urban WAste and water Treatment Emission Reduction by utilizing CO_2 for the PROduction Of Formate derived chemicals

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Publishable executive summary

The objective of the WaterProof project is to develop technology suitable for the electrochemical conversion of CO_2 emissions from waste incineration and wastewater treatment facilities into formic acid. The formic acid can be applied in different consumer products, such as cleaning detergents and fish leather. By-products from the carbon dioxide (CO_2) conversion processes, like peroxides can be used in the wastewater treatment system for the removal of pharmaceuticals and pesticides from wastewater. Further, the project aims to generate Acidic Deep Eutectic Solvents for the recovery of metals from wastewater sludge and incineration ashes. Renewable energy can be used for the electrochemical CO_2 conversion process. Overall project objectives include the contribution to the replacement of fossil resources with renewable resources, to climate neutrality and to circular economy.

Next to technological innovation, a socio-technical approach is adopted in the project to give insights into the social perception of the WaterProof concept. One research aim is to assess perspectives of local and regional stakeholders towards the WaterProof technology and its implementation at waste and wastewater treatment sites. To this aim an interview-based stakeholder analysis was conducted. The resulting stakeholder map, a description of the roles of various stakeholder groups and information on the perception of informational needs, drivers and challenges by stakeholders with regard to the WaterProof technology are included in this report (D4.2). Next to local and regional perspectives on technology implementation at treatment sites, the consumer perspective on product applications for CO_2-derived formic acid is assessed. Literature, interviews and a pre-study survey give first insights into this perspective and are included in D4.2. Additionally, a standardized online questionnaire was developed and an online study was set up in the Netherlands and Germany to further study the consumers' view on CO_2-derived cleaning products. The report D4.2 describes the method and survey for the online study.

Stakeholder interviews revealed perceived benefits of and drivers for the WaterProof approach, as well as informational needs and challenges for its implementation. For instance, stakeholder views related to the perceived fit of the technology with the existing waste and water treatment infrastructures and with future visions for waste and water treatment. Further, the view of the stakeholders concerned the processes design, social,

economic and environmental impacts, perceived risks and trust (e.g. towards technology developers and safety regulations).

Interviews that focused on the consumer perspective and a pre-study survey on product perception showed that participants are rather open towards the CO_2-derived products (e.g. cleaning products) despite current low knowledge levels. Interviewees stated that judging and comparing product sustainability could be a challenge for consumers. Further, product safety is brought up as a relevant purchase condition by consumers. Nevertheless, results from the pre-study give a first indication that CO_2-derived cleaning products are not perceived as particularly risky. Regarding communication research results show a wish for clear and understandable information on CO_2 conversion processes related to products. Future research activities in task 4.2.1 will be to analyse the results of the online consumer survey in order to complement first insights from consumer interviews and pre-study.

Recommendations for communication and stakeholder engagement highlight the importance of connecting with existing stakeholder networks and to include current topics that are prevalent in the waste and wastewater treatment context as well as in the context of circular economy and industrial-urban symbiosis. Moreover, a holistic approach should be adopted, including stakeholders along the entire value chain and taking into account stakeholder-specific needs and perceptions. Engagement should be viewed as a process with engagement opportunities in different phases.

Results from the online consumer survey as well as the ongoing exchange with and between relevant stakeholders in the scope of the WaterProof project will further deepen the understanding of the views and needs of relevant local stakeholders and consumers. Interview results and recommendations for communication and stakeholder engagement that are presented in this report can be used in further project activities. For instance, the recommendations can be taken into account in activities that aim to facilitate exchange between relevant stakeholders around the topic of industrial-urban symbiosis which will be described in the upcoming report "Good practice concept for stakeholder engagement in IU-S" (D3.5). Local drivers, barriers and discussions that interviewed stakeholders associate with projects like the WaterProof project indicate questions suitable to be discussed with regard to the wider aim of industrial-urban symbiosis. The results give an overview of subjects for knowledge exchange between stakeholders.

1 Introduction

The "Report on qualitative societal research – data collection and consumer insights" is a deliverable as part of the WaterProof project (urban WAste and water Treatment Emission Reduction by utilizing CO_2 for the PROduction Of Formate derived chemicals), which receives funding from the Horizon Europe framework programme. The goal in the WaterProof project is to develop electrochemical processes for the conversion of carbon dioxide (CO_2) from waste incineration and wastewater treatment facilities into formic acid (FA). The formic acid plays a role in the production of consumer cleaning products and in leather tanning (e.g. fish leather). Another application is the transformation into Acidic Deep Eutectic Solvents (ADES) relevant for the recovery of metals from incineration ash. Furthermore, peroxides, which are by-products of the CO_2 conversion can be used in the wastewater treatment (in the purification of wastewater from pesticides, antibiotics and pharmaceuticals). An overall aim of the project is to close the waste(water) carbon loop and to support the transition from fossil to renewable carbon sources, towards climate-neutrality and circular economy (CE).

Next to technical innovations the interdisciplinary project incorporates a social science perspective on the WaterProof concept. Research activities in task 4.2.1 "Social perception and acceptance" follow a socio-technical approach by assessing how the WaterProof technology and products link to the social context. The report describes the research methods and the current status of results related to task 4.2.1. The research on technology perception and acceptance is based on two main points of reference relating to different steps in the process chain (from CO_2 capture and conversion to the use of formic acid in products).

The first point of reference concerns the site-specific factors on a local or regional level. Here the analysis focuses on the views of relevant local and regional stakeholders on the pilot installation of the WaterProof technology and waste and wastewater treatment sites at Amsterdam and Alkmaar. Analyzing the local social context of a specific technology installation requires the identification of relevant local stakeholders and their views on this technology. Examples of research questions are:

- Which local (and regional) organizations, groups and authorities are relevant with regard to the specific technology and which roles do they have?
- Which topics do these stakeholders associate with waste and wastewater facilities (e.g. goals, challenges and trends)?

- Which questions do they have about the WaterProof technology?
- Which costs and benefits do they relate to the technology and which drivers and barriers do they perceive for the implementation of the technology?

The report addresses these questions by presenting the results of a stakeholder analysis and by describing the stakeholders' view on the WaterProof technology. The analysis includes a stakeholder map, visualizing stakeholder clusters in relation to the WaterProof process chain. The stakeholders' expertise on relevant stakeholder groups and the local network was incorporated into the analysis by conducting stakeholder interviews. One advantage of using interviews in the research method was that stakeholders could bring up relevant stakeholders and subjects that they find important with regard to the WaterProof technology.

The second point of reference is the application of formic acid from WaterProof processes in consumer products. Here, the research focused on the consumers' perspective on the product applications (e.g. for leather tanning and cleaning products). Related research activities are conducted in different countries, such as the Netherlands and Germany. Questions that are assessed are for instance:

- What do consumers know about and what do they associate with the utilization of CO_2 from waste and wastewater?
- Which priorities do they have when choosing products, like cleaning products?
- Which expectations do consumers have towards a product in which CO_2-based formic acid is applied?
- What is the level of acceptance with regard to the products?

The report provides first insights into the consumer perspective, based on interviews, a pre-study survey and relevant literature. Additionally, a standardized questionnaire is described, which was developed in the scope of task 4.2.1 and used to set up an online study on the consumer perspective.

The aim of this deliverable is to provide knowledge about relevant factors for social perception with regard to the different refence points in the WaterProof value chain and to provide recommendations for further communication and stakeholder engagement.

2 Stakeholder analysis

2.1 Focus, approach and aim of stakeholder analysis

2.1.1 WaterProof approach at the centre of the stakeholder analysis

At the heart of stakeholder analysis is a subject, which can be a social or natural phenomenon (Reed, et. al., 2009). In this case the WaterProof approach is at the centre of the stakeholder analysis: the utilization of CO_2 from urban waste and water treatment for the production of renewable formic acid. Included in the approach is the use of formic acid for cleaning products, fish leather tanning and ADES (for metal recovery), as well as the use of peroxides in wastewater purification.

2.1.2 Approach and aim of stakeholder analysis

In the analysis stakeholders, such as individuals, groups or organizations, can be identified, clustered into groups and their relationships can be assessed (Reed, et. al., 2009). The identification of stakeholders can be done on the basis of how or whether they are affected by a subject or how they can affect the subject themselves. The stakeholder analysis and identification of relevant actors can be used to prioritise or involve actors in decision-making processes (Reed, et. al., 2009). More precisely, stakeholder analysis can serve as a basis for stakeholder engagement with the aim of gathering ideas, exploring interests, solving conflicts and jointly designing a task (Nanz, & Fritsche, 2012). Further, knowledge about specific stakeholder perceptions, including needs, concerns, wishes and priorities can be helpful in considering procedural and distributional justice criteria for the development of technologies and for planning technology implementation. This is important because the extent to which technology development or implementation and related decisions are perceived as fair is viewed as one of the relevant factors for technology acceptability (Huijts, et. al., 2012; Wolsink, 2007). In the scope of the WaterProof project, such a process could have the aim to foster exchange between relevant local stakeholders. Another aim could be to discuss aspects that should be taken into account in the further implantation of the WaterProof technology and to support Industrial-Urban Symbiosis (I-US).

2.2 Stakeholder analysis method

Which methods are used for stakeholder analysis depends on the goal or scope of analysis (Reed, et. al., 2009). Stakeholders can be actively involved in the process of the stakeholder analysis, which can be iterative. One example of a method in this kind of

process is snow-ball sampling, in which stakeholders from identified stakeholder groups are interviewed, interviewees add information to the analysis and thus advance the stakeholder categories further (Reed, et. al., 2009). This method was used in this stakeholder analysis. Initially stakeholder groups were identified on the basis of experience in the consortium and literature. Attention was paid to covering stakeholder groups along the entire chain of the WaterProof approach, ranging from the capture of CO_2 at waste and wastewater treatment plants to its transformation into formic acid and (consumer) products. Individuals from these stakeholder groups were contacted and interviewed in semi-structured guideline-interviews. In an iterative process stakeholders were added to the stakeholder map on the basis of previous interviews and invited to an interview. In the analysis the focus lies on local and regional stakeholders in the area of the WaterProof pilot locations in Amsterdam and Alkmaar. More information on the interviews and related methods are included in section 3.1.2 "Interviews and analysis".

2.3 Visualization of stakeholder map

Stakeholder groups initially identified and stakeholders that were mentioned as relevant stakeholders in the interviews were visualized in the stakeholder map.

