthur Foundation, 2017). If this concept is applied, the whole economic system will shift on a different path, becoming more efficient and avoiding some of the problematic wastes from most human activities. Furthermore, the circular economy approach could decrease environmental impacts and improve economic performance by keeping the value of materials. CE promotes the recycling and reusing of resources, allowing systems to perform better with similar costs (Scheepens *et al.*, 2016).

As remarked by the European Commission, 2012, a helpful input in the process towards the CE transition, is eco-innovation. The Eco-innovation Observatory defines EI as: "*the introduction of any new or significantly improved product (good or service), process, organizational change or marketing solution that reduces the use of natural resources (including materials, energy, water, and land)*" (EIO, 2010, pp: 7). Eco-innovation could be a way to encourage industries to develop more solutions with "closed-loops" systems and change the linear materials and energy flows, providing a competitive advantage in many sectors (European Commission, 2012). This way, it can become a vital part of the strategies toward CE transition, searching to develop products and services that improve the efficiency of resources and reduce environmental consequences.

Even though it sounds very promising, having this mind shift in society is very challenging due to the complexity of the changes needed in the techno-economic, social, and political dimensions. An interesting theory that has been researched in previous studies about how these types of changes can occur is the Theory of Change (ToC). This theory presents the how and why projects or initiatives can generate specific changes. Furthermore, the approach helps to identify the needed inputs, activities and outputs that can lead to a desired outcome (Oberlack *et al.*, 2019).

European countries have taken different approaches regarding actions for the inclusion of the CE actions and the support of eco-innovation by creating different policy strategies and instruments (European Commission, 2019). An exciting example of the results that these

strategies can produce is the case of Austria. In 2019, Austria was ranked fifth place in the list Eco-Innovation Index of European countries regarding environmental innovation and circular economy. Some of the most remarkable strengths of the country are mainly in terms of waste management, recycling practices, and resource efficiency (Gözet, 2019). This way, Austria is considered a favorable location for green clusters and social enterprises to develop environmental technology related to CE and the possibility of becoming pioneers in the global market.

The current investigation will focus on one of the eco-innovation projects located in Vienna regarding wastewater reuse. This project is a prototype of a urinal that intends to become part of the city's initiative of the transition towards a circular economy. The main objective of the research will be to identify the stages, actors, and barriers to an eco-innovation project such as the LooPi. Also, to understand which are the inputs, activities, and outputs (based on the Theory of Change) needed for adopting the CE model in a product like toilets and closing the loop of nutrients and wastewater.

## 1.1 Problem definition

Even when eco-innovation and circular economy could be initially related by intuition, their association is difficult to understand due to their multiple interpretations. Although many studies have researched the terms separately, there is still not so much research done about how they influence one another. De Jesus *et al.*, 2018, represent the relation between eco-innovation and CE in the process represented in Figure 1-1. The question of how they can work together to change the current linear economy into a circular one is still being discussed. EI has been identified as one of the main strategies for creating new products and technologies that can close the material loops (Tregner-Mlinaric & Repo, 2014). Therefore, further examples and applications of eco-innovation for transitioning into CE models should be further evaluated to understand their potential role in the process. For this investigation, the main application of eco-innovation would be related to the possible reuse of water and nutrients available in wastewater.

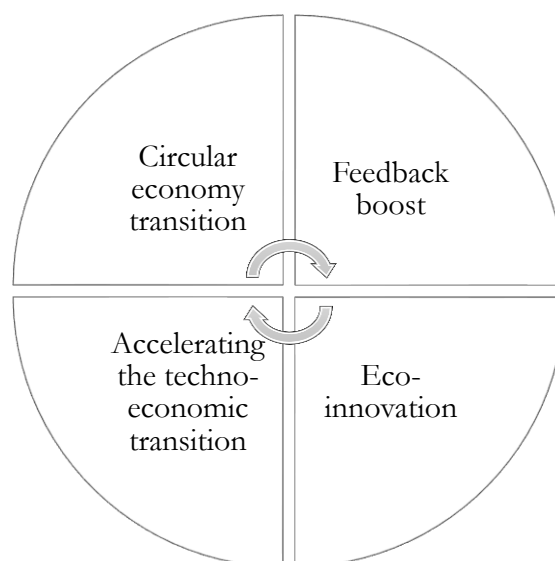


Figure 1-1 How can EI and CE be related? Source: Based on de Jesus, et al., 2018

One of the remarked topics mentioned in the EU Circular Economy Action Plan from 2019 is the reuse and recycling of key waste streams such as wastewater (European Commission, 2019). The availability of water worldwide has been an increasing concern in recent years due to the changes caused by climate change. Currently, almost 4 billion people face severe water scarcity, and the costs to maintain the current water management infrastructure are very high (Mekkonen & Hoekstra, 2016). Additionally, wastewater management systems require high amounts of energy and complex mechanical and chemical processes to treat the water adequately to meet the health standards. It is also known that some of these systems are reaching their capacity limits in most cities due to the growing population (Tilley *et.al.*, 2014). Other countries have not been able to properly install a centralized and safe system of wastewater management due to the economic inversion it requires. Consequently, they might be facing a health threat for the population without proper water treatment (Ramani *et. al.*, 2012).

A significant quantity of water is needed every day in households, especially for toilets. Some modern toilets can require up to 1.6 gallons per flush. If we consider that a regular person flushes around five times a day, it is a substantial amount of water needed that later transforms into wastewater that needs to be treated. Even though these numbers are better than some of the previous designs (5-7 gallons per flush), the high quantity of water used and then produced as wastewater from toilet use should be a call for action (Water Footprint Calculator, 2017).

An interesting eco-innovation product that has emerged from trying to reduce wastewater and closing the water loop is the development of eco-toilets or diverting toilets. Eco-toilets are systems that allow the separation and routing of human waste (urine and/or feces and toilet paper) from standard sanitary wastewater (Woods & Heufelder, 2018). This way, less amount of wastewater (or none) is produced from these toilets (Bhattacharjee, 2018). Usually, their main goal is to transform the original wastes and give them another valuable use by recycling water and capturing some of the nutrients from the urine or general human waste (Caspersen & Ganrot, 2018).

The current investigation will focus specifically on an example of a urine-diverting toilet. The urine-diverting toilet mechanism usually directs the urine into a storage tank where different processes will occur for the possible reuse of the nutrients contained in urine (Woods & Heufelder, 2018). Diverting toilets have also developed a different mechanism for obtaining water-efficient systems and the reduction of wastewater generated (Sgroi *et al.*, 2018). By doing this, the urine-diverting toilets can provide a way to close the loop of the nutrients we obtain by food, that are later contained in the urine.

#### *Case study description: the LooPi*

This research will focus on an eco-innovation project, currently in Austria, identified as the LooPi Urinal (Figure 1-2). This urinal was developed by one of the local research and development organizations named alchemia nova GmbH. This organization focuses mostly on researching nature-based solutions and circular economy projects. The urinal combines the use of green walls and water and nutrient circularity. This public urinal prototype was developed in 2021 in Vienna and the prototype was installed from the end of 2021 until May 2022 in the city's sixth district (Mariahilf). The prototype was developed in collaboration with

the University of Natural Resources and Life Sciences (BOKU) and EOOS Design GmbH. The project was also funded by the Austrian Ministry for Transport, Innovation and Technology and The Austria Research Promotion Agency (FFG).



*Figure 1-2 LooPi prototype developed and installed in Vienna*

*Source: alchemia nova*

The LooPi presents a revolutionary system for wastewater treatment. Once the urinal is flushed, LooPi's green walls (Figure 1-3) are designed for using the nutrients present in the urine that are later captured by the plants that form part of them. The plants thereby retain some pollutants and clean the water so it can be reused for another toilet flush. The prototype involves a combination of wastewater management & green infrastructure. (alchemia nova.net, 2022).





*Figure 1-3 LooPi's green walls*

*Source: alchemia nova*

Some of the main benefits of using this urinal are storing nutrients from human urine as plant biomass, working off-the-grid and being water & energy autonomous. Additionally, it can capture nutrients from the internal systems in a biochar that could potentially be transformed into a secondary product such as a fertilizer. Other advantages that the project brings with the presence of plants inside the city are cooling the environment, bringing biodiversity to the city, and capturing CO<sub>2</sub> from the atmosphere.

Despite the different benefits the LooPi provides, it is still challenging to place the product on the market. The eco-toilet market is developing, and toilets are still a taboo topic for society. The prototype is still being tested and the price has been a limitation due to the different systems needed, maintenance and the material required for it to resist weather and other factors.

## **1.2 Aim and Research Questions**

The research aims to understand how can eco-innovation in the case of LooPi be accelerated so as to support the transition to CE. The current research will focus on Austria and the possible wastewater reuse produced by toilets. The central perspective would be from the network surrounding the eco-innovators and related actors. The policies that will be reviewed are the ones applicable to the Austrian territory and related to eco-innovation incentives, funding, and the CE transition. Within the described scope, the following research questions will be the guide of this investigation:

**RQ 1: What is the process for implementing an eco-innovation project for water circularity such as LooPi?**

*Sub-question 1.1.: Which are the different stages of the process of eco-innovation?*

*Sub-question 1.2.: Which are the actors, possibilities and challenges in each stage?*

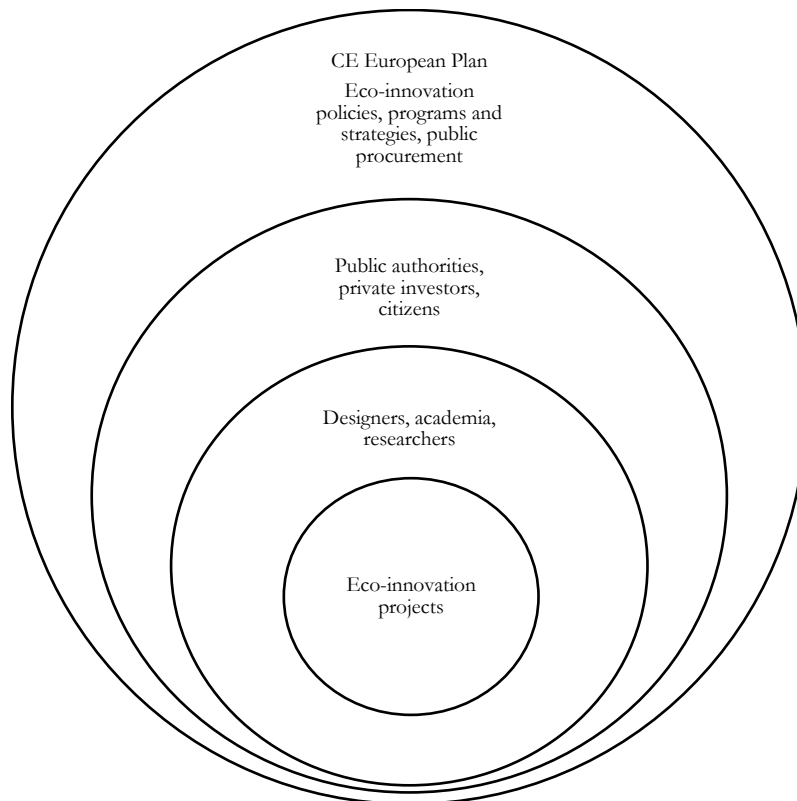
*Sub-question 1.3.: Which is the role of eco-innovators in the process?*

**RQ 2: Which are examples of inputs, actions and outputs that could help optimize the implementation process of eco-innovation related to wastewater in Austria?**

*Sub-question 2.1.: Which techno-economic, social and political criteria need to be considered for closing the wastewater loop?*

### 1.3 Scope and Delimitations

The scope of this investigation would be the process for developing an eco-innovation initiative. This process will be studied using the example of the LooPi urinal and how current networks and policy frameworks can further support it. Understanding the current situation from the lenses of eco-innovators and the related actors that form part of the process of an eco-toilet will allow having detailed knowledge of how possible it is to implement these projects. Figure 1-4 explains the different contextual elements that interact with eco-innovation projects like the LooPi. With this scope in mind, the results obtained from this research will allow having a clearer understanding of how eco-innovation initiatives can facilitate closing the loop of wastewater produced by toilets.