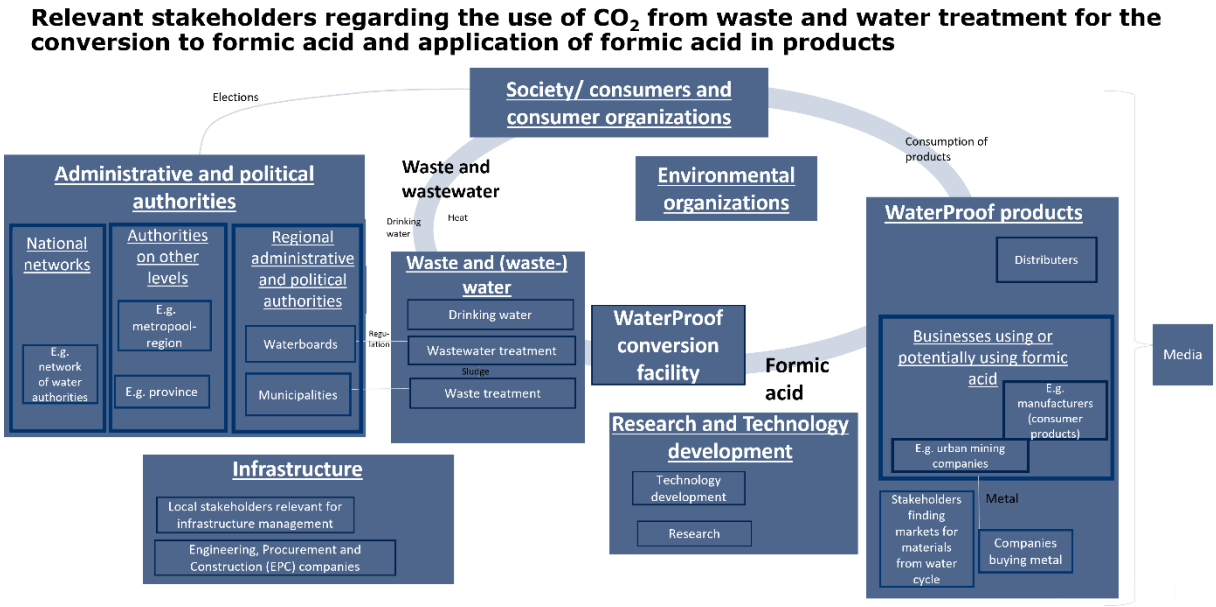

Figure 1: Stakeholder map

2.4 Description of stakeholder groups

Stakeholders in the waste and water sector

Stakeholders in the waste and water sector are relevant with regard to the WaterProof approach in several ways. Captured CO_2 from waste and waste water treatment can be

used in the WaterProof process by converting it to formic acid with electrochemistry. Thus, stakeholders in the waste and wastewater sector can provide the relevant input for the process. Additionally, they can also serve as sites for the WaterProof technology. Therefore, the conversion process can physically be implemented on waste and wastewater treatment sites. Furthermore, stakeholders in the water sector have an additional role as by-products from the WaterProof process can be used in the treatment process (e.g. in the purification of wastewater from pesticides, antibiotics and pharmaceuticals).

Administrative and political authorities

Administrative and political authorities are relevant as they shape the contextual frame in which circular approaches, such as the WaterProof approach can be implemented. These authorities exist on different levels. As the focus of this analysis lies on local and regional stakeholders, local and regional authorities are especially relevant. These can include municipalities as well as waterboards, the metropolitan area and the province. Additional relevant stakeholders for the WaterProof approach are networks of authorities focusing on circularity topics, e.g. in the waste and water sector.

Infrastructural stakeholders

Infrastructural stakeholders can serve as hubs for circular projects and can foster symbiosis of various companies. Additionally, they have expertise in infrastructural questions, such as questions related to the transport of materials etc. and questions related to the need of space etc.. This stakeholder group includes for instance ports and Engineering, Procurement and Construction (EPC) companies.

Stakeholders in research and technology development

Stakeholders in research and technology development are relevant because they can bring approaches, such as the WaterProof approach forward by providing and piloting relevant innovations, such as new technologies. These stakeholders can provide the relevant expertise to inspire new ideas through innovations and to further improve the environmental, social and economic benefits of these innovations.

Stakeholders related to WaterProof products

Producers of consumer products are relevant as they have the possibility to include formate derived chemicals in production. Distributers of consumer products have an influence on the selection of products that will be available in the store.

Media

The media, e.g. local newsletters, have the possibility to report on projects in the field of Carbon Capture and Utilization (CCU), such as the WaterProof project. How they depict subjects related to CCU can shape public perception of these projects. Thus, media

stakeholders, such as local newsletters can be seen as relevant stakeholders in the WaterProof project.

Environmental organisations

Environmental organisations can draw public and political attention to environmental goals and subjects, such as emission reduction and resource efficiency. Therefore, their perspective is relevant with regard to approaches, such as the WaterProof approach.

The public / consumers and consumer organizations

Consumers are a relevant stakeholder group because they potentially buy and use CO_2 derived consumer products. Therefore, their perception and acceptance of these products matters.

Existing networks

Characterizing the existing stakeholder network, for instance in terms of its structure, can be useful for the development of a suitable stakeholder engagement strategy. The structure in a stakeholder network can be rather organized around a coordinating hub or rather self-organized (Kaipainen, et al., 2023).

3 Stakeholder interviews

In the scope of the WaterProof project the perspective of the different relevant stakeholder groups on the WaterProof approach and related topics were assessed.

3.1 Method for stakeholder interviews

3.1.1 Interview guide

An interview guide was created which contained questions on the perception of the existing waste and water treatment system, of the WaterProof technology and of related products. More specifically, the interviewees were asked about goals, challenges and trends in waste and water treatment.

Additionally, interviewees were asked which potential impacts of the WaterProof technology they expect and which drivers and barriers they see with regard to implementation. Interviewees were also asked about their perception of product applications. The interview guide was adapted to fit the specific stakeholder groups.

3.1.2 Interviews and analysis

16 stakeholder interviews that were conducted in task 4.2.1 were recorded and transcribed. The interviewed actors include the following groups: waste treatment sector, wastewater treatment sector, drinking water treatment sector, administrative and political authorities, infrastructural stakeholders, research organizations, technology development, stakeholders related to finding markets for residues, environmental organizations, distributers of consumer products and consumers. The interviews were conducted between February 2023 and July 2024. The duration of most interviews was between 40 and 60 minutes. Three interviews were 30 to 40 minutes and one interview was slightly above 70 minutes. Twelve of the interviews focused on the perception of the WaterProof concept and four interviews focused more on CO_2-derived consumer products. The language of the interviews was English. The list of interviews consists of interviews with one interviewee and group-interviews in which up to three people were interviewed in a group. The interview transcripts were analysed with the qualitative data analysis software MAXQDA. Codes were assigned to different parts of the interviews and clustered in categories.

3.2 Stakeholder perception of WaterProof context

3.2.1 Introduction to the WaterProof context

An overview of subjects from the stakeholder interviews is shown in figure 2. The stakeholders' views on the existing waste and water system and related infrastructure, were assessed. This infrastructure is relevant as the treatment facilities provide the CO_2 source for the WaterProof processes. Moreover, WaterProof (by-)products (ADES and peroxides) can be applied in these sectors. More information on WaterProof processes and products can be found in section 1 "Introduction".

Further, views on topics related to circular economy and sustainability of consumer products were examined. One of the overall aims of the WaterProof project is to contribute to a circular economy by supporting circular processes and using recovered resources for products. Related to the topic of circular economy is industrial symbiosis as an approach to reach CE goals, placing emphasis on stakeholder networks (Batten, 2009; Domenech, et al., 2019). The topic of sustainability and circularity of consumer products is relevant as WaterProof aims to provide renewable feedstock for product ingredients.

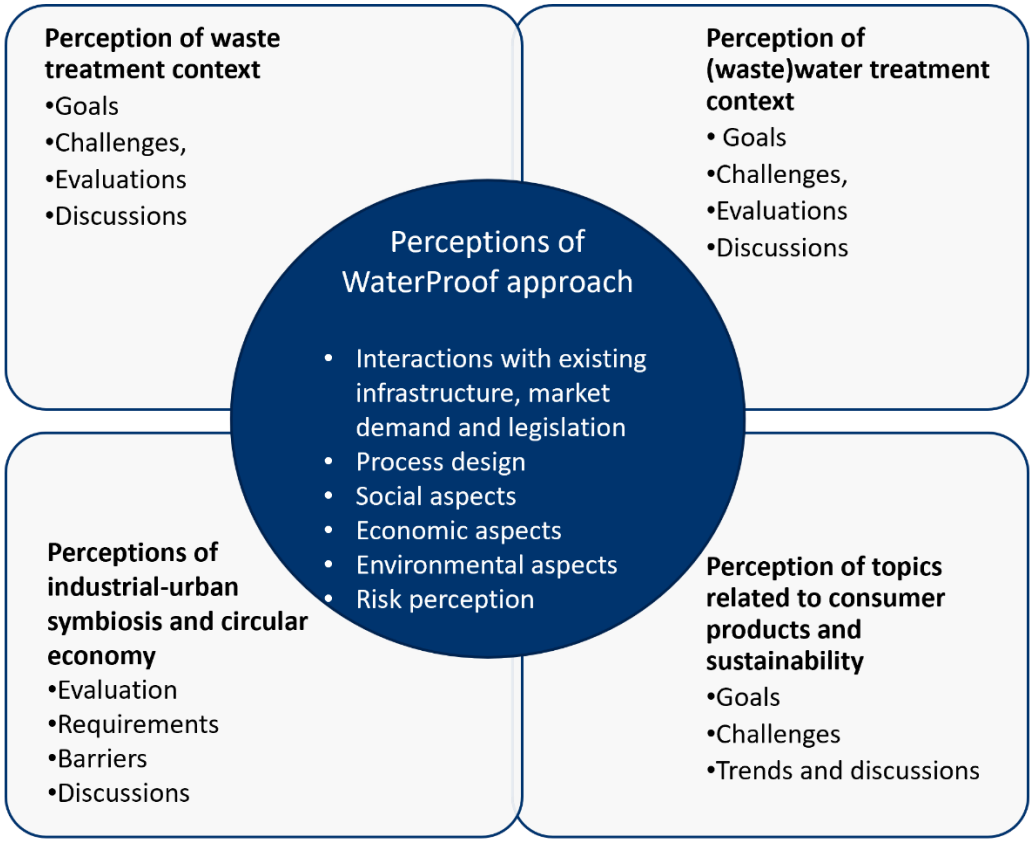

Figure 2: Framework for assessing stakeholders' perceptions of WaterProof approach

3.2.2 Perception of waste treatment system and infrastructure

***Challenges in waste treatment**:*

Challenges that interviewees perceived regarding waste treatment facilities were related to environmental topics, such as recycling and dealing with pollutants, as well as challenges regarding regulation, such as the permitting process for plants.

***Goals with regard to waste treatment**:*

Interviewees were asked about their hopes and goals for waste treatment. A frequently mentioned wish was that waste incineration will decrease in the future (e.g. by reducing waste or preventing waste from being incinerated with waste separation). Reducing waste incineration was also perceived as a political goal. Further, the analysis reveals the goal of resource retrieval from waste. Interviewees hope that uses for CO_2 from waste treatment can be found. The term circular carbon was used when referring to waste treatment goals. According to the interviewees, the aim is to keep carbon in the system. Further, goals that were expressed in the interviews, were to improve the retrieval of materials from ash and producing more energy from waste.

***Perception and evaluation of waste treatment**:*

From the interviews it becomes clear that the perceived necessity of treating waste is high. At the same time interviewees see potential to optimize processes in treatment plants. Interviewees refer to negative environmental impacts, such as the loss of valuable materials that are not recovered. Heat production from waste treatment was associated with positive impacts by some interviewees and evaluated critically by others. While some perceive heat production as an added value, others see a possibility of a lock-in effect in which the demand for heat supports the continuation of waste incineration or stands in the way of waste reduction. When evaluating waste treatment in the Netherlands, however it was mentioned that it is perceived positively in comparison to waste treatment in other countries. It becomes clear from the interview results that waste incineration is perceived negatively and that it is seen as a solution for waste that cannot be recycled by some interviewees. Additionally, it was mentioned that the amount of waste that is being produced is too high in general.

Discussions related to waste treatment

Topics of discussion were identified from the interview results. These topics included the question to what extent and for how long waste incineration should be continued in the future and the discussion on the benefits and doubts related to heat production.

3.2.3 Perception of water treatment system and infrastructure

Challenges in water treatment

The challenges that interviewees perceive in water treatment range from environmental goals (e.g. better water quality, more circularity and energy efficiency) to financial, logistical and infrastructural conditions.

Water pollution and related impacts on surface water quality were seen as adding to water treatment challenges. Interviewees mentioned the challenge of fulfilling regulations regarding further cleaning steps and of finding solutions for water pollution. Another present topic was the transition towards circular water treatment plants. For instance, it is perceived as difficult to have complete information for material flow analysis. Further, the dependence on contractors and their sustainability and circularity standards is viewed as adding to circularity challenges. Moreover, the adoption of new, more circular products needed in water treatment itself is regarded as a difficult and as a long process. For example, long and thorough testing of new products and methods is required before they can be used in the drinking water sector. Next to the adoption of products is the challenge of bringing the residues from the water sector to the market and matching the quality and quantity of the available residues with the quality and quantity of resources needed at the market. Barriers, including financial barriers were mentioned in relation to finding uses for CO_2 and making products out of CO_2 stream. Regulatory requirements, such as requirements for the use of sludge for agriculture (regarding heavy metals) were seen as adding to the challenge of using residues. Another challenge that was mentioned in relation to environmental impacts is reducing the energy consumption of treatment processes.

Other subjects that were brought up were financial challenges of water companies, the challenge to provide sufficient water to industries and limited physical space at treatment sites.

Goals with regard to water treatment

The interviewees named predominantly environmental goals evolving around the hope to recover and reuse more resources and use resources efficiently and other environmental subjects. Most frequently mentioned was the overall goal of reaching a circular economy in the water cycle. Fitting to this overall goal are the subgoals of recovering and producing energy at wastewater treatment plants (e.g. biomethane) and the production of other materials, such as bioplastics, the capture of CO_2 and use of CO_2 for pH control in water treatment. Further, stakeholders would like to remove barriers relating to the end-of-waste status of treated wastewater and the optimization of sludge treatment (regarding transport

and finding uses, reducing incineration of sludge). Interviews also indicate that circularity is viewed in connection with the goal to make treatment plants resource independent and climate proof. Other aims concern the efficient use of resources (e.g. water and energy), carbon neutrality and nature protection, including the improvement of water quality with the creation of further cleaning steps. Some interviewees expressed their hope for radical changes in the water treatment system and the use of new and different technologies and processes. The goal is to advance the sites further through research and to communicate more about sustainability goals and monitoring.

Perception and evaluation of water treatment:

Interviewees underlined the necessity of water treatment. It was mentioned that water treatment in the Netherlands is regarded as having good standards. It is perceived positively, that water is purified and some interviewees mentioned that they see water treatment as being worth the costs due to its necessity. Further, energy recovery in water treatment is seen positively and interviewees refer to the opportunity of treatment facilities to provide physical space for renewable energy (e.g. with solar panels).

The interview responses show that stakeholders see room for improvement in terms of the environmental impacts. Specifically, they see the incineration of sludge critically. It is commented that materials are currently not recovered enough. Further, interviewees criticize the energy and resource consumption and the emission of greenhouse gases. Interview responses include a remark that the design of water treatment plants is seen as not being future-proof. Next to environmental impacts, the distribution of costs for water treatment and perceived fairness is addressed. In an interview it was reflected upon whether costs of water treatment should be distributed according to the pollution caused by actors, such as companies.

Discussions related to water treatment:

Identified discussions centered around circularity aims, the use of recovered materials and future treatment approaches: The definition of clear circularity goals can cause discussion, for instance within companies. Opinions also seem to diverge when it comes to the reuse of certain materials, such as sludge (in agriculture) or treated wastewater (for industry). Additionally, different ideas for future treatment approaches exist. Questions that can be discussed are whether water treatment plants should stick to their core business or whether they should change and take up new tasks. Another topic of discussion concerns different views on the centralization or decentralization of the waste water treatment system.

Perception of circular economy and industrial-urban symbiosis

Interviewees observed that circularity topics become more prevalent and view circular economy as a global trend. The transition towards circular economy is viewed as a necessity by interviewees. However, certain circular economy practices and CCU-approaches are viewed critically. This critique includes the view that certain measures, (e.g. CCU-measures) are strongly advertised and may distract from overall environmental impact and other environmental goals, such as waste reduction. Detailed results will be reported in D3.5.

3.2.4 Perceptions of sustainability and circularity regarding consumer products

Hopes and goals

Hopes and goals concerning consumer products that interviewees discussed regarded new sustainability standards for products. The wish for regulations making the use of recovered or recycled resources obligatory was expressed. Interviewees underlined the importance of clear communication about product sustainability and credibility of information. When speaking about product sustainability it was mentioned that sustainability should become mainstream. Goals relating to the environmental impacts of consumer products included reducing the impact of ingredients, moving away from fossil-based ingredients, reducing waste, decreasing microplastic, increasing biodegradability and increasing circularity (e.g. by using recycled plastic). Other environmental goals referred to climate- and energy neutrality as well as emission reduction (e.g. by reducing transport).

Challenges

When talking about barriers for sustainability of consumer products several challenges (e.g. relating to production, distribution and consumption) were discussed by interviewees. Competition between brands was perceived as a challenge. For instance, this challenge was referred to in connection to the choice of materials or ingredients and in connection to the communication about sustainability. An additional remark about sustainability challenges was that different sustainability requirements for products can compete. Goal-conflicts were also viewed in relation to the balance between product prices and the achievement of sustainability aims.

With regard to consumers, judging and comparing overall product sustainability and identifying credible information sources was seen as challenge. This difficulty was perceived in connection to the complexity of product sustainability and different ways of communicating about product sustainability by brands. When speaking about complexity, it was referred to various different product characteristics that impact product

sustainability (e.g. performance, or impact of ingredients). Consumers' perceptions and preconceptions towards products and ingredients were named as a factor that adds to communication challenges. It was mentioned that consumers can have preconceptions about environmentally friendly product options in certain product domains (e.g. cleaning products) and ingredients that sound unfamiliar to consumers can have a negative connotation for them.

Trends, events or changes

In the area of consumer products and sustainability interviewees perceived a shift in the target group from a specific consumer group with strong environmental concern towards a broader consumer group. Interviewees also mentioned a shift away from fossil-based ingredients in products. Another perceived trend was a shift in the focus of brands from only focusing on waste reduction goals towards circularity goals.

Perceived discussions

Topics of discussion that were broad up in interviews were an observed discussion on the definition of product sustainability. It was pointed out that product sustainability can be viewed in terms of ingredients, performance, endurance or in terms of efficiency regarding consumers' product adoption. Discussions can also arise with regard to specific sustainability aspects, such as discussions on the definition of microplastic.

3.2.5 Summary of stakeholder perceptions on the WaterProof context

Assessing how relevant stakeholders view the context in which the WaterProof approach is developed can be useful in understanding their hopes, expectations and questions about the WaterProof technology (in section 3.3). For instance, information about the interviewees view on waste and water treatment can be used as basis or starting point, in assessing how the WaterProof approach fits within the perceived goals and challenges at treatment facilities. Further, knowledge on current prevalent subjects with regard to circularity and with regard to product sustainability contributes to an understanding of stakeholder perceptions towards the WaterProof concept.

The WaterProof concept proposes a way of using CO_2 from waste and wastewater treatment and of producing an alternative for fossil-based product ingredients. This aim fits with the overall goals of increased circularity, of increased retrieval of resources from waste and water treatment and of a use of retrieved resources in products. Being aware of the challenges that are already perceived in the context of waste and water treatment (e.g. infrastructural and economical) can be useful with regard to technology implementation.

As some of the discussed challenges could also affect the implementation of the WaterProof technology taking these challenges into account can support successful implementation. Discussing and finding ways in which concepts, such as the WaterProof technology and processes can benefit the stakeholders in the sectors, such as the waste and water sector and does not add to existing challenges can contribute to the stakeholders' acceptance of the WaterProof concept. A summary of the results from the stakeholder interviews on current topics related to waste and water treatment, circular economy and product sustainability is shown in figure 3.

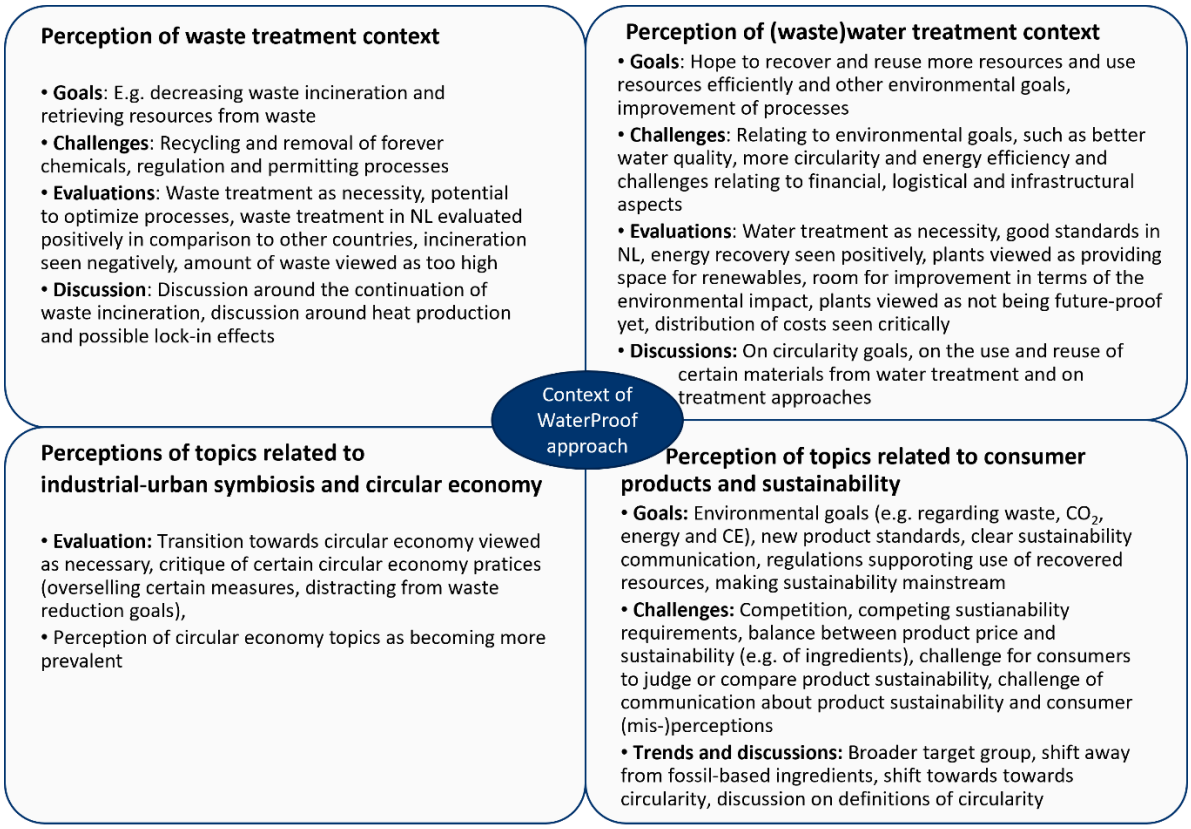

Figure 3: Results from stakeholder interviews – current topics related to waste and water treatment, circular economy and product sustainability

3.3 Stakeholder perceptions of WaterProof approach

In the interviews participants were given an introduction to the Waterproof approach in case they were not familiar with the project. Subsequently they were asked questions on their perception of the approach. The participants' answers were clustered into categories. The results give an overview over the perceived drivers and barriers, over perceived potential positive and negative impacts, and over informational needs associated with the WaterProof concept. Interview results are presented in six topical clusters: 1) Expected interactions with existing infrastructure, market demand and legislation, 2) process design, 3) social impacts, 4) economic impacts, 5) environmental impacts and 6) risk perception.