*Figure 1-4 Scope limits applicable for this research*

*Source: Author*

The central policies and programs that will be reviewed are the ones that include direct and indirect support for eco-innovation, funding for projects, financial benefits, and other topics that can be related to the transition to the circular economy. Although the LooPi project will be the main focus of the investigation, additional initiatives with similar water and nutrient reuse goals were reviewed.

Some of the identified limitations are related to the actors' time availability and participation in workshops and interviews, mainly due to the ongoing COVID-19 pandemic restrictions or other time limits. Therefore, online resources such as emails or video calls to capture their perspectives will be used as needed. Additionally, language barrier issues might also limit the research since the information might not be available in English.

## 1.4 Ethical considerations

### 1.4.1 Researcher honesty and personal integrity

The current investigation was done in cooperation with an external organization identified as *alchemia nova*, located in Vienna. Other private organizations developing similar initiatives related to wastewater reuse were interviewed to obtain a wider perspective and experience. Furthermore, the related actors will be consulted to provide their perspectives on the case of LooPi and, in general, to discuss the related topics to the possible reuse of wastewater and nutrients in Vienna.

### 1.4.2 Ethical responsibilities to the subjects of research, such as consent, confidentiality, and courtesy

Since an external organization was part of the process, consent and confidentiality of the information provided should be agreed upon beforehand. Furthermore, the organization is aware of the need for accessible information for this research and the final publication from Lund University. The interviews and the information collected in the workshops required objective information from the participants. If any of the participants requests to be presented as anonymous, the case should be considered to avoid possible consequences for the participants. The research's primary goal is to obtain relevant perspectives and opinions without compromising their integrity. Participants were informed with anticipation that the information related to the workshop was intended to be used as part of this master thesis that is available to the public.

## 1.5 Audience

The audience for this project can be actors in different sectors. First, public authorities representatives related to environmental projects and interested in the possible acquisition of products or services that can improve their performance in resource efficiency and the transition into a circular economy. Second, private organizations, additionally eco-innovators, NGOs and end-users of toilets such as the citizens of Vienna. These organizations could benefit from new projects that improve their sanitation options in public spaces.

Additionally, representatives from academia or private investors interested in researching possible reuses of wastewater and nutrients produced from toilets. Finally, professionals involved in construction that are considering alternatives for green buildings and are interested in eco-innovation projects that can improve the resource efficiency of buildings.

## **1.6 Disposition**

The disposition of the present document will be the following:

The first chapter introduces some of the most relevant topics related to circular economy policies and eco-innovation. Additionally, it mentions the relevance of Austria in the eco-innovation processes and their strategies for circular economy transition and why the LooPi public urinal and wastewater reuse were selected for further investigation. The main research questions, main scope and some of the expected limitations are also described as part of this chapter. Lastly, it mentions the intended audience that could benefit from this work's content.

The second chapter contains the literature review that presents some of the main topics related to the research questions. The conceptual framework will also be included in this chapter, with a more detailed description of the theory and concepts used for the investigation.

The third chapter describes the research method selected for this master thesis project and the details of data collection and analysis tools.

The fourth chapter presents the main findings and results from the data collection and analysis.

The fifth chapter discusses the results and a deeper analysis of the obtained results, and a possible comparison with other published articles that could support some of the results obtained.

The last chapter contains the main conclusions of the work and includes some recommendations for the principal audience. It also outlines some of the possible areas for future investigation.

## **2 Literature review**

The information presented in this section provides a summary context of eco-innovation projects and their relationship with CE in Europe. Also, it compiles the available information about the research and importance of eco-toilets and sanitation worldwide.

### **2.1 Eco-innovation and CE in the European policy context**

Several documents from the European Union focus on strengthening innovation development since innovation is catalogued as one of the leading forces for busting economic growth. The concept of eco-innovation is described by the European Commission, 2012, pp: 2, as the following:

*"Technological and non-technological innovation – that create business opportunities and benefit the environment by preventing or reducing their impact or optimizing the use of resources. Eco-innovation is closely linked to how we use our natural resources, how we produce and consume, and the concepts of eco-efficiency and eco-industries."*

Why is eco-innovation considered one of the best strategies to develop the European economy? Leitner, 2018, mentions that in addition to the positive impact on European society regarding climate change consequences, environmental protection, and resource use, it can also contribute to recovering from the recent global economic and financial crisis. Considering these benefits, the European Commission developed the Europe 2020 Strategy to search for sustainable growth and include innovation as a powerful strategy for efficiently using resources (European Commission, 2020). Additionally, the Resource-Efficient Europe initiative highlights the importance that eco-innovation provides in addition to other EU policy instruments (European Commission, 2012). Finally, a specific plan explicitly related to eco-innovation was developed, searching to solve some of the main barriers eco-innovators could have.

The primary goal of the Eco-innovation Action Plan (EcoAP) is to provide the needed resources to encourage investment in environmental processes and technologies that can further develop innovation (European Commission, 2011). Another important program related to this topic is the European Competitiveness and Innovation Framework, which supports innovators with approximately 430 million euros. This program involves different areas such as promotion, risk capital financing and network creation. The plan provides strong support for eco-innovators for several reasons, as mentioned by the European Commission, 2012: "The plan includes seven targeted actions on both the demand and supply sides, on research and industry and policy and financial instruments. This includes establishing credible verification of environmental performance to increase confidence in eco-technologies". This way, it is expected that these new solutions developed from eco-innovation will attract and create a new generation of high-tech enterprises, increasing European competitiveness.

Other parallel financing programs currently in place are Horizon 2020 and Framework Programme for Research and Innovation for 2014-2020 (European Commission, 2011). Furthermore, private investors are also starting to become interested in the opportunities that eco-innovation can provide. As mentioned by European Commission in the brochure of eco-innovation as the key to Europe's Future Competitiveness, 2012, pp: 3, : "*Investors such as banks, venture capitalists, investment funds, and insurance companies are also becoming increasingly aware of*

*the opportunities presented by environmental technologies"*. This report also mentions that some of the European eco-industries have been considered an essential part of the whole economy in the past years due to their importance in turnover and employment force. As an example of this, it was estimated that in 2008, they had an annual turnover of around 319 billion euros and had a working force of around 3.4 million people.

The circular economy's ultimate goal is to transform current systems and consumption patterns into new systems where waste is avoided, initial resources can be reused, and their value can be extended for longer (Urbinati *et al.*, 2017). Europe has taken a proactive approach in searching for ways to transform a linear economy into a circular economy in recent years. However, with the current economic model based on linear systems and high consumption patterns, only few industries have returned wastes into the process again (European Commission, 2019). Due to this, creating a plan that would give and prioritize actions from the European governments was needed and was finally compiled by the European Commission in 2015 with specific targets in different sectors and topics that could measure their strategies towards change.

As part of this plan, the EU Commission considered vital stakeholders that must be engaged in different regions, economic activities, industries, citizens, national governments, businesses, academia, and international organizations (Triguero *et al.*, 2022). The main goal of the involvement of the different actors is to encourage the transition by improving competitiveness, and innovation, generating new jobs and modifying the markets into sustainable economic growth (European Commission, 2015). Therefore, the creation of this document was identified as part of the needed actions and an essential role in achieving the Sustainable Development Goals (SDGs) for the 2030 UN Agenda.

In the upcoming sections, the documents created by the European Commission such as the Circular Economy Action Plan 2015 report developed in 2019 (European Commission, 2019) and the new Circular Economy Action Plan for 2020, will be reviewed (European Commission, 2020). However, since the document refers to the whole strategy designed for several sectors and specific topics, the main focus of the present research will be on the sections that concern waste streams into resources and closing the loop of recovered materials.

## **2.1.1 European Union Circular Economy Action Plan 2015 Report**

### *Key messages*

This report includes some of the changes that occurred in the EU from 2015 to 2019 and the effects this plan had on the European economy. The Circular Economy Action Plan included 54 actions related to multiple sectors and waste streams that were successfully implemented in some of the member states from EU or are on the way to being implemented. Some of the general conclusions related to the topic of this research from the EU Monitoring Framework for the Circular Economy are the following:

- An increase in job creation: from 2016, four million work options were created (an increase of 6% compared to 2012). More jobs are expected to be created out of demands generated by the markets of reused materials in the following years
- The development of new business models and markets inside and outside the EU: reusing, recycling and even repairing were able to generate an estimate of €147 billion

- An increase in municipal waste recycling from 2008 until 2016. Despite this improvement, there is still a gap related to the demand for possible recycled materials since it is estimated that recycled materials might only cover less than 12% of the demand in Europe
- Creation of the Enterprise Europe Network and the European Resource-Efficiency Knowledge Centre: the primary goal of this network is to guide Small and Medium-Sized Enterprises (SMEs) in the transition
- Creation of the EU Environmental Technology Verification (ETV) pilot programme intended to help technology developers gain credibility for their products in new markets

#### *Waste into resources*

One of the main objectives of this plan is to modernize waste management systems all across the European Union and establish a unified and effective system. For this reason, a revised waste legislative framework was developed and approved in July 2018. One of the main topics included was the strengthening of waste prevention and waste measures. Furthermore, since the situation of waste streams and waste management in the different member States differ, the Commission supports these members by sharing experiences and policies on how to meet the objectives of the waste policies from successful models.

#### *Closing the loops of recycled materials*

Some of the main changes needed in legislation are related to recycled materials and their reinsertion into the system. For example, new policies should include clear rules for using and producing organic fertilizers produced with secondary raw materials recovered from bio-waste and agricultural by-products. Some of the characteristics added to the new Fertilizing Products regulation include important considerations such as the facilitation of market entry to sustainable and more circular products. Additionally, the Raw Materials Information System, started in 2017, helps industrial sectors identify recycled materials and their availability.

The reused water is also part of the action plan due to the high demand all over Europe and the possible scarcity expected in upcoming years. The water reuse mainly focuses on agricultural irrigations, but the importance of water planning and management are also included in future reviews.

## **2.1.2 European Union Circular Economy Action Plan 2020**

### *Key messages*

The most recent version of the European Union Circular Economy Action Plan was published in 2020, considering some of the previous experiences from the plan implemented in 2015. In this new version, the Commission remarks on the importance of how to measure the effective and efficient application of the sustainable product framework. Some examples of these actions are:

- Facilitate the platform of European Dataspace for Smart Circular Applications with information about product characteristics and some of the value chains related to it

- Enforcement of applicable sustainable requirements for product development in the European Union in cooperation with the local authorities
- Increase of market surveillance actions and inspections regarding sustainable products

The document also highlights the public authorities' purchase power as a powerful driver of the demand for sustainable products. As estimated by the Commission, 14% of the actual GDP from Europe is related to public procurement. Considering this data, the CE plan proposes the need to set a minimum mandatory Green Public Procurement (GPP) and additional monitoring reports from the actions taken. Furthermore, the Commission will also support the needed training and guidance for public buyers with the "Public Buyers for Climate and Environment" program.

### *Water and nutrients*

The European Commission has an objective also to ensure the possibility of renewable bio-based materials through the Bioeconomy Strategy and Action Plan. Also, a new Water Reuse Regulation will serve as a guide to encourage the inclusion of water reuse in agriculture instead of becoming additional wastewater. The main goal of this regulation will be to provide and facilitate water reuse in industrial processes. Lastly, The Integrated Nutrient Management Plan will focus on the stimulation of markets for the insertion of recovered nutrients and the revision of some of the directives regarding wastewater treatment for capturing some of the nutrients found in these waste streams.

## 2.2 Eco-innovation in Austria

Eco-innovation is also very present in the Austrian economy and legislation. The Eco-Innovation Observatory identified 12 policies, programs, and strategies developed explicitly for eco-innovation purposes in their last report about the country. Additionally, the creation of financial support programs and mechanisms and collaborative platforms shown were developed with support from the public authorities (Gözet, 2019). This report also positions Austria as 5th among the 28 European countries with an overall score of 130. Austria is located in the index between Germany and Finland, which are recognized leaders in environmental aspects.

The government highly supports innovation in Austria with different policies and programs. The following section will present five of the main policies and strategies that currently support eco-innovation initiatives in Austria and in which ways they can facilitate the inclusion of these projects in this context. These documents were selected based on the Eco-Innovation Observatory Report from 2019 that would apply for the context of this research (Gözet, 2019). The information summarized in this section is based in the official webpage of the policy or strategy.