3.3.1 Informational needs of stakeholders

The stakeholder interviews reveal insights into the informational needs by stakeholders. Various questions on the WaterProof concept were asked by stakeholders during the interviews. The questions relate to different aspects, such as the fit of the WaterProof technology with the existing waste and water treatment facilities, the process design and technical aspects, social impacts, economic impacts, environmental impacts and risks. The specific questions are listed in table 1.

Aspects of WaterProof approach	Questions about the WaterProof concept asked by stakeholders in interviews
Fit with waste and water treatment system	• How much space is needed for technology implementation? • Should formic acid production be incorporated at treatment sites? • Who (which stakeholder) will be the producer of formic acid in a larger scale implantation? • What is the extent of transportation of materials needed for the implementation of the technology? How will materials be transported? • To what extent do the quality and quantity of materials available and demanded/ needed match?

Process design and technical aspects	• What are the steps from formic acid to the final product? • Can other by-products be valorised, aside from peroxides? • What is the capacity of the WaterProof technology? • What kind of maintenance is needed for the technology? • Can formic acid be used for energy production? • Does the CO_2 have sufficient quality for the electrochemical process at the sites or does it need additional steps in-between?
Social aspects	• How will lay-people react to the fact that the CO_2 stems from waste and wastewater treatment? How will they respond to the connection to waste and wastewater?
Economic aspects	• What are the costs of the WaterProof approach and how does the cost-benefit ratio compare to investments into other sustainability measures?
Environmental aspects	• What is the overall goal of the project? • What is the potential environmental impact of the WaterProof concept? • How do the WaterProof processes compare to the alternative approaches? What is the default right now and how does the default look like? • What happens with the methane? • Could the CO_2 from aerated basins be used for the WaterProof processes? • Is the water quality affected in any way by the WaterProof processes?
Risks	• What will be the quality of the formic acid? • Would the processes impact water quality?

Table 1: Informational needs of stakeholders – questions on the WaterProof concept asked by stakeholders in interviews

3.3.2 Interactions with existing infrastructure, market demand and legislation

Expected interactions of the WaterProof technology with the existing infrastructure at treatment plants, market demand and legislation were discussed in the interviews. An overview of the stakeholders' perception on these subjects is shown in table 2.

Available CO_2 at waste and water treatment plants and infrastructural aspects

Drivers: Interviewees pointed out an aspect that they saw as a driver of the WaterProof approach and an example of how the WaterProof concept fits to the existing waste and water treatment infrastructure. They mentioned that at many plants CO_2 is already captured and is therefore available for processes like the WaterProof processes. Some interviewees saw wastewater as a stable CO_2 source. The choice of wastewater as CO_2 source is seen positively by these interviewees as wastewater treatment is seen as a factor that will continue to be there and available as CO_2 source.

Challenges: It was also discussed in the interviews whether the WaterProof approach would still fit to the infrastructural context if the waste and water treatment system evolves. For instance, it was mentioned that wastewater treatment plants might advance and not emit as much CO_2 anymore. Additionally, they addressed the subject around the goal of waste reduction and concluded that the availability of waste as a CO_2 source might decrease in a changing system.

Other infrastructural challenges that were mentioned concerned the limits of the electricity grid and the question of connecting the process steps physically. The congestion of the electrical infrastructure in the Netherlands was mentioned as a discussion point in the Netherlands. The interviewees pointed out that renewable energy needs to be available for the WaterProof processes to run sustainably and that infrastructure to deliver the energy is necessary. According to the interviewees the WaterProof technology should be designed in a way that does not make the problem connected to the congestion of electrical infrastructure bigger but rather integrates a solution for this subject. Further, according to interviewees, it could be a challenge to combine all WaterProof processes physically while including as little transportation as possible and while dealing with limited physical space at treatment sites. In the case of using waste incineration as CO_2 source in the WaterProof processes interviewees asked themselves whether it would make sense to combine waste incineration, wastewater processes and the transformation of CO_2 into formic acid in one location or whether it would make more sense to transport resources from one site to the other. It was mentioned in the interviews that expertise about the WaterProof processes would be required at the treatment sites for the WaterProof approach to be implemented beyond pilot scale.

Demand for alternatives for fossil-based ingredients

Drivers: From the interview results it becomes clear that the interviewees perceive a demand for alternatives for fossil-based chemicals.

Challenges: Although there is a demand for renewable chemicals according to the interviewees, they perceive the specific demand for formic acid as rather small. Additionally, barriers for the use of by-products of the WaterProof processes in the water system were mentioned. Peroxides that are by-products from the conversion of CO_2 could be applied in the purification of wastewater. Regarding other potential application areas in the water treatment system, barriers were discussed. Specifically with regard to the drinking water sector, it was pointed out that long testing and thorough research is necessary in order to use products in companies like drinking water companies due to reasons, such as the complexity of processes and the responsibility for consumers.

Regulations

Challenges: Gaps in legislation were identified by interviewees, for instance regarding the classification of waste. It was mentioned that CO_2 legislation is perceived to be focusing rather on energy production than on chemical production. The permitting process of projects like the WaterProof project is seen as a barrier. Further, it was wondered whether CO_2 from different sources could be used in the electrochemical conversion at the same time and whether the use of CO_2 from two different sources for the WaterProof process might be complicated in terms of regulations. Regarding the adoption of WaterProof products interviewees identified the need for legislation supporting the use of alternatives for fossil-based chemicals.

Expected impacts of the WaterProof concept on treatment sites

When looking at possible effects that the WaterProof concept could have, the responses of interviewees differ. While some interviewees expected that the WaterProof processes would not affect the waste and water system much, others described expected positive effects and expected challenges that could be created by implementing the WaterProof processes.

Positive impacts: Interviewees saw the possibility to improve the wastewater system by implementing processes like the WaterProof processes. Further an opportunity for job creation in renewable fields was perceived.

Challenges: According to interviewees, a possible challenge, that could result from implementing the WaterProof technology is that it might increase the complexity of wastewater treatment processes.

Expected interactions with existing infrastructure, market demand and legislation		
	Drivers and aspects that are perceived positively	**Perceived challenges, barriers and critique**
Availability of CO_2 at treatment plants and other infrastructural aspects	• CO_2 already captured at many plants • Perception of wastewater as a stable CO_2 source	• Evolving treatment system: possible reductions in emissions and waste • Infrastructural challenges:_e.g. electricity grid & physical connection of processes (transportation and space). • Expertise_will be required at the plants
Demand for alternatives for fossil-based ingredients	• Perceived demand for alternatives for fossil-based chemicals	• Demand for formic acid seen as rather small • Perceived barriers for use of by-products in water system, (e.g. drinking water): long testing and thorough research necessary
Fit with contextual conditions: Regulations		• Gaps in legislation, e.g. regarding the classification of waste • Permitting process • Need for legislation supporting the use of alternatives for fossil-based chemicals
Effect on the context	• Possibility to improve wastewater system • Opportunity for job creation	• Perceived possibility that WaterProof processes might increase the complexity of wastewater treatment

Table 2: Interview results, perception of WaterProof approach, expected interactions with existing infrastructure, market demand and legislation

3.3.3 Process design

As summarized in table 3, topics that interviewees addressed regarding the WaterProof processes were circularity, simplicity, complexity, flexibility, process integration into existing systems and efficiency and sustainability of the CO_2 conversion method.

Circularity of processes

It was mentioned frequently that the circular approach of the WaterProof processes is seen positively. Nevertheless, some interviewees pointed out that they do not see the WaterProof processes as a fully closed loop, in which all resources (including the products) fully go back to the system.

Simplicity, flexibility and complexity of processes

While some interviewees pointed to the simplicity and flexibility of the WaterProof processes as an advantage, others find that projects with circular approaches are rather

complex. According to the interviewees many steps are involved in this type of projects (e.g. environmental permitting, financing, technological aspects, partnerships etc.) and the projects depend on many different stakeholders.

Integration of processes

Overall, the interviewees liked that the processes are integrated into an existing system (e.g. due to the possibility to use by-products in the water cycle) but they also expect that the integration can be challenging (e.g. by increasing complexity).

Technological aspects and choice of conversion method

Regarding technological aspects of the WaterProof approach interviewees mentioned perceived advantages of electrochemistry, as well as perceived challenges related to this conversion method. One perceived advantage that was pointed out was that electrochemistry was perceived as a sustainable and as an efficient process (with regard to chemical processes of formic acid production form CO_2). Challenges that were seen with regard to the technology was that the technology readiness level should be advanced further and that the operability of electrochemical processes in the wastewater treatment facilities could be challenging.

Process design: **Perception of the process design in the WaterProof approach by interviewed stakeholders**		
	Drivers and aspects that are perceived positively	**Perceived challenges, barriers and critique**
Circularity of processes	• Perceived circularity of processes	• Perception of the processes as not being a fully closed loop
Simplicity, flexibility and complexity	• Perceived simplicity and flexibility of processes	• Projects with circular approaches perceived as complex
Integration of processes	• Integration into existing system perceived positively	• Integration of processes into existing system perceived as challenge (e.g. increased complexity)
Technology and methods	• Electrochemistry perceived as sustainable • Processes seen as efficient	• Technology readiness level perceived as low • Operability perceived as challenge

Table 3: Interview results, perception of WaterProof approach, process design

3.3.4 Social aspects

Social aspects that were addressed in the interviews are summarized in table 4. The topics addressed centre around the social acceptability of the WaterProof approach. Challenges related to social acceptability were rather expected with regard to the WaterProof consumer products than with regard to the CO_2 conversion facility at the project site.

Acceptability of WaterProof products

When assessing interview responses about the CO_2-derived consumer goods, the interview responses included both positive expectations regarding product acceptability as well as perceived barriers for product acceptability.

Drivers: For instance, the choice of product categories for the application of formic acid in the project (cleaning and leather products) were seen as an advantage as they are not close to the consumers' body (e.g. as opposed to creams or products related to food). Furthermore, most interviewees thought positively about the products and would use the consumer products themselves.

Barriers: A barrier that interviewees expected regarding the acceptability of the products was that according to the interviewees' experience chemicals often have a negative connotation for non-expert consumers. Another possible barrier for product acceptance by consumers was seen in the CO_2-source from waste and wastewater treatment which could be associated with feelings of disgust by consumers, according to the interviewees. Furthermore, the interviews included the expectation that it would be challenging for consumers to judge the sustainability of a consumer product in which CO_2-derived formic acid is used and to compare the product to other product options. Related to the product perception, interviewees also brought up that the communication about CCU on a product package is challenging. Interviewees see this challenge of communication in relation to the perceptions and misperceptions of consumers towards consumer products in combination with limited space on packaging and the complexity of CCU processes.

Factors that were associated with product acceptance were product safety, trust into sustainability claims made by brands, product price and price difference to conventional products (involving chemicals based on fossil fuels) and the extent to which WaterProof consumer products are regarded as sustainable by consumers. Interviewees discussed the importance of the base for formic acid in a product for product overall sustainability. The relative importance of the chemical-base was compared to other sustainability aspects in products. Since the perceived relevance of the chemical-base in products for overall

product sustainability was a topic of discussion in the interviews, the perception of the sustainability of WaterProof products seems to vary between consumers.

While many interviewees addressed the topic of product acceptance as relevant factor for successful implementation, one stakeholder pointed out that they see legislation /obligation regarding the use of renewable feedstock for chemicals as a more impactful driver for projects like WaterProof.

Social aspects: **Perception of social aspects in WaterProof approach by interviewed stakeholders**		
	Drivers and aspects that are perceived positively	**Perceived challenges, barriers and critique**
Acceptability of WaterProof technology at sites	• Social barriers not perceived with regard to the sites (rather with regard to products).	
Acceptability of WaterProof products	• Product category of leather and cleaning products as advantage (not close to body) • Positive perceptions of interviewees towards consumer products, willingness to use products	• Expectation of a negative connotation of "chemicals" for consumers • Possible negative associations with waste and wastewater • Challenge for consumers to judge product sustainability • Challenge of communication about CO_2 - derived chemicals
	• Factors mentioned as relevant for acceptability: product safety, trust into sustainability claims, price, perception of WaterProof products as sustainable, • Discussions around key factors for successful implementation of WaterProof approach (product acceptability vs. legislation/ obligations to use renewable feedstock for chemicals)	

Table 4: Interview results, perception of WaterProof approach, social aspects

3.3.5 Economic aspects

Economic aspects that the interviewees brought up as drivers and challenges of the WaterProof approach concerned the costs and benefits of the technology implementation as well as perceived competition to the technology and its products. An overview is shown in table 5. Economic benefits were associated for instance with the transformation of formic acid into Acidic Deep Eutectic Solvents for metal recovery from incineration ash. The interviews showed uncertainty and informational needs among interviewed stakeholders regarding the costs of the technology for the transformation of CO_2. Interviewees were interested in the ratio between financial as well as environmental costs and benefits. Interviewees were curious about a comparison of the cost-benefit ratio of the WaterProof

approach with the cost-benefit ratio of other sustainability measures in the waste and water treatment sector. Additional barriers that were talked about were competing uses of CO_2 and the competition of WaterProof products /chemical against conventional products or chemicals that might be more familiar and cheaper.

Economic aspects: **Perception of economic aspects in WaterProof approach by interviewed stakeholders**		
	Drivers and aspects that are perceived positively	**Perceived challenges, barriers and critique**
Costs and benefits	• Economic benefits of the WaterProof approach were perceived positively.	• Informational need concerning implementation costs
Competition		• Competing uses of CO_2 • Competing against conventional products

Table 5: Interview results, perception of WaterProof approach, economic aspects

3.3.6 Environmental aspects

The interviewed stakeholders addressed several positive environmental impacts that they associate with the WaterProof approach. They also addressed perceived environmental challenges connected to the WaterProof approach. The stakeholders commented about the contribution of the WaterProof concept to overall sustainability goals, about the utilization of CO_2, about the energy and resource consumption of the technology and environmental risk perception. An overview is shown in table 6.

Contribution to overall sustainability goals

Drivers and aspects that are perceived positively: Many positive comments of the interviewees related to environmental benefits of the WaterProof approach, namely its contribution to a greener, more sustainable, climate-neutral future. The implementation of the WaterProof approach was seen as a possible demonstrator for circular economy showing that circular economy is possible. The approach is perceived as one of many technologies in industrial transformation.

Perceived challenges, barriers and critique: A worry that interviewed stakeholders expressed was that the use of CO_2 from waste and wastewater could be used as an excuse to continue waste incineration and keep producing CO_2. According to interviewees, a lock-in effect (related to a system that would be dependent on CO_2 emissions in the waste or

water sector) should be avoided. Interviewees found it important that benefits from the technology do not distract from environmental problems, like water pollution. Furthermore, an environmental barrier that interviewees saw for the WaterProof approach was the energy consumption of the technology.

CO_2 utilization

Aspects perceived positively: Interviewees liked that resources, such as CO_2, are recovered and used and emissions are saved in the WaterProof approach.

Perceived challenges, barriers and critique: Interviewees wondered about the size of the CO_2-utilization potential of the WaterProof technology in relation to the extent of CO_2 that is captured or can be captured at the waste or wastewater treatment plants. Further, they commented that the CO_2 is not bound in the WaterProof processes but will eventually be released at the end of product life. Further, interviewees pointed out that, aside from CO_2, waste and wastewater treatment facilities create other greenhouse gas emissions and that these emissions should be paid attention to as well.

Energy and resource consumption

Interviewees discussed several perceived challenges with regard to sustainability goals related to the WaterProof approach. They pointed out that due to the energy consumption of the technology the approach requires the use of renewable energy in order to be sustainable. Additionally, interviewed stakeholders wondered about how much transport of materials between different locations would be involved if the WaterProof technology would be implemented beyond pilot scale. Aside from concerns about transport, interviewees wondered what kind of recourses would be needed for the technology itself and whether or to what extent resources would be strained by the technology.

Perception of environmental risks

Low environmental risks were mentioned as a positive aspect of the WaterProof approach. While some interviewees perceived environmental risks to be low in relation to the WaterProof technology, others wondered whether the technology would have environmental risks related to contamination.

Environmental aspects: **Perception of environmental aspects in WaterProof approach by interviewed stakeholders**		
	Drivers and aspects that are perceived positively	**Perceived challenges, barriers and critique**
Contribution to overall sustainability goals	• Environmental benefits (contribution to a greener, more sustainable, climate-neutral future) • Demonstrator for circular economy • One of many technologies in industrial transformation.	• Worry that WaterProof approach could be used as excuse to keep incinerating waste and producing CO_2 • Worry about distraction from other environmental topics • Energy consumption of technology
CO_2 utilization	• Recovery and use of resources, such as CO_2 and saving of emissions	• Uncertainty about CO_2 utlization potential in proportion to CO_2 emissions at plants • CO_2 is used but released eventually • Relevance of other greenhouse gas emissions
Energy and resource consumption		• Energy consumption of technology • Potential transport of materials • Resources used for technology
Environmental risks	• Low environmental risks mentioned as a positive aspect technology	• Questions about environmental risks related to contamination

Table 6: Interview results, perception of WaterProof approach, environmental aspects

3.3.7 Perception of risks

Interview responses included different types of comments on the perception of risks with regard to the WaterProof technology. The responses are summarized in table 7. Some interviewees perceived the risks to be low and saw this as an advantage of the WaterProof technology. Furthermore, comments included the expression of trust towards the technology, towards the developers and in relation to safety regulations. Other interviewees wondered whether the formic acid produced in the WaterProof process would have the same quality as the chemical that is based on fossil fuels. One interviewee also associated peroxides (by-product of the CO_2 conversion process) with the importance of safety measures but trusted that safety measures are in place. Other perceived risks that interviewees referred to where social risks, environmental risks, economic risks or risks related to the operability/ practicability of the WaterProof concept beyond pilot scale. These comments are included in the sections "3.3.3 Process design", "3.3.4 Social aspects", "3.3.5 Economic aspects" and "3.3.6 Environmental aspects".

Perception of risks: **Perception of risks in WaterProof approach by interviewed stakeholders**		
	Aspects perceived positively	**Perceived challenges, barriers and critique**
Risk perception and trust	• The low risks of the WaterProof technology were mentioned as an advantage of the approach • Trust in technology developers and safety regulations	• Risks rather expected later on than in the pilot state, • Perceived risk: Will the formic acid have the same quality as conventionally produced formic acid • Mentioned safety risks: safety questions in relation to peroxides but trust

Table 7: Interview results, perception of WaterProof approach, risk perception

3.3.8 Conclusion on stakeholder perceptions towards WaterProof approach

Several aspects were brought up by the relevant stakeholders in the interviews on their perception of the WaterProof approach. Interviewed stakeholders talked about perceived drivers and benefits. Especially environmental benefits were mentioned in relation to the WaterProof concept. The circularity connected to the use of recovered resources and the replacement of fossil sources for chemicals were perceived positively. Wastewater was regarded as a stable CO_2 source and a demand for renewable chemicals is perceived by stakeholders. However, future goals of waste reduction and reduction of waste incineration should be taken into account in CCU approaches, according to the interviewees. While potential positive economic impacts were mentioned as benefits interviewees also see economic barriers (e.g. related to scaling up the technology). Factors, such as the energy consumption of electrochemistry, market needs and competition, infrastructural limitations at plants and permitting or legislation were mentioned when referring to possible barriers for the WaterProof technology.

4 Consumer perspective on WaterProof consumer products

Next to the stakeholder perception of the WaterProof technology and implementation at waste and water treatment sites the consumers' perspective on product applications is assessed. One application area for CO_2-derived formic acid are consumer products, like cleaning products and tanning agent for fish leather. Different steps connected to the use of captured CO_2 from waste or wastewater, to the conversion of CO_2 to formic acid and the use for cleaning products are visualized in Figure 4. More information on WaterProof can be found in section 1 "Introduction".

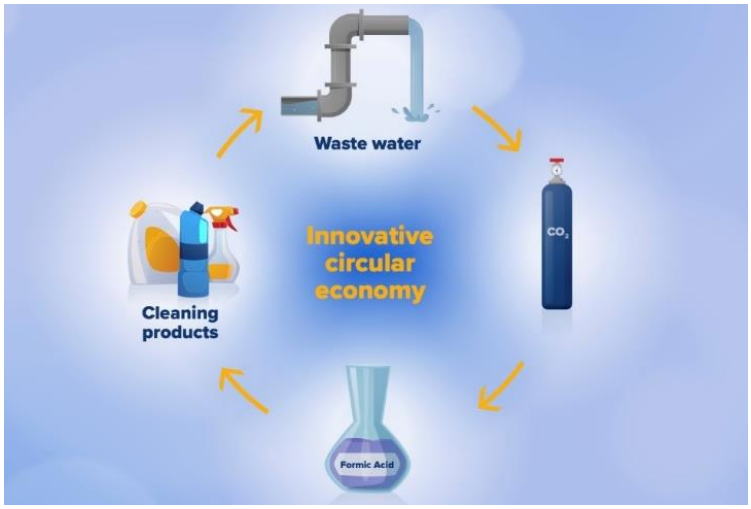

Figure 4: Circle from wastewater CO_2 to cleaning products, image from project video of the WaterProof project

To study the perception of the WaterProof consumer products existing literature on consumer behavior was reviewed, interviews with consumers were conducted and a pre-study with a short paper-pencil survey was carried out. Furthermore, a questionnaire for an online consumer study was designed. An overview of the methods is shown in figure 5.