### **Technologies for Sustainable Development 2000**

This program was created by the BMK (Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology) by the end of the 2000s. It is part of the initiative part4innovation in cooperation with the FFG (the Austrian Fund for Investigation). This programme is catalogued as one of Austria's most important promoters of eco-innovation



(Gözet, 2019). Its main objective is to support the country's economic development by using innovation and R&D projects.

This project has been ongoing for several years and was divided into different sub-programs such as Building of Tomorrow, City of Tomorrow, Factory of Tomorrow and Energy Systems of Tomorrow. The only ongoing programme is the City of Tomorrow and another new collaboration with IEA cooperation since 2003 (Nachhaltigwirtschaften.at, 2022).

The City of Tomorrow program “*aims at researching and developing new technologies and solutions for future cities and urban developments. The program follows an applied and demand-oriented approach and, with this mission orientation, can make an essential contribution to the modernization and resource efficiency of Austrian cities*” (Nachhaltigwirtschaften.at, 2022). These subprograms allow eco-innovation ideas related to buildings, cities and energy consumption to be financed and further developed into better options for the public.

### **naBe 2010**

Another initiative funded by BMK and implemented by BBG (Federal Procurement Agency) is the naBe. This program is known as the Austrian Action Plan for Sustainable Public Procurement (Aktionsplan nachhaltige öffentliche Beschaffung). This plan emerged as part of the invitation of the European Commission back in 2003 to state members to create National Actions Plans (NAP) regarding sustainable public procurement. naBe was produced finally in 2010, and its main target are federal public procurers that are part of Ministries and the Federal Procurement Agency (BBG) (naBe.gv, 2022).

As indicated in their online platform, naBe's core objectives are the following:

- Anchoring sustainable procurement in all federal institutions
- Harmonization of criteria concerning sustainable public procurement
- Securing Austria's pioneering role in sustainable public procurement in the EU

As part of the steps to successfully implement the action plan, the BMK connects a lot of different actors and their partnerships and networks. Some examples are from the federal government authorities and on a smaller scale, such as cities, municipalities, and other divisions. Other important partners are NGOs, the European Commission, academic institutions, and the Federal Environment Agency. In 2019, the naBe platform was launched to guide public procurement officers in applying sustainable selections in their decisions in their daily job by providing the naBe criteria and even organizing events and workshops. With the support of this action plan, eco-innovation projects can also be prioritized from regular or traditional products in the markets and become part of the public procurement buys (naBe.gv, 2022).

### **Austrian Resource Efficiency Action Plan (REAP) and Reset: Resource efficiency in the Federal Ministry 201**

The Austrian Resource Efficiency Action Plan (REAP) was published in 2012 by the Ministry of Agriculture, Forestry, Environment and Water Management. Its primary purpose is to set targets for resource efficiency in the national industries and activities. Part of its main goals is to identify in which specific fields more actions are required to improve efficiency. The scope of this plan is related to their definition of resource efficiency as “*the*

ratio between monetary output and input of natural resource ‘materials’, comprising energy, water, air and land”. The action plan intends to improve this ratio to have the best possible results from the natural resources used. The REAP focuses on four specific topics: circular economy, public procurement, resource-efficient production, and awareness (European Environmental Agency, 2016).

On the other hand, the Federal Ministry for Sustainability and Tourism presented the Reset2020 (Ressourcen Effizienz Technologie) initiative. The main purpose of this document is to bring together the efforts in resource efficiency and sustainable consumption and production. This initiative was promoted in 2018 and included six action areas: sustainable consumption, innovative environmental technology, sustainable resource management, renewable resources, production, and procurement (Götze, 2019). Reset 2020 will also help in the cooperation and creation of knowledge networks with different stakeholders like public administration, business, academia and civil society. Also, this initiative should work to implement ongoing Austrian and European additional strategies and policies such as the REAP and the CE Plan from the European Union (BMK, 2022)

As part of the goals of the project, the following topics are mentioned:

- Understanding the environmental agendas from the Federal Ministry regarding the resource efficiency and circular economy
- Reinforce the position of the Austrian government related to resources, efficiency, consumption, production, and technologies
- Reduce the environmental impacts and improve the production of sustainable jobs
- Support the circular economy framework from the European Union and achieve the international requirements for resource efficiency

### **Smart Cities Initiative (2019-2050)**

The Smart City Wien Framework Strategy 2019–2050 was adopted by Vienna City Council on 26 June 2019. It was based on the European Strategic Energy Technology Plan (SET-Plan) and was drafted in 2014, but it came into force in 2019. The Smart Cities initiative surges as part of the support from the city of Vienna into an integrated approach for improving life in the city and having their citizens for increasing their life quality (Smart City Wien, 2022). This strategy also reinforces some investigation projects that can provide innovative city solutions. It contains ten different topics between the ones we can find buildings and environment for projects such as the LooPi. The Smart City Framework Strategy has also been adopted in other cities in the past years, trying to go beyond the binding European and national targets. This project is financed by the Austrian Climate and Energy Fund, bringing in cooperation multiple stakeholders from inside and outside the municipal administration.

Circular economy and innovation come up as some of the main topics for this strategy from the city of Vienna. As mentioned by the 2019 Framework Strategy: *“The development of innovative solutions for sustainable cities, in particular, could become a recognized Viennese strength in fields such as combining new technologies with social innovations, developing urban infrastructure and services, and evolving new forms of public participation and balancing of interests.”* This way, science, and research organizations such as ÖKlo or alchemia nova could benefit from the city’s reputation as an innovation leader. Furthermore, it may increase the opportunities for their participation in international projects or contracts. At the same time, the city becomes attractive for new

research organizations and a possible target for additional international investments since it can provide a solid and mature environmental awareness and proper framework strategies already implemented.

Eco-toilet projects could be included in the circular economy and innovation and could also be relevant for developing sustainable food systems and the share of green spaces. For example, projects like LooPi could help improve the use of fertilizers needed for growing food by closing the nutrient loop with their reuse in the agricultural supply chain. In the case of green spaces, the availability of an eco-toilet with plants can help improve the quality of the common spaces and bring additional benefits like the ones mentioned previously.

### **Austrian government programme (2020-2024) 2020**

Different important topics regarding resource efficiency and circularity are mentioned in this new plan from the Federal Government for 2020. Some of the main topics that can be related to supporting eco-innovation, resource efficiency and circularity are the following:

- A waste policy with the promotion of a circular economy and the recycling of materials
- Significant support for science and research for social process and innovation with strengthened governance structures and expansion of research funding.
- Expansion of Horizon Europe from 2021 until 2027 for basic and applied research
- The transformation into Austria Future Fund (Fonds Zukunft Österreich) for research in technology and innovation
- The Research Financing Act which focuses on non-university research with funding, planning and growth plan support for innovation to become more attractive and secure in the long term

## **2.3 Eco-toilets: eco-innovation developed for resource circularity**

### **2.3.1 Water circularity**

Water is one of the principal resources addressed with the circular approach in processes and systems (Global Water Partnership, 2021). It is a critical resource needed for social-economic development and some of the major human activities such as agriculture, energy production and general human well-being. Additionally, the central importance of sanitation and human health is another of the main uses of this resource. Therefore, the increasing concern for its conservation, preservation and proper use is why it is also considered part of the Sustainable Development Goals (WHO, 2021).

The efficient use of water and its reuse needs to be approached in combination with other instruments such as innovation development tools. There are still several barriers to water reuse, such as technological, social, safety and regulatory, that are still to be solved (Wallis, 2010). One of the strategies for this transition could include integrated water management that could establish defined parameters for its safe reuse. The application of water quality standards for specific use can be a way to provide reliable water reuse in different systems supported by regulatory enforcement (Global Water Partnership, 2021). This could promote the improvement of wastewater management systems and even the possibility of capturing

biosolids for secondary uses such as agriculture. Additional to the regulations, the availability of infrastructure that allows these innovation initiatives to be further developed and implemented would also need to be provided (Wallis, 2010).

### 2.3.2 Toilets and their importance in resource use

Toilets are usually taken for granted, and their role in human health, environmental protection and even economic development is often unnoticed. (Sara *et al.*, 2021). One of the most important factors for adequate sanitation is the proper and safe use of toilets. It was estimated that in the year 2020, at least 30% of the population of the European Region lacked the availability of a safely managed sanitation service. Sanitation was categorized as a human right by United Nations, and affordable access to a toilet is an essential part of this decision (WHO, 2021). The adequate management of toilets can provide better conditions for gender equality, improve resource use, and reduce environmental impacts.

The use of toilets is one of the main demands for water use. Toilets analyzed from a sustainable perspective are extraordinarily wasteful, and, most of the time, this passes unperceived. It is estimated that from a calculation of a regular household water use, around 30% of the water required is used for flushing the toilet, and each standard flush could require around 157,000 litres of water a year (ECJ, 2019). The water required for public washrooms worldwide is incalculably huge, mainly since there is usually an incorrect use.

The availability of resources for innovation in sanitation is one of the most relevant steps towards achieving the 6th SDG of water and sanitation for all by 2030. Changes in different stages of the sanitation process such as toilets, collection and treatment of human waste need to happen also to avoid further environmental impacts and damage. Some eco-innovators around Europe have already designed eco-toilets that include circular economy concepts and resource efficiency. Some examples are the following:

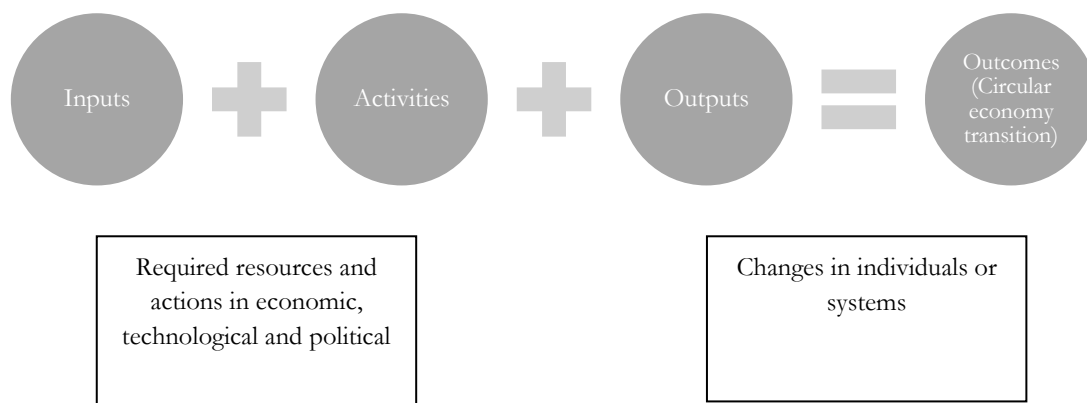
- **öKlo (Austria):** This organization offers a composting toilet that has a system developed for waste separation. It requires very few amount of water and produces no wastewater. Additionally, it requires no chemicals for treating the waste. öKlo uses dry wood shavings, a waste product, instead of the chemicals it uses sawdust for neutralizing the odors. The eco-toilet is mostly made out of wood produced in Austria. It is also easy to assemble, this way they can be located in difficult locations such as in the mountains or outdoors (öKlo, 2022).
- **Sanitronics (Netherlands):** This company developed the “Revolving Toilet”, which includes an auto-cleaning toilet that changes and cleans the toilet and floor once every user comes into the cabin. Some of the central circular concepts included in this product are the idea of the circular building since the parts that conform the product are durable and easily exchangeable in need of repair. In the use of resources, specifically water, the water used for cleaning the floor and toilet is under high pressure, which helps clean it better and faster. This water is also reused for the flushing of the toilets (Sanitronics, 2022).
- **Kakis (Slovenia):** This company offers eco-toilets categorized as composting toilets. They do not require infrastructure and work off-grid with no need for water or chemicals. They are also classified as zero waste since human waste can be reused as biomass or fertilizer. The company mentions that its primary customers are municipalities in Slovenia to renovate public areas in difficult places to access. (Kakis, 2022).

- **Trobolo (Germany):** This company also developed a diverting toilet made from certified wood. The company is also committed to sustainable production with limited use of fully recyclable resources (Trobolo, 2022).
- **WeCo (France):** This organization offers the option of RecycLoo. This bio-toilet looks like any other public restroom but has components like bacteria and sediments that produce electrochemical reactions for cleaning the polluted water and being clean again for another flush. This eco-innovation just started to develop new partnerships with sewer flush toilets, a greywater management company, which has helped the business expand further. Their main target is offering “off-grid” toilets to sustainable cities and new buildings (WeCo-Toilet, 2022).