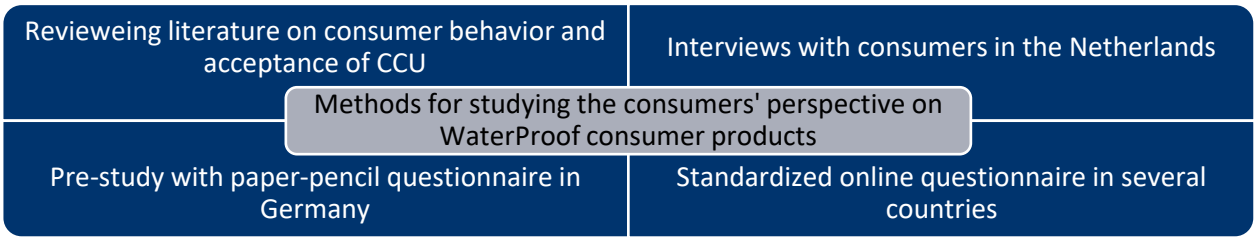

Figure 5: Methods for studying the consumers' perspective

4.1 Literature on consumer perspective

Part of the research on the consumer perspective with regard to the WaterProof approach and related products is to assess relevant literature on consumption topics. Several concepts are relevant with regard to the consumers' perspective on the WaterProof approach:

- environmental behavior, including consumer behavior (e.g. with regard to cleaning products) and
- technology acceptance, specifically the perception of Carbon Capture and Utilization (CCU).

CCU refers to the capture and utilization of CO_2 for products. For instance, fuels, chemicals and buildings are often based on fossil fuels. CCU is an approach to replace fossil fuels by using CO_2 as renewable feedstock for these products. CCU approaches can vary with respect to the CO_2 source, the technology for the conversion of CO_2 and the application (CO_2 Value Europe, n.d.). The following studies provide relevant factors and variables that may influence consumer perceptions towards CCU consumer products (e.g. cleaning products).

4.1.1 Literature on environmental behavior and technology acceptance

As consumer behavior, including product choice, can have an effect on the environment, literature on influencing factors for environmental behavior is relevant in this context.
Review studies on environmental behavior describe behavior as being affected by hedonic, gain and normative goals: feeling good, maximising resources and behaving in a way that is perceived to be in line with personal and other people's wishes or expectations. The effect of goals on behavior can be shaped by personal value priorities and by the situation (*Steg, et al., 2016*).
Whether a technology or a product resulting from the technology brings personal benefit or gain depends on which costs, benefits and risks are associated with it. To explain how perceived costs, benefits, risks, norms and other factors influence technology acceptance the technology acceptance framework by *Huijts and colleagues (2012)* can be used. The framework was developed as a model that can be used for research on energy technologies that are seen as novel by consumers or citizens. The use of CO_2 as feedstock for new products and the related technology seems to be a rather novel subject for consumers and the knowledge on CCU is rather low (*Arning et al., 2018*). As the technology and acceptance framework is seen as specifically relevant when assessing the acceptance of new technologies, its constructs might be relevant for the WaterProof technology. According to the framework many different factors are involved in consumers' technology

acceptance. These factors include experience and knowledge, trust, affect, costs, risks and benefits, outcome efficacy and problem perception, social and personal norms, perceived behavioral control, attitudes and intentions to accept the technology. This technology acceptance framework can serve as a starting point when assessing a technology that seems new to consumers.

Nevertheless, the specific technology (CCU) and product type (e.g. household cleaning products) need to be taken into account when assessing literature relevant for the WaterProof context.

4.1.2 Literature on factors in consumer perception of cleaning products

For instance, studies on the perception of cleaning products have identified factors that play a role for product choice, for the ability to judge the credibility of sustainability information (*Fella, & Bausa, 2024*) and for the perception of risks of cleaning products (*Bearth, & Siegrist, 2019; Buchmüller, et al., 2022*).

How the information on the sustainability of the cleaning product is displayed influences whether consumers choose the product option that is most environmentally friendly (*Gorissen, et al., 2024*). Further, the anticipated feeling of pride influences the choice of more eco-friendly cleaning product options (*Gorissen, et al., 2024*).

The ability of consumers to judge sustainability information on cleaning products can also be increased. Reminding or prompting consumers about the topic of greenwashing helps them to identify greenwashing and differentiate between products.

Cleaning products that are seen as more eco-friendly seem to be judged differently by consumers with regard to their risks. Eco-friendly cleaning products are perceived as having lower risks (*Bearth, & Siegrist, 2019*). Risk perception is also influenced by the package design of cleaning products (*Buchmüller, et al., 2022*).

4.1.3 Literature on public and consumer perception of CCU

Even though CCU is a new topic to consumers general perceptions of CCU seem to be rather positive *(Arning et al., 2018)*. In a study by *Arning and colleagues (2018)* positive evaluations of the CCU technology and positive evaluations of the CCU product example of foam mattresses were found. Specifically, the CCU product was rather seen as beneficial, useful and rather not associated with risks.

However, there are differences in acceptance of CCU that are related to various factors.

There can be differences in the acceptance between CCU product types *(Offermann-van Heek, et al., 2018).* For instance, in a study by *Offermann-van Heek and colleages (2018)* CO_2-derived fuels were viewed more positively than the application of CCU for mattresses

or beverages. Also, types of CCU approaches can be viewed differently (e.g. differences in CO_2 source and CO_2 transport-options; *Offermann-van Heek, et al., 2020*). It was found that giving laypersons information, such as information on energy consumption and on environmental aspects of CCU processes can affect which CCU approaches people prefer (*Offermann-van Heek, et al., 2020*). Informational needs that were identified regarding CCU include facts related to price, performance, product quality, ingredients of products and the country in which a product is produced (*Offermann-van Heek et al., 2018*).
As trust plays a role in technology acceptance (*Huijts, et al., 2012*), it is important to look at this variable in relation to CCU acceptance. Information from research institutions and environmental organisations were perceived as most trustworthy in a study by *Offermann-van Heek and colleagues (2018)* while information from companies were viewed as less trustworthy. How consumers view benefits of CCU is related to different aspects of trust, such as the image of the company, values and the companies' relationship to the consumer. How barriers to CCU are seen is related to different aspects of distrust (*Offermann-van Heek, et al., 2018*).

4.2 First results from consumer interviews

The stakeholder interviews with relevant stakeholders in the Netherlands described in section 4 "Stakeholder interviews" also included some questions on the interviewees' personal consumer perspective (e.g. stakeholders' personal perception of the WaterProof consumer products and their willingness to buy these products). Additionally, in three interviews with consumers (in the Netherlands) the questions focused on the consumers' perspective. As explained in section 4 "Stakeholder interviews" the interview language was English. In the three interviews in which the consumer perspective was the central topic, questions were asked about purchasing habits in general and in relation to cleaning products and about the perception of CO_2-derived products, more specifically products based on CO_2 from waste and wastewater.

4.2.1 Interview results on consumption and product choice

Consumers were asked what they pay attention to when purchasing products, such as cleaning products. The factors that were mentioned in the interviews can be clustered into factors relating to the wider societal and economic context, the purchasing context in the store, the social context (other peoples' preferences), the living situation, personal factors and product-specific factors (e.g. performance, price, brand, production conditions and environmental aspects of the product). The frequency at which the different aspects were mentioned in the interviews gives a first indication of their perceived relevance by

consumers. Among the factors that are not directly related to the product but rather relate to the consumer and the environment of the consumer, *preferences of others in the household* were mentioned most frequently. Regarding the product characteristics, the relevance of the *product's performance in terms of its efficiency* was mentioned most frequently. An overview of the factors mentioned in the interviews and the frequencies can be found in Figure 6.

The interview results relate to the literature in different ways. For instance, product performance as well as price seem to be relevant product characteristics for consumers. In literature, information on price and performance of products has also been identified as being important to consumers in the context of CCU products (Offermann-van Heek, et al., 2018). Further, the interview results give a first indication that the social context of consumers plays a role in their decision-making in purchase-decisions. This factor might be related to the concept of social norms. The influence of social norms is included in many psychological models, such as models on environmental behavior and technology acceptance (Huijts et al., 2012; Steg, et al., 2016). Moreover, the interviews give an indication that consumers pay attention to eco-tags and labels when choosing products, such as cleaning products. The relevance of eco-ratings and their design for cleaning product choice is also pointed to in literature (Gorissen, et al., 2024).

Level	Influencing factors for product purchase mentioned in interviews		Relevance of factors (based on frequencies at which factors were mentioned)
Wider context	Price trends (in general)		1
	Media		1
Purchasing context	Position in store		1
Others' preferences	Preferences of cleaning personnel		1
	Preferences of others in household		3
Daily life at home	Life phase (age, studying vs. job)		2
	Living situation		2
	Time		1
Personal factors	Personal motivation		1
Product specific	Performance	Efficiency	5
		Result (how clean)	1
		Ease of use	2
	Price		3
	Brand		2
	Design		1
	Perception of product safety		1
	Social factors (e.g.) working conditions in production		1
	Envionmental factors	Eco-tag at store	1
		Eco-label	3
		Regional product (transport)	1

Figure 6: Interview results on consumption-related factors and product choice

4.2.2 Interview results on the perception of WaterProof consumer products

When assessing the interview results with regard to the perception of the WaterProof consumer products, it was assessed to which extend the interviewees accept the products and whether they would be willing to buy this type of product. Further, it was examined which role pre-existing knowledge plays, how consumers view product sustainability and risks and which wishes they have for the communication of the products. A summary can be found in figure 7.

General evaluation and acceptance

Generally, interviewees showed a positive attitude towards the application of the WaterProof approach for consumer products (towards the use of WaterProof formic acid for consumer products). Most interviewees were open to buy WaterProof consumer products, and some would also choose the products if they were slightly more expensive than other products.

This indication from interviews of an overall positive evaluation of the CCU approach is in line with studies that found a rather positive evaluations of CCU, despite the low knowledge on the capture and use of CO_2 (Arning et al., 2018).

Knowledge and understanding

Interviewees described that a background in chemistry helps in understanding CO_2-derived consumer products. The interviewees with pre-existing knowledge did not expect the CO_2-base (from waste and wastewater) to affect the end-result of the consumer product.

Perceived sustainability

While some interviewees mentioned that formic acid and its CO_2-base might play a small role in the sustainability of the overall product, others found the CO_2 source / formic acid base to be an important aspect of product sustainability. Furthermore, the challenge of judging the sustainability of a product or comparing two products in terms of sustainability was addressed in the interviews. Weighing up the relevance of CO_2-derived chemicals against other sustainability aspects might be challenging for consumers. Nevertheless, in the interviews WaterProof products were seen as a step towards shifting the way that products are produced and their CO_2-base was seen positively.

Risk perception

The topic of product safety came up in the interviews as a condition for product acceptance. One interviewee described that they would use a cleaning product based on CO_2 from waste or wastewater if they think that it's safe. The product type was mentioned as relevant for product acceptance. A product that is further away from the body (e.g. a cleaning product) was preferred to a product that is closer to the body or to food. This implies that consumers seem to be cautious. Similarly, a study by Offermann-van Heek and colleagues (2018)

found that evaluations of different CCU applications differ. CO_2-derived fuels were evaluated more positively than mattresses or beverages. As mattresses and beverages are product categories that are closer to the body than fuel, the findings from Offermann-van Heek and colleagues (2018) might be similar to the indication from the interviews in WaterProof on a preference for product categories that are further away from the body.

Wishes for communication and trust

The wish for transparency was mentioned several times in interviews. The wishes for transparency concerned background information on the product price as well as information about the sustainability of the product. In some interview responses the relevance of transparency was mentioned in relation to trust or mistrust towards sustainability claims. This seems relevant as trust was also described as a condition for product acceptance. This result from interviews also underlines conclusions from other studies on the relationship of trust and CCU acceptance (Offermann-van Heek, et al., 2018).

Some interviewees suggested that consumers should be informed about the use of CO_2 on the package, for instance in the form of a label. Others suggested that the processes related to the use of CO_2 should be explained shortly in an understandable and interesting way, for instance with an infographic or a video. The importance of information on CCU that interviewees expressed can also be found in literature on CCU acceptance. Information on CCU is regarded as helpful for consumers in making informed decisions (Offermann-van Heek, et al., 2020).

The challenge of communicating complex processes with limited amount of space on product packages was discussed in interviews. One idea to tackle this challenge was to deliver extra information on processes related to the use of CO_2 via a QR-code leading to additional online information.

Product-specific perceptions: CO_2-derived formic acid for (fish) leather tanning

The use of fish leather was a rather new subject for most interviewees. However, there were positive remarks about fish leather as a unique / special material. When thinking about the application of the WaterProof formic acid in leather tanning interviewees reflected upon the use of leather in general. Interviewees identified a trend towards vegan leather and they thought about the advantages and disadvantages of leather and vegan leather alternatives. The interview results give an indication that there is a discussion around the use of leather. While some appreciate leather and associate it with luxury others think that the market should shift to vegan alternatives. Here it was mentioned that the use of formic acid stemming from WaterProof processes in leather tanning might not fit to overall sustainability goals and that the demand for formic acid for leather tanning might decrease with a decrease in the leather market in general.

Product-specific perceptions: CO_2-derived formic acid for cleaning products

Cleaning products are perceived as a necessity that will always be needed. Searching for ways to increase the sustainability of cleaning products is viewed as important. Therefore, the application of formic acid stemming from WaterProof processes in the production of cleaning products is viewed as suitable application area. Moreover, the connection of toilet cleaner and wastewater is perceived positively as it creates a mental circle (from the toilet over wastewater treatment, CO_2, formic acid and toilet cleaner back to the toilet).

Figure 7: Interview results – consumer perspective on the use of WaterProof formic acid for consumer products

4.3 First results from consumer pre-study

4.3.1 Pre-study method and questionnaire

The pre-study was conducted between the 20th of September and 22nd of November 2023. A short paper-pencil survey was distributed at four different times in Saarbrücken and in Aachen, Germany (inner city and university campus). The language of the survey was German.

The first section of the questionnaire included questions on socio-demographic information, such as age, gender, education and income. In the next section participants were asked about their consumption habits regarding the consumption of cleaning products (e.g. type of products, frequency of purchase, priorities in product aspects).

In the third section of the pre-study the application of the WaterProof concept in cleaning products was introduced and participants were asked to rate statements on a scale from 1 (completely disagree) to 5 (completely agree). The answers to these statements assessed the expectations of consumers towards cleaning products based on recycled CO_2.

4.3.2 Pre-study results

Sample

The sample consists of 34 participants with a mean age of 43.94 and a standard deviation of 18.3. 14 participants were male, 17 female and 3 did not indicate their age. The level of education ranged from elementary school to PhD or higher with "general university entrance qualification" being the biggest group. The participants' annual gross income ranged from less than 20,000€ to over 110,000€.

Pre-study responses concerning the consumption of cleaning products in general

The results of the pre-study show that laundry detergent, dishwasher detergent and toilet cleaner belong to the most frequently used cleaning product types among the participants. Concerning the frequency at which cleaning products are being bought, the answers differ. The frequency of purchase varies from purchasing cleaning products every week (12%) to purchasing cleaning products every year (3%). 33% indicated to buy cleaning products every month. According to the participants, cleaning products are being bought mostly in drugstores or supermarkets while only few participants indicated to buy cleaning products online (3% of participants) or in organic stores (3%). A small percentage (6%) of participants indicated that they make cleaning products at home.

As displayed in figure 8, when buying cleaning products more than half of the participants pay attention to the product price (74%) and to the product's effectiveness (59%). 47%

pay attention to the product's sustainability. 30-35% pay attention to aspects, such as product smell, ingredients, quality and performance. Product aspects that only 10-20% of participants indicated to pay attention to were: the form of the product (powder, liquid or concentrate), packaging, recyclability, and brand.

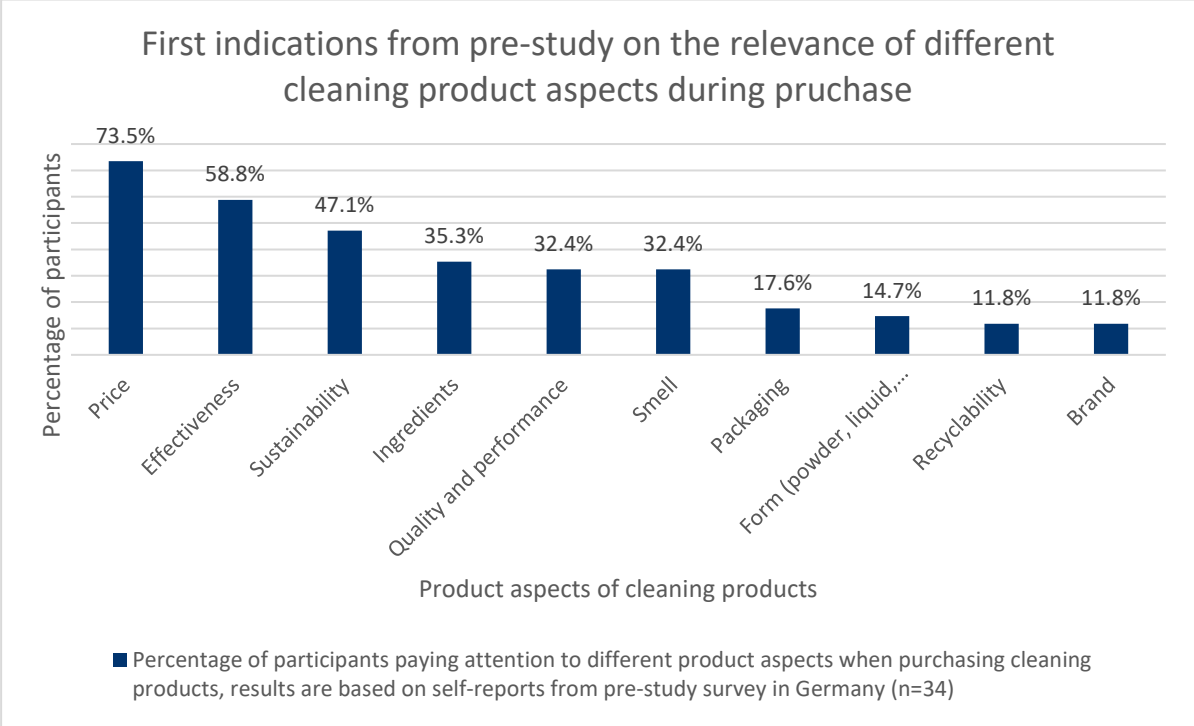

Figure 8: First indications from pre-study survey in Germany on the relevance of cleaning product characteristics

On average, participants agreed that they aim for a more eco-friendly consumption. At the same time, they also seem to worry about health risks of cleaning products.

Pre-study responses concerning the application of the WaterProof concept in cleaning products

The pre-study results, as depicted in the graphs in Figure 9, give first indications on the consumer perception of the WaterProof cleaning products.

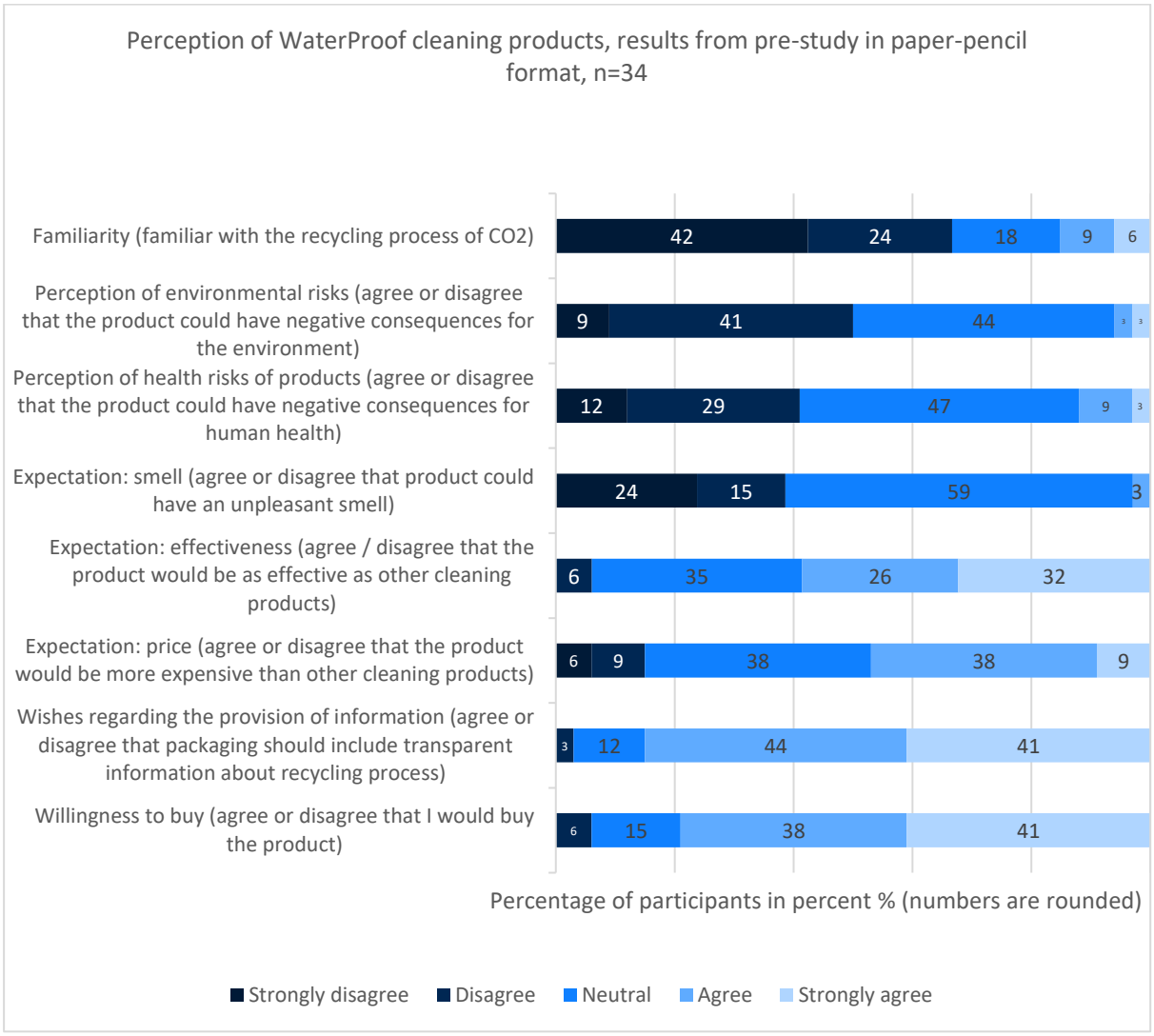

Figure 9: First indications from pre-study survey on the perception of WaterProof cleaning products

The first indications from the pre-study include the following indications. The numbers of percentages are rounded.

- The participants are rather unfamiliar with the recycling of CO_2. 67% disagree or strongly disagree with the statement that they are familiar with the CO_2 recycling processes. 18% chose the "neutral" option and 15% agree or strongly agree that they are familiar with the processes. This first indication from the pre-study of a low

knowledge level on CO_2 conversion and use is in line with findings on CCU-related knowledge in other studies (Arning et al., 2018).