## 2.4 Theory of Change (ToC)

The principal framework for this research is based on the Theory of Change considering eco-innovation initiatives as a way to change the current situation of the linear economy into a more closed loop economy. Additional concepts like the circular intermediaries and the boundary work would also be analyzed for adding the lenses of the perception of the eco-innovators and their possible role in the transition to CE.

The adoption of new projects such as those derived by eco-innovation can be challenging to fit into solid and mature systems that have been reinvented for several years. One crucial theory that forms part of this thesis project is the theory of change. This concept was originated approximately 30 years ago as a theory-driven approach related to understanding the impacts of social programs (Mattos *et.al*, 2022). This theory presents a mental representation of how and why several actions derived from projects or initiatives can generate specific changes (Oberlack *et al.*, 2019). This mechanism shown in Figure 5 can represent the process by which changes can occur and how the current situation can transform into another desired outcome with different inputs and actions. For the context of this investigation, the current situation would represent systems as they are perceived as a linear economy, and the desired outcome would be the adoption of the circular economy approach.



*Figure 2-1 Theory of change representation applicable for this research*

*Source: Adapted from Mattos et. al., 2022)*

An important factor for adopting the Theory of Change is also related to impacts or risks related to changes. This theory improves the identification and communication of impacts from the different activities needed for changes to happen and the possible outputs these actions could generate (Jackson, 2013). Also, as mentioned by Mattos *et.al*, 2022, pp: 2: "*it presents a model that specifies the logic, hypotheses, influences, causal connections, and expected results of a project or development program*". This way, once the different risks and critical factors are identified, the project's strength can be further understood. Also, it could potentially gather more support (more investments or social support) and cause a more significant impact with the support of data collection and analysis (Jackson, 2013). The potential use of this model for the present investigation will allow an understanding of how the current situation with eco-toilets could be improved in Vienna and even how this could be applied to other contexts considering that some of the factors might be similar in different locations.

For the case of the role of eco-innovators, two concepts were selected for understanding their role in society, especially in the transition towards a circular economy. First is the concept of "*circular intermediaries*", as they are highly interested in connecting the different stakeholders for their projects to be successful and create proper business models for the markets they want to be part of. Second, eco-innovators are the ones that will need to contact and push forward projects and changes needed in different areas such as techno-economic, social and political by using what has been defined as "*boundary work*". These two concepts will be explained in more detail in the following sections.

## 2.5 Circular intermediaries

The new concept of circular intermediaries mentioned by Barrie and Kanda, 2020 with their concept of "ecology of circular intermediaries" needed for the proper connection between the gaps between the various niche-regime levels and the different stakeholders play is one of the main topics in this research. As mentioned by the authors: "*These actors might be part of different societal systems and geopolitical scales. Sustainability intermediation has been recognized as being critical for mediating the machinery of societal transitions*" (Barrie & Kanda, 2020, pp. 1) . Circular intermediaries or facilitators, as mentioned by Hansen and Schmitt, 2020 would be able to then "co-orchestrate" eco-innovation projects and communities. This way, by understanding the different networks created by an eco-innovation project, such as the LooPi, will allow understanding of the different possibilities for knowledge exchange and possible collaborations to enhance eco-innovation.

## 2.6 Boundary work

The concept of boundary work mentioned by Zietsma and Lawrence, 2010 describes different social actors' attempts to reshape, disrupt, and even create new boundaries. A way to create this boundary modification can also be through "boundary devices" that are the ones that mediate different actor worlds (Briers & Chua, 2001). For this applied investigation, the boundary device would be identified as the eco-toilets and the reshaping of the boundaries related to wastewater and nutrient reuse. By using this example, the boundary work realized by entrepreneurs such as eco-innovators could be described as the following: "*the multiple cycles of institutional innovation, conflict, stability, and restabilization needed for disrupting the practices that are considered legitimate within a field*" (Zietsma & Lawrence, 2010). Therefore, by identifying some of the changes needed in techno-economic, social, and political areas, a better understanding of future actions for overcoming some of the current barriers to eco-innovation can be adequately identified.

In conclusion, by using this theory and the mentioned concepts, the investigation will research the eco-innovation process in general and intend to understand the role eco-innovators play in the CE transition. By researching their different networks, their influence and power as intermediaries and change starters can also be further understood.

### 3 Research design, materials and methods

#### 3.1 Research design

This project is structured as an exploratory single-case study of the LooPi urinal developed in Vienna, Austria described in detail in the section 1.1. The case study research method can provide useful insights to analyze complex phenomena that involves real-life context and the different factors that might influence the obtained results (Yin, 2009). For this investigation, this type of research design will be applied in the search of the main possibilities and barriers for the LooPi urinal and an overview of the policies, strategies and programs that apply for this context. The research will obtain the data from a literature review of policies, stakeholders’ interviews, and their perspectives with a participation in a workshop.

For this investigation, the validity of the information obtained from the LooPi study case would follow the constructed validity mention by Yin, 2009. The author mentions, as seen in Figure 3-1, which are some of the tactics needed for constructing validity of the research design.

Tests	Case Study Tactic	Phase of research in which tactic occurs
Construct validity	Use multiple sources of evidence	Data collection
	Establish chain of evidence	Data collection

Figure 3-1: Tactics suggested for a good quality of the case study research design

Source : based on Yin, 2009

Despite that this thesis will focus mainly on Vienna, the possible extrapolation of other eco-innovation project located in different contexts should not be discarded. One member of öKlo (explained previously in section 2.3.2, another eco-toilet example with a similar context to the LooPi) was also interviewed for further understanding of the context for this type of eco-innovation in Austria.

#### 3.2 Methods used to collect data

##### 3.2.1 Mapping of actors in networks

The initial step for capturing the actors’ perspectives is appropriately identifying which of them are currently involved in the LooPi project or could be potentially involved (Appendix I). This matrix was made in collaboration with alchemia nova to identify individuals related to the innovation projects regarding sustainable toilets in Vienna. These actors were invited to participate from the workshop but also if they were not able to attend, additional online interviews could be done.



### **3.2.2 LooPi workshop**

Representatives from the identified actors matrix were contacted via email for their participation in a workshop in Vienna on the 30th of March 2022. The main topics for the discussion were the following:

- Benchmarking eco-toilets: exploring the case analysis of LooPi and other sustainable toilets
- Analysis of significant challenges related to policies, economic factors, and users' response
- Identification of current state and main barriers for further development
- Identification of the stages of eco-innovation and the actors involved in each
- How to engage some of the missing actors?

The main objective of this workshop is to provide further guidance on the current situation, discuss the main challenges experienced by these innovation organizations and create an open discussion regarding some of the changes needed. The list of assistant to the workshop can be found in Appendix II.

### **3.2.3 Actors interviews**

Interviews conducted were semi-structured and included both specific and more general questions for obtaining different arguments from the participants. Open-ended questions were also included in the core set of questions following an interview protocol (Appendix III). However, additional questions could be included based on the interviewee's role and relevance.

The interviews were recorded with the approval of the participants additional to extensive notes. The interview length should be between 30-40 minutes, but this may vary due to the participants' time restrictions or similar factors.

## **3.3 Materials collected**

### **3.3.1 Mapping of actors in networks**

Different contacts from academia, private organizations, non-governmental organizations, and representatives from public authorities of the city of Vienna were identified with the help of alchemia nova. Once they were identified, the information was captured on the Actors Identification Matrix based on the method mentioned by WWF, 2005 (Appendix I). This matrix contains the different categories involved in similar projects as LooPi involved in eco-innovation and eco-toilets. Based on this results, the invitations to the workshop were sent so the participants from the different categories could interact in the workshop.

### **3.3.2 LooPi Workshop**

The workshop was performed on the 30th of March at Central European University in Vienna. Four representatives of alchemia nova and one representative from BOKU university were able to participate in the discussion (Appendix II). The different sections of the workshop allowed the participants to create an open discussion of the project's current situation. The data obtained can be categorized as the following:

- List of the main benefits and challenges for the LooPi.
- A list of the current and future challenges for similar projects and how some of the actual policies might negatively affect the development of water reuse projects
- A categorization of the needed stakeholders for these types of projects to be successfully implemented in the different stages of the eco-innovation process.
- A compilation of ideas for creating networks between the stakeholders, users, and media.
- Compilation of recommendations for future projects.

### **3.3.3 Actors interviews**

Six additional actors were contacted for additional online interviews since they could not join the workshop. Some of the interviews were performed by an email communication due to some difficult schedules from the public authorities of the city of Vienna. The online interviews were done via the Zoom platform and recorded with the needed permission of the interviewees. The recordings are stored in the personal computer and will be reviewed again for further analysis.

## **3.4 Methods used to process information**

### **3.4.1 Mapping of actors in networks**

A matrix with the identified actors was created with the results from the current investigation to understand their different categories and how they interact in the stages of eco-innovation. The matrix allows to understand the current panorama respective to LooPi.

### **3.4.2 Workshop data analysis**

Since the workshop was divided into several parts and different topics, the data analysis will also be specific for each topic:

- Analysis of the main benefits and challenges from the implementation of sustainable toilets in the city of Vienna
- Identification of the significant challenges: a list of the current techno-economic, social, and policy-related challenges.
- Analysis of the different categories of actors and the possible solutions for involving them in current projects and their participation in the different stages.
- Analysis of needed actions for future projects and how could they be implemented.

### **3.4.3 Interview analysis**

The primary process for the analysis of the content obtained from the interview process for the selected stakeholders is:

- Transcription of the interviews in a digital form for analysis and proper data storage.
- Highlight the important topics they are related to and categorize the most relevant words and phrases with codes related to specific concepts and opinions.

- Identify categories and subcategories of the following topics: circular procurement, national or international policies, projects of the city of Vienna, significant challenges, and main benefits.
- Segment the data and connect the different arguments and opinions for every topic.

## 4 Results

The eco-innovation process has different stages depending on the project developed. Some of the barriers found in one of the stages might not be found in the next one, or they might come up until the last phase. Barriers related the economic, social, and environmental factors might also become an unexpected problem in different phases of eco-innovation projects. The proper identification of the different actors, possibilities, and opportunities of the LooPi urinal in each of the project's phases might be considered an example for future projects and anticipating some of the barriers found in this case.

In the case of eco-toilets, the further implementation of them in more places worldwide might also need the participation of public authorities and the financing support from the public and private entities, in addition to the already in place policies, strategies and other programs that support these types of initiatives. Important agreements such as the CE Plans from the European Commission might also become essential allies but eco-innovation projects regarding water reuse and nutrient recycling such as eco-toilets.

### 4.1 Perspectives about eco-toilets in Austria

This section's principal objective is to understand the current situation of eco-innovation projects from the perspective of different actors present in the Austrian context. Although the project focuses mainly on the LooPi urinal, an interview with a collaborator from öKlo composting toilet was included to obtain more substantial evidence about the context.

#### 4.1.1 Identification of actors in the different stages of the eco-innovation process

As a result of a complex process, eco-innovation surges from the interaction of multiple actors and factors that may interact at different moments before the final result of a product or system. Several of the interviewees agreed on the categorization of the different actors related to eco-toilets projects in their own experience:

- Funding/Investors
- Public authorities
- Eco-innovators
- Researchers/Designers
- Clients

The following results compiled in Table 4-1 were obtained from the workshop and the interview data presents some examples of the actors related to eco-innovation projects such as eco-toilets for the case of Vienna.

*Table 4-1: Identified actors in the network of eco-toilets in Vienna.*

<b>Funding/Investors</b>	<b>Public authorities</b>	<b>Eco-innovators</b>	<b>Researcher/Designer</b>	<b>Clients</b>
Private and public funding agencies	MA48	alchemia nova	Innovation centers	Citizens
Ministry of Innovation	Regional managers	öklo	BOKU	Building companies
Investor/innovator finance platforms	Head of districts		EOOS	Municipalities
	Federal Ministry of Sustainability and Tourism		Manufacturers	Households
	MA42			Cleaning companies
	City planners			Farmers
	Ministry of Environment			Wastewater managers

*Source: Actors interviews and workshop.*

The chart represents just a glimpse of the complex network created by eco-innovation projects since most of these projects are interdisciplinary and involve many factors and knowledge for them to be successfully implemented and not stuck in one of the middle phases without further progress. Also, it is important to notice that the case of LooPi is still in the prototype phase. This way, from the information shown in Figure 4-1 with the stages of innovation, additional actors might be included for the last phase of the implementation of the project. Furthermore, the actors identified as clients might be part of the plans since the development of eco-toilets is still on a small to medium scale due to the technology and tests needed for their appropriate function.

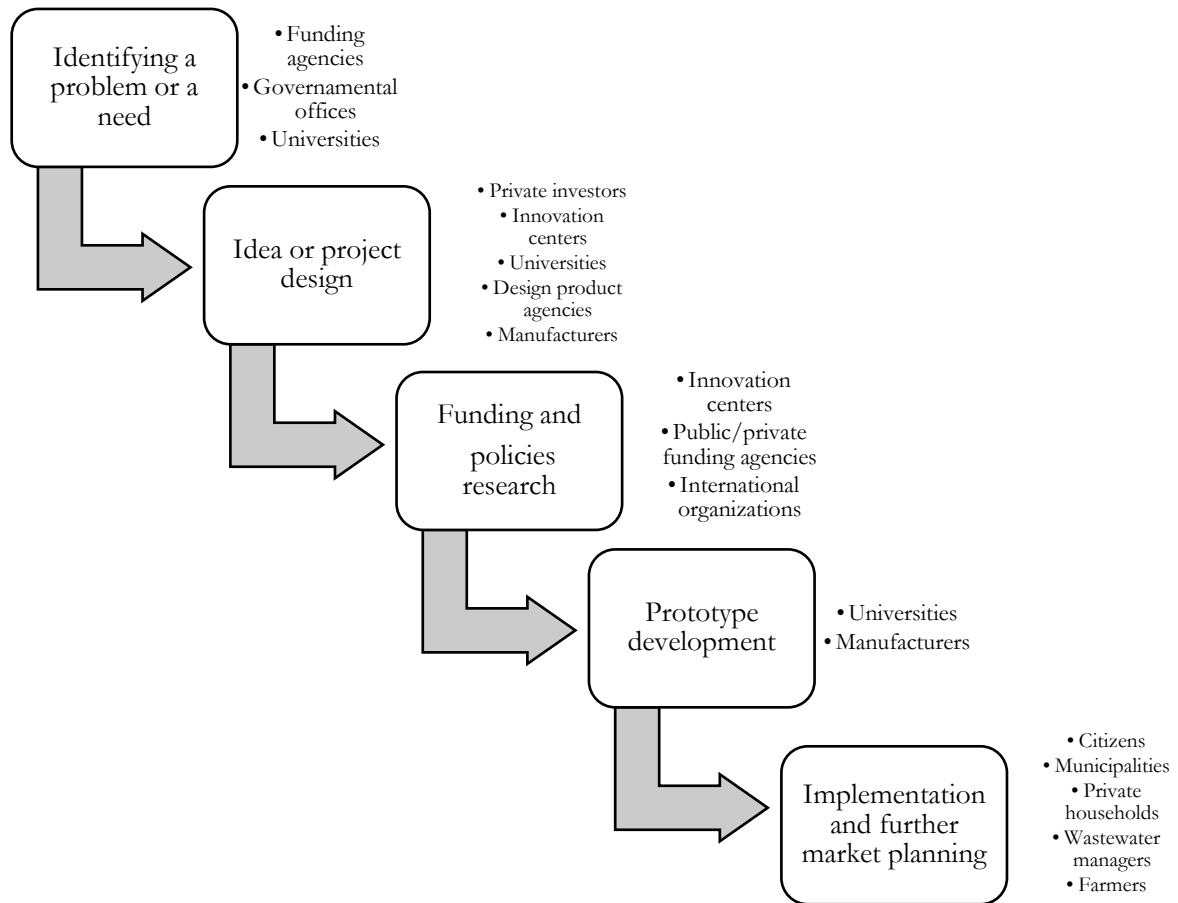


Figure 4-1: Actors in the different stages of eco-toilets in Vienna

Source: Actors interviews and workshop.

The identified actors can be found in one or more stages but do not necessarily interact with each other simultaneously. The eco-innovators will deal with these actors at different moments or maybe through all of the stages.

#### 4.1.2 Possibilities and challenges in the different stages of eco-toilets

As mentioned in the previous section, the final form of a product comes after several steps and with the support of different actors as shown in Figure 4-1. The following sections will present the results found from the different interviews and information obtained in the workshop related to this topic.

##### 4.1.2.1 Identifying a problem or need

###### *Possibilities*

The need for innovation comes in different ways in an organization or industry. Some organizations develop innovative systems changes due to the need to optimize their processes for resource efficiency and cost reduction. This type of eco-innovation comes from the inside of the organization, but innovation might as well be guided or influenced by other external factors. One of the interviewees from alchemia nova mentioned:

“Eco-innovation in Austria is very high, but most of it is focused on small and medium industries that are very good at innovating and improving efficiency. Optimization in some of the industries such as building and automobile industries. So, in that area, the results are outstanding, but usually, they do not develop disruptive innovation that would change whole systems. Usually, they take technologies already in the market, and they use them to improve material or resources use or add intelligent technology”.

The development of new technologies, trends, emerging market problems, and other incentives can be considered external factors that influence industries to search for solutions to an identified problem. However, despite this might be the case in some industries, not all of them have eco-innovation initiatives since there might be systems that have not evolved in many years.

According to one of the eco-innovators perspective:

“Most of the innovation we make is guided by international organizations and their search for solutions for particular topics regarding resource use or environmental impacts. These calls are usually what we use for coming up with solutions. This depends on the types of projects we have also developed in previous years and how mature we have a product or process that we can work further to respond to the call”.

This way, international organizations can also guide innovation, which might be an important support for small and medium organizations that will need funding options to develop possible solutions. According to one of the researchers from BOKU University:

“It depends. Usually, there are calls from funding agencies like Horizon 2020 program from Europe or the FFG in Austria like the LooPi project. However, sometimes they have calls for specific topics, and then, a partnership is created from persons who have the idea for a project”.

Research and development centers and academic investigation centers are constantly producing knowledge. They are one of the primary sources for innovation to continue due to their constant knowledge sharing with available literature for other organizations to take as reference. This way, their results and knowledge can also be used for creating new ideas for solving or identifying problems that eco-innovation projects could solve. For example, Olivier Duboc from BOKU University mentions the following:

“Sometimes companies approach us, and the company pays for the project itself or gives an idea for us to cooperate in a specific experiment in which someone of the research center might have enough knowledge and experience working in. Projects are usually cooperation between BOKU research centers and the organization with financial support from FFG (LooPi is this case)”.

### *Challenges*

Short-term solutions might be more manageable in terms of time and economic resources but might be problematic in the long run. Short term solutions with few investments might work better for some companies. Expensive products that need many systems to be changed

might not be as attractive as regular products with few changes that could get better results than the average ones. One of the designers mentions:

“The price is a quite sensible topic for integrating the eco-innovation such as eco-toilets due to the need to include additional pipes that increase costs. Also, when it comes to the treatment processes, it needs to be affordable to have a successful treatment process. An important aspect to be considered is that every single expense adds up to the final product, and you want to create something attractive to the market; otherwise, it cannot be a good business”.

Another inconvenience that could arise from this first stage is that only a few companies might be able to provide solutions for specific calls due to their innovation advantage. This way, the calls might be only open for some of the companies that have more expertise and more resources and could exclude small and medium organizations.

In other cases, the context of some problems or needs is different from context to context or in the case of the European Union; what might be attractive for a country might not be a need in another one. The specific case of water in some parts of Europe is still not a concern, so it might take some time until this becomes a priority. One of the researchers in BOKU mentions the following for the Austrian case:

“I think especially in Vienna, and mainly with the private sector to make this point because we have sufficient water supply. Some other countries, like the Mediterranean sector, have these practices already in place since they also are experiencing abrupt droughts and still need to supply their agricultural needs. Despite this, it is difficult to estimate how many years countries like Austria will need these changes to come. However, like with predictions, you could say that there will be a need in 30 or 50 years, and then the question is when it should start the implementation”.

#### **4.1.2.2 Idea or project design**

##### *Possibilities*

Networks of innovation are an excellent way to complement a need for an eco-innovation product and a possible design for a prototype. Some organizations cannot have their own research and development program and might need cooperation from other sources. This way, networks can connect organizations that can develop different parts of an idea or project design. An example of this is the way Grünstattgrau operates. They specifically work as an interface between the public sector, business, and research centers. As mentioned by one of their collaborators:

"Grünstattgrau is currently involved in the projects Metabuilding (METABUILDING, innovation Funding and Support for SMEs of the Built Environment Sector - H2020 - INNOSUP-01-2018-2020 (cluster facilitated projects for new industrial value chains) (metabuilding-project. eu) and Infinite (INFINITE - GRÜNSTATTGRAU (gruenstattgrau. at) regarding Circular Economy transition. These initiatives support different organizations and can connect interested actors with each other".

Product or systems designers play an essential role in this specific stage. For example, EOOS is a design agency that works closely with eco-innovation projects related to the circular



economy. This organization is in contact with different actors such as universities, private researchers, and organizations as the construction building. By having different connections with them, the design agency can combine their clients in some of their projects. In the case of eco-toilets, they have obtained experience through collaboration with other organizations that reach to them with new ideas, such as the case of LooPi.

The knowledge produced from research is also an opportunity for some organizations to develop new ideas or designs for specific systems or products. In addition, the literature produced by research centers or universities is usually available for public use. For example, one of the researchers interviewed from BOKU university mentions the following:

"Sometimes they have calls for specific topics, and then a partnership is created from persons who have the idea for a project. In our case, we are mainly approached to be also included since they need a research partner".

### *Challenges*

Although networks might be beneficial for some stakeholders, from the perspective of the design agencies, they are very dependent on the funding available from the other research partners since there are not many funding options available specifically for them. One of the EOOS collaborators highlights:

"I think when it comes to funding, companies as ours (considered to be a startup), it becomes a complicated process to apply to the fundings such as the ones of FFG because not all the costs are covered. We are in this in-between role of being designers but not producers, so we would always need a partner to work with. For researchers might be a different process than for designers. The research outcome is a publication or a paper and, in our case, must be a product. It seems that there is still missing a program that includes the progress of developing a new product.

Another important challenge to consider is that some of the technologies needed for the design might not be ready yet for implementation as part of another system. This way, it might become an expensive design with a high risk of failing or not working in obtaining the intended result, and the testing phase takes time and economic inversion that would sometimes delay the final product. Also, some other simpler and cheaper technologies might work better, so eco-innovation would not become the primary option for customers.

### **4.1.2.3 Funding and policies research**

#### *Possibilities*

For some years, the options for funding from international and local organizations have notably increased in the sustainability and innovation area, especially in Europe. Different initiatives such as Horizon 2020, City of the Future and many more are starting to support eco-innovation projects significantly. Apart from this, some other local initiatives from the Austrian Research Promotion Agency, known as FFG, are constantly available for participants to obtain funding for research in eco-innovation. One of the examples of this is the new funding call: Call: FTI-Initiative Kreislaufwirtschaft from FFG, which focuses mainly on circular economy projects (FFG.at, 2022).

One of the researchers supports this argument by mentioning the following:

"There are several options from Austrian funding agencies for nature-based solution projects and circular economy projects. For example, the City of the Future call and other funds are available for organizations to apply at FFG. So, this main funding agency is for applied sciences in those companies".

Funding support is one of the main concerns for eco-innovators due to the high amount of expenses required to develop a possible prototype and the hours of research needed for some of the projects. The availability of options from the Austrian government and the European Commission has been increasing in the past years with different programs to which some organizations can apply.

One of the principal organizations that fund eco-innovation projects is the Austrian Research Promotion Agency (FFG), supporting industrial research and development. One of their primary roles is to generate knowledge, incentivize the development of new products or services, and increase market competitiveness. This way, in the case of eco-innovators, the agency tries to make the whole process easier by contra resting some of the risks involved in innovation. An important sector of the Austrian economy and the innovation system relies on a solid business and science sector, which can be benefited from FFG funding options. The agency has multiple options for national organizations, research institutions and individual researchers for all the different phases of technology and innovation development.

As for the international programs, FFG is also the contact point for the EU program Horizon 2020 and other additional programs such as ERANETs and the Enterprise Europe Network. In addition, FFG also offers consulting services for Austrian organizations that wish to get involved in additional European research programs and networks.

Three main points reasons by which FFG is considered vital support for eco-innovators are the following (FFG.at, 2022) :

- Entry ticket to the world of innovation: it serves as a subtle way of entering the innovation process by helping small and new enterprises to find suitable partners and research networks.
- Corporate research, SMEs and start-ups: the availability of funding for submissions of any topic and at any moment of the year is one of the main advantages of funding options such as the General Programme single firm projects. The approval of this type of project can take a little time, just weeks, which is very helpful for some organizations. They also offer special funding schemes for small and medium enterprises or start-ups.
- Focal areas and collaborative projects between business and science: the agency offers different funding programs for specific topics that might be considered relevant for economic or social concerns. Some examples of these topics are related to energy, cities and the environment, and others. Usually, these projects might involve different organizations working together with research institutes and universities.

As for the policies that can support eco-innovation, these might be a consequence of changes in the European Commission or even local initiatives supported by local and international stakeholders. Additionally to these national policies, in the case of Vienna, the

districts can have different action plans for the priorities established by their members. Mr. Rumelharts (district mayor of district 6 Mariahilf) mentioned that the “*Wiener Stadtverfassung*” regulates their tasks and responsibilities”. For instance, each district council is responsible for managing the budget regarding the district’s public streets, kinder gardens, and city parks. Due to this, environmental agendas can be different between districts in Vienna.

“District 6 priorities, goals and activities regarding the environment are written down in our “*Klimaschutzleitbild*”, which was voted by the district council in 2020. Furthermore, we established the “*Mariabilfer Klimabeirat*”, which has the participation of both district councillors and experts on environmental and climate matters”.

*Markus Rumelhart, District Mayor of Mariahilf*

### *Challenges*

Discussing with the stakeholders that attended the workshop, it was concluded that there are still essential stakeholders to be reached like investors, other authorities from other districts, cities or even countries for the case of the LooPi. Furthermore, the differences in the funding options and local policies might be a barrier to expanding the business from Vienna. One of the researchers points out the following:

"One big barrier can be existing legislation and how the systems are already implemented. For example, changing the common wastewater system might be a big barrier in Austria. So then, if you want to implement something, you need to persuade the person in charge of giving the go-ahead from the government or from the contractor and different departments from the local government. With the different permits, you would be able to handle water in your property or project. However, it also comes into being able to convince the person in charge that you can handle it properly because if something goes wrong, they are actually responsible for a big part of it."

One of the main barriers related to policies is the complex process of modifying them or making exceptions for some innovative projects. For the case of oeKlo and their intention of obtaining composting material from the human waste, public authorities were very clear on standing that the policy would not be modified and that their idea cannot be done at the moment. One of the members of the composting toilet öKlo mentions the following:

"For the specific part of my job, such as the composting area, we have more boundaries than initiatives or improvements mostly because we wanted to modify the Compost Ordinance or Regulation. We did our best to propose some modifications, but unfortunately, the people involved in changing those ordinances were not open to change in that direction. So in our case, it is not possible to produce these products because they are categorized as "outside" of the Composting Ordinance. Therefore, we are not allowed to display or advertise it as a product called "compost". Moreover, they also made it clear to us that there would not be any change shortly.

#### **4.1.2.4 Prototype development**

##### *Possibilities*

In recent years, environmental awareness has been increasing, and also more and more people are willing to change from conventional and unsustainable products to new alternatives. This is one of the advantages that eco-innovation could take from developing new products. In the case of eco-toilets, the business is starting to grow in several countries not only for water efficiency but also due to the costs of being connected to a sewage system. Sometimes, in places outside of the main cities, the connection to the system might be costly or even not possible. Several initiatives are all over Europe and in other emerging economies where sanitation is sometimes a complex problem that might significantly affect the population's the interviewees mentioned:

"From the point of view of research, I think eco-toilets are interesting, and awareness is rising with these new initiatives. If there is enough information that the people can see, the awareness could be improved. It is interesting to see this as a different concept, and people also start to think about it."

### *Challenges*

One of the main conclusions identified from the workshop was the lack of participation from private investors in Austria with eco-innovation projects due to the possible risks related to prototypes. Due to this, similar initiatives might be highly dependent on public funding in the first stages of a product or system. Additionally, the testing phase of prototypes can be considered expensive and will require much follow up work due to all the factors that can affect the product. The risk of the product not being able to work correctly and deliver the needed results is a risk not many investors or customers are willing to take. One of the members from the öKlo composting toilet also mentions that the current wastewater system is also not ready for these projects. He states the following:

"In general, in the production of the toilets and the services there is no issue or challenges. But we still have a lot of waste produced that a specific waste treater is helping us to collect them and treat them in a safe and legal way. It is always difficult for them go get rid of the human waste. These stakeholders are limited by our collection of the biomass. We can offer people from Vienna to collect the waste and then give them to the treating company but for people from outside or far away from Vienna we cannot offer the collection system".

There is also the taboo subject of toilets in general, and there might not be so much willingness to change the regular "water closet" design. Despite the idea of diverting toilets and so many benefits from the separation of human waste, it is still a challenging idea to be sold to users and public authorities in the case of public toilets. One of the leading developers of the LooPi urinal states the following:

"Toilets are a taboo subject. Toilets are still perceived as "Disposal units, "and not "Collection-Treatment/Resource-Recovery units". I guess that is why there are only little to zero innovation drivers concerning toilets. For the same reason, toilets are not easy to "sell" to politicians/voters, investors, and others".

## **4.1.2.5 Implementation and market planning**

### *Possibilities*

The general increasing awareness of environmental concerns all over Europe is one of the main drivers for eco-innovation projects to become a reality and have a successful implementation. Several initiatives and programs enhancing sustainable projects are emerging in most of the countries of Europe and creating "green jobs" by implementing new technologies and more efficient and clean systems. Essential aspects such as shortages of resources, the climate change effects such as droughts and the increase in food demand from agriculture businesses are some of the main factors that could improve products such as eco-toilets in addition to some of the multiple benefits they provide.

The continuous increase in population, mainly in cities, is causing wastewater systems to start getting saturated. Water shortages due to the increasing demand can also be an important factor in considering alternatives to conventional toilets. As cities continue to increase, sanitation becomes a social interest and is even considered part of the SDGs. Also, with the outbreak of the COVID-19 pandemic, the citizens have noticed the importance of available toilets for proper hygiene. There are still many public areas that need the availability of toilets. They should be part of the priorities of the public authorities for supporting healthy sanitation options for citizens. One of the alchemia nova collaborators mentions:

"With LooPi there is also the important fact that there are still missing a lot of public toilets in cities and municipalities, and citizens are noticing it, but for the cities, they represent only more costs. Therefore, LooPi might become an interesting idea since it is a very different toilet compared to the rest of the toilets in the market due to being an innovation, having green elements such as plants and the idea of a sustainable product."

The price is usually a significant factor in public authorities' decisions for implementing some of the eco-innovation projects for their processes. Of course, the prices of eco-toilets might vary depending on the product and the complexity of their systems, but usually, it would be not so different from a regular toilet. For the case of LooPi specifically, the following was mentioned by one of the interviewees:

"Usually, it can also represent a benefit for the politicians in showing environmental awareness and a different system for the citizens' use and somehow improve the social areas. People and politicians are more aware that implementing these solutions in the city is important and attractive. When costs are analyzed, LooPi's price might be similar to a regular public toilet in Vienna and some big cities, from around 200 000 or 300 000 euros, including several seats and urinals. The LooPi would need to add around 30 000 more for the plant filter wall. However, the big difference might be in the maintenance costs for the biochar and the inner systems. This cost difference is the one trying to be covered by some of the environmental benefits the system can provide".

### *Challenges*

One of the main challenges for eco-innovation related to water reuse might how difficult it is to try to change complex and mature systems such as the wastewater management system in a conservative country like Austria: As mentioned by one of the consulted actors in one of the interviews:

"There are still taboos around the use of toilets. Changing the implemented systems might be difficult in a country like Austria, which has optimized its processes into

really efficient ones. Although they are expensive to maintain, it is challenging to implement a different system when the actual one works correctly, and there is not an urgency in the resource of water ".

Two of the researchers from BOKU University support this argument with the following statements:

"Previous municipal monetary investments for wastewater management systems could have been miscalculated into designing costly systems that need to recover their value from the users. Due to this, also it might be a barrier from the same authorities on trying to implement these changes".

"From the implementation point, it is difficult to try to change the standard system since it is pretty convenient. The system is very convenient for the user and the municipalities since the sewage system is a very efficient transport system. If you want to do something else, you will need to develop a different transport system"

Different possibilities and challenges were identified from the interviewed subjects and from the workshop data. Table 4-2 summarizes the information previously mentioned:

*Table 4-2: Summary of the different possibilities and challenges for each of the stages of eco-toilets development in the Austrian context.*

<b>Stages of eco-toilets development</b>	<b>Possibilities</b>	<b>Challenges</b>
<b>Identifying a problem or a need</b>	Open market for innovation  Clear calls from organizations for new solutions	Cheap short-term solutions  Other priorities in political agenda
<b>Idea or project design</b>	Previous working networks  Innovation agencies support	Missing needed technologies  Funds might not apply for all organizations
<b>Funding and policy design</b>	Austrian government support with FFG  Several policies and agendas supporting eco-innovation	Complex process for modifying policies  Lack of clear responsibilities from public authorities
<b>Prototype development</b>	Business idea in several countries	Lack of private inversion  Expensive stage of testing
<b>Implementation and market planning</b>	Increased environmental concern  Public authorities support	Complexity of wastewater managements systems  Difficulty to change established systems

*Source: Actors interviews and workshop*

### 4.1.3 Inputs, activities, and outputs needed for closing the wastewater loop

From the research conducted in this study, as well as from the data collected in the workshop and interviews, it was noticed that there are missing inputs and actions needed for reaching the intended results. As a result, the different needed inputs, activities, and some of the desired outputs were captured in Table 4-3.

*Table 4-3: Inputs, activities and outputs related to technoeconomic, social and political factors for eco-toilets*

	<b>Techno-economic</b>	<b>Social</b>	<b>Political</b>
<b>Inputs</b>	Private and public investors  Replicable technology  Researchers  Eco- toilets designers	Actors networks  Research partners	Eco-innovation policies  CE compromised public authorities  Circular public procurement
<b>Activities</b>	Network creation between with other eco-innovators of toilets  Involvement of building constructors  Involvement with wastewater managers  Understanding the logistics and infrastructure of wastewater management  Benchmarking with private investors	Involving citizens  Contacting farmers  Benchmarking with other countries or cities  Involving NGOs	Establishing water reuse policies  Modification of fertilizers/composting policies  Incentives for private users for saving water
<b>Outputs</b>	Eco-toilets markets  Data supporting safe and efficient products	Strong social network  Sustainable supply chain (manufacturer-farmer)	Reduction in wastewater production  Reduction on water use

	<p>Several eco-toilet models</p> <p>Business model for eco-toilets</p> <p>Wastewater systems adapted to diverting toilets</p>		<p>from public/private toilets</p> <p>Increase in eco-toilets in the city and buildings</p>
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*Source: Actors interviews and workshop*

It was mentioned by the interview subjects that some of these inputs in the techno-economic, social and political dimensions are already in place or starting to work together for adopting eco-toilets into more spaces. However, eco-toilets are still not known or popular with general citizens since, as mentioned by some of the participants in the workshop, most of them do not understand why eco-toilets are beneficial or how they work.

As for the activities, there is still much to be done, especially in the techno-economic and political dimensions. Primarily, since the technology is still considered new, many of these products are still in a developing phase where different prototypes are being tested and adapted to different contexts. One of the collaborators from öKlo mentions the following:

“The business of producing, renting and selling toilets is working fine for at the moment, but the waste management area needs to be improved. When it comes to the treatment of the waste, it is still in progress and there is still more research needed. We need to generate more data that proves that the whole process is working and to integrate them to the whole system of renting and selling the toilets”.

Also, since most wastewater management systems, at least in the European context, have been tested for years and optimized for efficient performance, changing the current supply chain of wastewater is challenging. Additionally, for construction it is starting to become an interesting option, as mentioned by one of the designers from EOOS:

“The building sector is starting to be interested in diverting toilets, but that means a higher inversion of time and knowledge in developing the building map. Also, the company needs to make sure that it will not be a problem for the municipal permits or something similar or a problem for the customer when they decide to buy. Toilets are still a taboo in society, but with good designs, these changes should not be a problem for users.”

Finally, some of the outputs were identified by asking the participants which future actions they considered were needed and how they believed some of the current barriers could be overcome. By identifying these outputs for a proper transition into closing the wastewater loop, it could be easier for eco-innovators to trace a way to achieve these milestones for changing the current perception of eco-toilets.



## 5 Discussion

The following section will discuss the results obtained and link them with the previously stated research questions. Additionally, the stated theory selected for the framework will be analyzed to comprehend further how it can represent the path that eco-innovation could lead to the change for closing the loop of wastewater. Finally, the possible role in this path to change of eco-innovators will also be discussed, considering the previously mentioned concepts of circular intermediaries and boundary work.

### 5.1 The eco-innovation process

As shown in Figure 4-1, the eco-innovation process is formed by different stages that work together to implement a project successfully. The five identified stages (identifying a need, product design, funding and policy research, prototype development and implementation and market planning) have different characteristics and actors that might make some of them more complex. Completing each of the stages can also depend on how much research was done in the previous steps. As an example, properly researching the current policies and requirements in quality standards for wastewater reuse could allow beforehand to understand the expected characteristics of the desired product. Gathering this information before trying to sell a product could allow knowing some of the limitations of the business strategy in a specific context. As for the case of the design and prototype phases, thinking about market development, the product should bring something new to the market for it to be different from some of the competitors (Hojnik & Ruzzier, 2016). The organization must also consider the limits of operation the product can have and its target group. Also, if a barrier in one of the stages, such as the policy research, is not possible to overcome, the whole project could need to be redirected. One of the interviewed eco-innovators from Vienna mentions the following:

“Since we had no hope of changing the fertilizer policy for Austria, we are now researching the possibility of using our by-product as compost. This way, we could also get into the market a product derived from our process while some other changes are happening”.

*Joshua Skala, öKlo GmbH*

The possibility of eco-innovation projects to complete the process will allow these projects to achieve their primary goal, to provide new solutions to modern problems better than what is already available in the market. However, the development of these projects is not similar to conventional products and requires multiple factors to come together simultaneously for its development. As mentioned by one of the collaborators of *alchemia nova*:

“The complexity of some of our products results from the interaction of multiple knowledge gathered by the group of different professionals such as architects, engineers, chemists, and biologists that invest multiple hours researching and testing new systems. As a result, our products and technology do not advance as quickly as other products due to the number of factors that need to be tested and the high possibility that one of them could fail.”

The different actors identified in each stage have a different amount of power and influence for the projects to continue. Building solid networks between eco-innovators and other interested parts would also help the process be faster and easier to implement due to the

support of the different parts (Yarahmadi & Higgins, 2012). Even though it was not evaluated in this research, the support from the public is a critical factor for the last phase since they would be the final users (Hojnik & Ruzzier, 2016).

## 5.2 The role of eco-innovators in circular transition

Eco-innovators can be considered as the “spark that lights the fire”, as they are the ones that have researched and obtained the data to make sure the processes developed can work. This way, their initiatives, which might as well be guided by the concern of the public, NGO or even the authorities, are the ones that might be able to provide a solution for specific problems. Eco-innovators capacity to become “circular intermediaries” will allow them to form solid networks with academics and other important actors such as manufacturers or developers of specific technologies can be the ones that also provide the markets with new options (Barrie & Kanda, 2020).

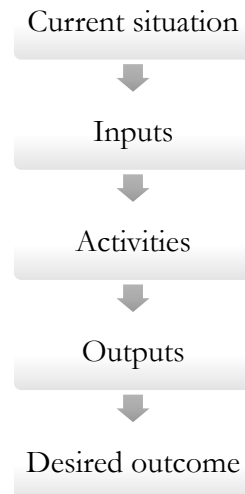
The proactivity of eco-innovators could determine how far their projects can reach out to the public since, in most cases, the world could continue working as usual without their initiatives. Additionally, since they are also the ones that could be receiving some profit or funding for their projects, they are also the ones with the main interest in their initiatives coming to reality. This way, they lead the creation of networks and possible supply chains to elaborate sustainable products that can offer a better option than what is already in the market.

The capacity to influence changes in the world might depend on the observed context. Significant changes from the standard systems we currently have might happen with the cooperation of multiple actors that might have the influence or power capacity for disruptive changes to occur Zietsma & Lawrence, 2010. The role of eco-innovators related to boundary work could be by creating solid networks with civil society, industry and public authorities. With significant support from the most relevant stakeholders, changes in policies and the influence in markets could happen.

Another role of eco-innovators related to boundary work is to provide reliable data on how these new systems can benefit society and the environment and even provide economic advantages. Although they provide essential solutions for some of the main problems society needs to deal with, support from citizens, industries, NGOs, and others is needed for their initiatives to become a reality.

## 5.3 Inputs, activities and outputs for wastewater and nutrient reuse

As mentioned in the introductory chapter, the Theory of Change provides a mental map for representing some of the inputs, activities, and outputs needed for changing from a situation into another desired outcome as reflected in Figure 5-1. The inputs could be considered as the required resources from any form that are needed; activities refer to the interventions or actions that need to take place to obtain a specific output, and the outputs are tangible results that work as evidence for claiming the desired outcome was achieved. (Mattos *et al.*, 2022).



*Figure 5-1 Visual representation of Theory of Change and its main components*

*Source: based on Mattos et. al., 2022*

By applying this theory to the Austrian context, this tool can facilitate the proper identification of some of the components that are still missing for eco-toilets to become a popular option for public authorities or even for private organizations interested in wastewater reuse. The main results from the analysis of policies and the results from the stakeholders' perspective, as mentioned in section 4.1.2, provide guidance on understanding some of the following steps needed for a project such as LooPi to further develop in a proper eco-business model.

In the following sections, the obtained outputs and their inputs and activities will be further discussed.

### **5.3.1 Techno-economic and political dimensions**

The techno-economic and political dimensions are highly related for the influence they have in one another. For markets to become a reality, the support from the required policies and the regulation from public authorities should also be in balance. The possibilities of developing the needed technologies for properly adapting wastewater systems with eco-toilets and the creation of a proper business model for these products. With these outputs in mind, the following topics will be further discussed:

#### **New business models for eco-toilets and nutrient recovery markets**

Despite the multiple benefits that eco-toilets could bring for the European Union to recover nutrients for agriculture, there is still much testing and data needed for these markets to become a reality. Moreover, data is still missing that can prove the needed quality standards for presenting their results to public authorities and boost the idea of the safe recovery of nutrients from human urine, and the needed market for it to become profitable is still missing (Cornel & Schaum, 2009; European Commission, 2013; Hukari *et. al.*, 2016). This might be the case in some European countries; however, other countries have already started developing these eco-toilets business models due to the necessity of an appropriate sanitation option different from central wastewater systems.

"An important part is, for example, in some African countries, they have created some business from these toilets, which can also generate different jobs for the local people. So additionally, to the business aspects, they also have improved conditions from previous options that could even cause health problems for the population."

*Bernhard Pucher- BOKU*

The creation of products from human waste is emerging in countries such as Sweden (Turlan, 2019) and other countries on the African and Asian continents (Wipo Green, 2014). These products do not only represent a solution for wastewater production but also solve agricultural needs. This way, possible business opportunities could be developed in a regulated context.

The importance of creating regulations that are in charge of maintaining healthy and safe standards needed for reintroducing these nutrients in activities such as agriculture are the ones that create and support the whole markets for consumers to trust these products (Hukari *et. al* 2016). Furthermore, different parts of the supply chain of nutrients for agriculture need to be involved in eco-innovation projects such as eco-toilets to close the loop of nutrients such as phosphorus, nitrogen, and other relevant nutrients found in human waste.

One of the researchers from BOKU University mentions the following:

"As long as we do not understand or want to understand how agriculture should work, the nutrient loop will still be a problem. We produce outside the city; we transport into the city, we consume; we go to the toilet, and it goes away. This is still problematic because this is becoming a need in the agricultural process. As long as we do not see the bigger picture, it is just difficult to argue for it". Additionally, the number of economic resources used in importing fertilizers is still not being considered. Situations such as the one currently with Russia and the dependence of Europe on some of their fertilizers make you wonder when countries will start to consider the importance of nutrient circularity at the local level".

Although it seems it is a very risky market to start to invest in, there are some other benefits that these types of products can offer. Looking from the perspective of social transformation and using the potential marketing and awareness strategy of selling CE products, these products could potentially increase their value for some markets searching for more sustainable options for their supply chain (Okem *et al.*, 2013). The possibility of introducing them to the market and their multiple benefits could be considered "premium". An example of this could be the SOIL compost in Haiti, that even produced compost with favourable prices that helped them maintain the operation (Moya *et al.*, 2019). However, the lack of these markets not only results in massive disposal of nutrients into water bodies with negative repercussions for the environmental balance, but it also disposes of approximately 50 million tonnes of fertilizer contained in the global wastewater (CGIAR, 2013).

Other strategies for engaging some of the participants of eco-innovation organizations have resulted from investor/innovator finance platforms that mainly connect interested stakeholders regarding specifically funding. These platforms even provide training for eco-innovators to prepare essential documents for the investors, such as business plans. This way, they can sell their ideas in a way that can more clients with the required data provided.

One of these platforms created as part of a Horizon 2020 project from the European Commission is Bioeconomy Ventures. This platform has eight partners working on different topics, and their main objective is *"To help start-ups and spin-offs to gain access to finance (CSA)"* (Bioeconomy Ventures, 2022). Another attractive platform is the one provided for Austria with BioBASE. BioBASE main goal is to connect the actors related to science and business to be on board with new projects and possible collaborations related to bioeconomy and circular economy. Currently, this platform has around 82 members from different areas related to bioeconomy businesses (BioBASE, 2022).

### **Wastewater management systems**

Wastewater management systems are a costly way of treating human waste. Despite many of these processes have been optimized for years and new solutions have been developed, the complexity of the process is still very high. The damaging or saturation of sanitation infrastructures in developing urban areas also serves as evidence that conventional approaches have missed in planning and service provision (McConville, 2010). Also, the maintenance of the wastewater plants represents a high cost to the city and would keep increasing with population growth. For selection of future sanitation systems, factors such as the technology selected and the context of the areas should be considered to allocate the required resources for maintenance and operation of the infrastructure (Starkl *et.al.* , 2013).

An interesting point of view given by one of the researchers from BOKU mentions the following regarding the benefit of having nutrient separation at the source:

"It also makes so much sense, from the water use perspective, the big difference in wastewater production produced by diverting toilets. There is an important difference between regular toilets that produce almost 130 liters of wastewater and the 60 to 80 liters of greywater produced by some of the lightly polluted eco-toilets. So, I would say that our existing wastewater treatment system is not sustainable. First, it is expensive since you are bringing one product such as the wastewater and then changing it into another problem, the sludge, and you somehow have to get rid of it."

The possible adaptation of these systems and their long-term solutions for the expansion of cities is an important factor that needs to be considered by the city planners and public authorities. For example, the possibility of implementing in new buildings solutions such as the LooPi or öKlo would not only reduce the use of water per day but would also the production of wastewater significantly that the city needs to treat. Understanding the whole sanitation system should start being studied beforehand in municipal planning and the selection of the most appropriate technologies to the context specific (Spuhler *et.al.*, 2018).

### **Public authorities support mechanisms**

The commitment of the public authorities and the availability of the needed networks for innovation to be successful might be key for further implementation of these initiatives for CE transition. The importance of the local governments and their possible actions in driving change is something that could make a difference from one context to another. Despite it could be considered that much work is still pending from the public authorities, the support from their part and the priorities in some of the agendas regarding environmental topics is considerably increasing. As mentioned by the District Mayor Markus Rumerharts of District 6:

The “Klima Energie Fonds” provides financial support – both for research and production – of different sustainable projects all throughout Austria. A big priority for “Klima Energie Fonds” is to support local corporations in their efforts to engineer sustainable technologies which will enable them to compete on the global market. Since 2007, the “Klima Energie Fonds” has put almost 2 billion Euros of grants into different projects”.

From the documents reviewed in the research, it is noticeable that efforts from the authorities in including incentives and providing the financial support needed for eco-innovation projects and also CE initiatives is ongoing. Additional responsibility is assigned to the authorities as some of the projects from the European Commission are focusing more and more in CE and sustainable development and their expectations of results are increasing with the passing years due to the climate emergency.

Green Public Procurement and circular procurement can also be considered as important factors in the eco-innovation success in public services or products (European Commission, 2016; European Commission 2017). These two concepts could become important strategies for adopting eco-innovation initiatives in the public sector if the projects can adapt to the requirements stated in the policies that regulate them. The development of projects that can be implemented in different contexts and can adapt to different conditions could allow public authorities to adopt them if they could have enough evidence that they are better than the standard options in the market.

The amount of trust in eco-innovation is another aspect that challenges its implementation. Accepting the risks related to it might only be done by some pioneer countries willing to implement these disruptive solutions and change the standard products and methods used in the past. Most countries have conservative approaches to implementing public services and observe how some countries that experiment with new solutions perform. The resistance to use products derived from human waste could also be overcome with the backup support from policy. Public authorities could act as a driver for supporting these new business models related to products derived from wastewater (Mallory *et. al.*, 2020). Despite globally it might be more difficult due to the health standards, local support to some of the initiatives could open the door for market development inside the country.

Another critical barrier identified from the investigation is the gaps in the current policies related to the public authorities' responsibility as noted by the workshop participants. It might need the coordination of different departments or public offices to obtain the required permits for the product or system to be implemented. As one of the Loopi's designers mentioned:

“It might become very frustrating for eco-innovators to consult in different offices and be redirected multiple times without a clear answer about the requirements needed for being able to sell a new product developed from an eco-innovation initiative.”

Trends can also influence policies and funding availability. In the case of Europe, it can be considered that the trendiest topic is in the recent years focused on energy. Most countries are interested in investing in innovation related to energy technologies due to the current high energy need for industry development. Due to this, some other topics such as water or nutrient reuse might be left aside. Another political aspect can be that governmental parties

change from time to time, and their opinions about specific topics can change, affecting some of the previous decisions or directions from previous periods.

### **5.3.2 Social dimension**

#### **Increasing concern in society and public authorities**

The increasing concern related to environmental challenges is reaching multiple sectors of society. Although not all countries are suffering the consequences of climate change yet, social media and research are providing every day about new evidence about how our world is changing and how much damage human activities are causing to nature (Holzinger *et.al.*, 2008). As a result, sustainable development, circular economy and more terms related to resource conservation are becoming more present in citizens' daily life. Some of the ones mentioned, especially for the case of Austria and Vienna by the interviewed actors, are the following:

“The topic is addressed in the Mission 2030 Strategy Plan of Vienna. Neue Stelle stadt Wien Also, a separate department was founded in October 2021 Archivmeldung: Wien bestellt Bereichsleiter für Klimaangelegenheiten - Presse-Service“.

“Several eco-innovation policies and strategies are being developed lately. In my perception, some institutions and people are quite motivated (MA22 Jürgen Preiss Jürgen Preiss - bauinformation.com, Anna-Vera Deinhammer DTCC30 - Mitglieder des Kernteams (wien.gv.at) with strong movements from the civil society (e.g., Andreas Gugumuck at Zukunftshof Zukunftshof — gelebte Utopien) and science community (e.g., alchemia-nova and others)”.

As a result, stakeholders like public institutions, civil society, and non-governmental organizations are getting more involved in environmental projects and initiatives. The urge of action is coming to most of the institutions in government and is closer to civilians in part also from the media and the knowledge developed by academia and research institutions.

#### **Societal networks strengthening**

The participation of an increasing number of organizations interested in developing eco-innovation projects is helping the available networks to improve and grow. Although it has been identified that many of the innovation organizations in Austria seem to be disconnected one from another, recent initiatives such as workshops, innovation hubs and other strategies are becoming more common in the past years. Additional communication channels for eco-toilets, such as Toilet Day and Mission Innovation Austria, were mentioned by the stakeholders in the workshop related to LooPi.

"Usually, the same organizations that provide the innovation fundings try to involve the organizations in networks, workshops and trying that research organizations meet some of the private investors that could be interested in their products. Also, there are some start-up "kicks" in which we have tried to be active."

*Heinz Gattringer- alchemia nova*

Even though many people consider being sustainable a "trend" given the increasing number of "greenwashing" that occurs worldwide, this should not minimize actions and efforts done by society to change habits (Kopnina, 2018). Having a society compromised with eco-

innovation and willing to welcome new beneficial products for the planet should not be taken for granted.



## **6 Conclusions**

### **6.1 Main findings**

The relevance of CE in the latest years in the EU has driven the creation of a series of policies, programs and incentives searching for changes in the current systems. Significant support for the development of new ways of performing human activities and the efficient use of the resources available in nature seem to have priority in most of the agendas in Europe. Ideally, it would continue evolving in the same direction, hopefully before time runs out. Closing critical loops such as the one derived from waste produced in our everyday lives could benefit society and the environment in multiple ways. However, it is a challenging change that requires efforts from many different actors and, in general, from our society's behavior.

Eco-innovation is considered an important mechanism to reach the needed changes for CE faster and support the systems to perform the same or even better. It represents a major opportunity for the development of industry and society at the European level and worldwide. The impact it has on the economy for resource efficiency and job creation is one of the critical aspects of its relevance. Its capacity to create new markets and business models should be a strong driver for providing the needed tools for further development. The successful creation of new products and markets derived from eco-innovation could also facilitate the transition for CE in the wastewater mainstream by providing safe and improved solutions for the problem it represents.

Understanding the different stages, the actors present in each of them, and the main barriers present, could make the process easier to follow and allow more and more organizations to join in developing this type of innovation. By remarking the multiple benefits in the society, economy, and environment from eco-toilets, they could be further implemented in more spaces and become the trend instead of the exception. The possible benefits for users, farmers, technology developers, and several actors are still to be discovered by replicating these initiatives in more places around the world.

The Theory of Change model obtained from the results of this investigation also allows visualization of an integral model in the techno-economic, social and political dimensions. Identifying some of the needed inputs and activities that lead to specific outputs could trace a roadmap of actions that could lead to closing the wastewater loop for the Austrian context. The intended outcome of nutrient and water circularity could become a reality by creating the needed markets, networks, infrastructure, supply chain, and policies for supporting and regulating wastewater reuse.

As mentioned previously, eco-innovators also have an important role in taking part in the force rooting for changes. As discussed in the previous section related to boundary work, their capacity to influence and work towards changing current conditions is a particular characteristic driven by their motivation for their projects to be further developed. Moreover, their role as circular intermediaries is connected to their ability to create strong bonds between the actors and stakeholders that are part of the process.

As for the case of Austria, there is a clear commitment from the public authorities on financial supporting for eco-innovation and providing aid for eco-innovators to grow by

enabling channels and networks through several strategies and programs. Despite some of the private investors and policies still being reached or adapted, knowing the possibilities and challenges allows the organizations to understand where they should root for change in searching for new doors to open.

Finally, eco-toilets represent an emerging market (found in different countries worldwide) that tries to solve a significant problem in human life. The relevance of wastewater production and the efficient use of a precious resource such as water should become a higher priority on the agenda of city planners by analyzing how much resources (water and economic resources) could be saved. It is a fact that changing the existing systems, such as infrastructure and policy framework, can be challenging, but the change needs to start somewhere.

## **6.2 Recommendations for future research**

Since eco-toilets have gained popularity and the CE innovation wave is getting worldwide, contacting some of the other eco-innovators related to the topic might be very helpful for a deeper understanding of the topic. Their perspective and experiences in the different contexts would be an important insight in identifying the needed inputs, activities and outputs for eco-toilets to become a reality in different scenarios. Furthermore, comparing different contexts and talking with stakeholders based in different countries would also be necessary for organizations like *alchemia nova* and *öKlo* to understand some of the steps needed for expanding their businesses.

In the case of the actors involved in the research, for further investigation related to the topic, it would be interesting to have the approach citizens and more public authorities representatives regarding how possible is to implement these initiatives on a small and larger scale. Also, to understand their willingness or main doubts related to changing from a regular toilet to an eco-toilet. This way, adding their perspective will allow organizations to consider these factors in future initiatives.

It should also be mentioned that the LooPi is still being tested and the first prototype was just created in 2021. The possible changes and modifications that it might need would also bring new research needed and additional actors for strengthening their network. This way, in a nearby future, it could be an option for users that wish to collaborate in closing the loop of wastewater and the multiple benefits for the economy, society and the environment.

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## Appendix I: Actors Identification Matrix

Stakeholder category	Potential role in eco-innovation	Organization
Eco-innovators	Project developers	öKlo
Eco-innovators	Project developers	alchemia-nova
Private organizations	Designers	EOOS
Academia	Researchers	BOKU
Innovation promotor	Promotors/funding	GRÜNSTATTTGRAU
Public authorities	Promotors/funding	Ministry of Climate Action, Environment, Energy, Mobility, Innovation and Technology

## Appendix II: Assistants to LooPi Workshop in Vienna

Name	Organization	Category
Tiziana Centofanti	alchemia-nova	Eco-innovator
Johannes Kisser	alchemia-nova	Eco-innovator
Heinz Gattringer	alchemia-nova	Eco-innovator
Olivier Duboc	BOKU	Academia
Julia Edlinger	alchemia-nova	Eco-innovator
Theresa Heitzholfer	WWF/alchemia nova	NGO

## **Appendix III: Interview Subjects**

<b>Name</b>	<b>Organization</b>	<b>Category</b>	<b>Date and place of the interview</b>
Joschua Skala	öklo GmbH	Eco-innovator	6/4/2022 in Zoom
Bernhard Pucher	BOKU	Researcher	13/4/2022 in Zoom
Lotte Kristoferitsch	EOOS	Designers	13/4/2022 in Zoom
Theresa Heitzholfer	alchemia nova/Austrian Fund	Researcher	Email questionnaire
Olivier Duboc	BOKU	Researcher	22/4/2022 in Zoom
Heinz Gattringer	alchemia nova	Eco-innovator	22/4/2022 in Zoom
Markus Rumelhart	District Mayor of District 6	Public authorities	Email questionnaire
Susanne Formanek	GRÜNSTATTGRAU	Innovation promotor	Email questionnaire
Irene Zluwa	GRÜNSTATTGRAU	Innovation promotor	Email questionnaire
Francesco Menconi	alchemia nova	Eco-innovator	4/5/2022 in Zoom

## **Annex IV: Interview protocols**

1. Can describe your main role in the organization you represent?
2. Have you been involved in any initiative related to eco-innovation and the transition to circular economy in Austria?
3. How would you rate the involvement of the government of Austria/Vienna regarding the Circular Economy Plan?
4. How related are you with the concept of eco-innovation? If yes, how would you defined it?
5. Are you currently involved in some projects related to any of the previous topics mentioned?
6. Are you aware of any program from the government that involves circular economy approaches in Austria/Vienna? If yes, can you mention your experience or knowledge of them?

7. Are you related to sustainable toilets and their benefits? If yes, how?
8. Are you aware of any possible challenges for implementing circular economy projects in Austria/Vienna?

**For eco-innovators:**

1. Can describe your main role in the organization you represent?
2. Have you been involved in any initiative related to eco-innovation and the transition to circular economy in Austria?
3. How would you rate the involvement of the government of Austria/Vienna regarding the Circular Economy Plan?
4. Are you aware of any program from the government that involves circular economy approaches in Austria/Vienna? If yes, can you mention your experience or knowledge of them?
5. Which are some of the main barriers for the further development of the project?
6. Which are some of the actors that currently support the project?
7. Which are some of the actors that are currently missing? What is the organization doing to also engage them?
8. Which stage would you say the project is currently?