- The percentage of pre-study participants that see environmental (6%) risks or health risks (12%) related to the products is rather low and there seems to be uncertainty related to risk-perception. A high percentage selected the option "neutral" when judging the risks of the products (44% for environmental risks and 47% for health risks). Considering that the capturing of CO_2, its conversion and use is a new subject to most of the participants, this result of a high percentage in "neutral" answers can be interpreted as showing that there is uncertainty about the products as well as the risks among consumers. Nevertheless, (almost) half of the participants disagreed or strongly disagreed that the products could have environmental risks (50% concerning environmental risks and 41% concerning health risks).
- The uncertainty about the product becomes more evident when examining product aspects, such as the responses concerning the expected smell of the product. When participants were asked whether they would expect the product to have an unpleasant smell, 59% participants selected the "neutral" option and thus do not agree or disagree. Nevertheless, the percentage of participants who did not expect the product to have an unpleasant smell (38%) was higher than the percentage who did expect an unpleasant smell (3%).
- It seems that participants have positive expectations towards the product's effectiveness. The percentage of participants who agreed or strongly agreed that the product would be as effective as other cleaning products (59%) was higher than the percentage of participants who disagreed (6%). 35% of participants neither agree nor disagree.
- The results indicate however that participants tend to think that cleaning products in which the WaterProof concept is applied would be more expensive than other cleaning products. 47% expected this price difference whereas only 15% stated that they don't expect the products to be more expensive. Again, 38% did neither agree nor disagree.
- The results show a clear wish for transparent information about the processes on the packaging (85%). 12% were neutral and only 3% disagreed.
  The result that there are informational needs among consumers on CCU processes is relevant as research has shown that information on CCU life-cycles, such as information on the energy consumption and environmental effects of different CCU approaches can affect which CCU approaches they prefer (Offermann-van Heek, et al., 2020).
- Most participants are rather open to buy cleaning products on the basis of recycled CO_2 (79%). 15% are neutral towards this question and only 6% disagree.
  Thus, the pre-study gives an indication of an openness of consumers towards the CCU product application, which was also found in other studies on CCU acceptance (e.g. Arning et al., 2018).

Figure 10: Pre-study - summary of first insights on the consumer perceptions of WaterProof cleaning products

4.3.3 Discussion of pre-study

The results from this pre-study should be viewed as preliminary results due to the limited number of participants (n=34). It should be taken into account that the pre-study was carried out in two cities in Germany and should not be generalized (e.g. to the consumer perspective in other countries).

4.4 Online questionnaire for consumers

On the basis of literature and first indications from interviews and from the pre-study a standardized online questionnaire was designed to assess consumer habits, perception of the WaterProof application for cleaning products and consumers needs and wishes concerning the CCU product. The online study is currently being conducted in different countries, such as the Netherlands and Germany in Dutch and German language. For survey distribution a flyer was created that consisted of a short description of the WaterProof project and of the study purpose. Further, the flyer included a visualization of the process chain related to the conversion of CO_2 from wastewater into formic acid and the use of formic acid in cleaning products. The link to the website of the WaterProof project was placed on the flyer, as well as a QR-code leading to the survey. So far, the flyer was

created in Dutch (Annex A) and German language (Annex B) and was placed on the project website.

The questionnaire consists of questions concerning the following concepts:

- Socio-demographic characteristics
- Consumption habits (e.g. which kind of cleaning products participants use)
- Environmental consciousness (e.g. concerned about environmental issues)
- Outcome efficacy (believe that purchase decisions can contribute to reducing the global environmental footprint and dependence on fossil resources)
- Perceived responsibility for the environment
- Knowledge on CCU (e.g. familiarity with "recycling process of CO_2", with carbon capture and utilization processes and with CO_2-based cleaning products)
- Social norms (e.g. expectation of relevant others towards the personal purchase decisions related to cleaning products) and personal norms (e.g. feeling of personal moral obligation)
- Trust (e.g. towards authorities that assess cleaning products)
- Risk-perception (e.g. perceived environmental or health risks of CO_2-derived cleaning products)
- Perception of costs and benefits (e.g. regarding environmental aspects, product quality, effectiveness, price and smell)
- Willingness to buy CO_2-derived cleaning products or to switch brand
- Preferences regarding product information on the package (e.g. information on the CO_2 conversion processes, information on CO_2 source, such as wastewater or information on the location of the CO_2 source)
- Preferences regarding information sources (e.g. written article, advertisement or costumer reviews)

The concepts are measured with several items using multiple choice answer options, single choice options with answer options based on the 5-point Likert scale as well as open ended questions.

4.5 Summary of first insights into consumer perspective

First results from the pre-study and interviews show an overall positive perception of the CCU approach in WaterProof and the application for consumer products, such as cleaning products, among consumers which is in line with other studies on CCU acceptance.

Consumers' decisions are influenced by external factors, such as the wider purchasing context, including overall prices, the context in the store and the social context. Their decisions are also influenced by the consumers' personal factors, like their own motivation

or personal norm, their feelings, their knowledge and awareness. Product characteristics, such as the price and performance of a product or the eco-friendliness are considered by consumers.

Knowledge on CCU is rather low among consumers and they wish for clear, understandable transparent information on CCU-related aspects of products. When imagining a CCU product, consumers show uncertainty towards some characteristics which might be related to the low level of experience with this type of product. Related to perceived costs and benefits the interviews and the pre-study give some first indications. Participants do not seem to think that CCU affects product performance but they tend to expect that the product would be more expensive than a conventional product.

5 Recommendations for communication and stakeholder engagement

The following recommendations for communication and stakeholder engagement can be concluded on the basis of stakeholder interviews, experience in the field of public and stakeholder engagement and on the basis of literature, interviews and a quantitative pre-study survey on the consumer perspective.

- The stakeholder engagement concerning the WaterProof approach should be embedded into the context of the stakeholder network. Current prevalent topics and discussion in the network can be used as a starting point for engagement activities. Relevant stakeholders include stakeholders in waste and water treatment, administrative and political authorities, research and technology development, infrastructural stakeholders, stakeholders related to products (e.g. organisations, producers and distributers), environmental and consumer organisations and consumers.
    - Engagement activities should be connected with wider topics of industrial-urban symbiosis, making stakeholder activities meaningful in terms of current prevalent topics in the stakeholder network. Drivers and challenges related to the WaterProof approach should be discussed, not as isolated subjects but in relation to: 1) current developments, challenges and goals in waste and wastewater treatment, 2) dynamics in the local and regional stakeholder network and current trends, goals and barriers with regard to industrial-urban symbiosis
    - An example of a topic suitable for stakeholder engagement could be the role of CO_2 utilisation from waste and wastewater with regard to overall aims for waste and water treatment (e.g. emission reduction, waste reduction and circularity).
- Information on technology requirements and benefits is helpful for stakeholders to judge potential technological impacts and feasibility of implementation: Benefits associated with the WaterProof approach indicate relevant implications for technology implementation. Examples are perceived benefits of integrating (by-) products from CO_2 conversion into the same treatment systems in which the CO_2 was captured. On the one hand this integration is seen as a possibility to further improve treatment plants, on the other hand increasing process complexity is mentioned as challenge. Information on the requirements (infrastructural requirements or expertise and maintenance) as well as the potential capacity of the technology (in proportion to captured CO_2 at plants and in proportion to the demand of formic acid) might be useful to judge the feasibility and benefits of implementation. Further, stakeholders are

interested in comparing the ratio of environmental and financial costs and benefits to the costs and benefits of other sustainability measures (e.g. in the waste and water treatment sector). Knowledge on identified informational needs and interests can be incorporated in communication.

- A holistic approach should be adopted, considering stakeholder perspectives along the entire value chain from waste or wastewater and the conversion of CO_2 to the use of formic acid, the use of formic acid in different applications, including the production, distribution and consumption of products.
- Stakeholder engagement should be viewed as process rather than one single event fostering ongoing exchange with and between stakeholders.
- Stakeholder-specific needs and perspectives should be taken into account. An example are recommendations based on the perspective of the general public and consumers: 1) Develop approaches to give consumers relevant, understandable and transparent information on the specific CCU processes related to products. 2) Include consumers in the development of information material in order to be able to provide information that is relevant for them. 3) The priorities of the general public should also be considered in the overall design and decision-making of CCU projects at an early stage.

6 Conclusion

The research in task 4.2.1 provides information on relevant stakeholder groups and their roles with regard to the WaterProof technology. Moreover, it gives an overview on the stakeholders' perception of potential technological impacts and on perceived or expected interactions with waste and water treatment sites. In addition, the research gives first insights into how consumers view the WaterProof product applications and what their expectations and hopes are with regard to the consumer products.

The stakeholder analysis, described in deliverable D4.2, focused on local and regional stakeholders in the Netherlands relevant with regard to the WaterProof concept, the pilot installation and related waste and water treatment sites in Amsterdam and Alkmaar. A stakeholder map was created as a visualization of relevant stakeholder groups. It includes local/regional actors in the waste and water treatment sector, local/regional administrative and political authorities, stakeholders in research and technology development, infrastructural stakeholders, stakeholder related to products (e.g. producers or distributers), environmental organisations, and consumers.

In qualitative interviews it was assessed which goals, challenges and discussions stakeholders currently associate with waste and water treatment, with circular economy and with sustainability of consumer products. Further, informational needs, drivers and barriers with regard to the WaterProof technology were identified. Recommendations for the communication about the WaterProof technology and for stakeholder engagement can be derived from the identified informational needs and perceptions. For instance, questions on the technology's requirements at treatment facilities (e.g. required infrastructure and maintenance) should be considered in communication. Generally, the idea to integrate CO_2-derived products in the same system in which CO_2 was captured and to produce renewable formic acid for consumer products was perceived positively. In order to understand the potential role of the technology and its products further it would be useful for stakeholders to receive information on the match between the technologies' capacity, the amount of available captured CO_2 at the sites and market needs for formic acid.
While the stakeholders associate the circularity of the WaterProof approach with environmental benefits (e.g. contribution to emission saving, to industrial transformation and to the replacement of fossil feedstock) they are interested to compare the technologies' financial and environmental costs, risks and benefits with other uses of CO_2 or with other sustainability measures. Furthermore, the importance of reducing waste incineration was

highlighted in interviews. According to interviewees using CO_2 from waste incineration should not contribute to its continuation. The role of the WaterProof technology in relation to sustainability aims, like waste reduction and circularity, could be one of the topics for further stakeholder activities.
Barriers that interviewees associated with the implementation of the WaterProof technology concerned financial costs of scaling up electrochemical processes, energy consumption, infrastructural barriers (e.g. in energy infrastructure or with regard to limited space at treatment sites) and to barriers related to permitting processes and legislation. In engagement activities stakeholders can contribute with their expertise to find ways of alleviating barriers and to define implementation scenarios in which the perceived challenges are taken into account.

Next to the view of local and regional stakeholders, the consumers' wishes and preferences regarding CO_2-derived products should be taken into account, for instance in product design or in the communication about product applications (e.g. cleaning products and fish leather). The results, described in deliverable D4.2 are based on first insights from interviews, a pre-study survey and literature. Overall, interviewees and survey participants showed an openness towards the use of captured CO_2 for product ingredients, despite current low knowledge levels on CO_2 conversion. A wish for clear, understandable and credible information on CO_2-derived ingredients could be identified from the research. Factors relevant for product acceptance vary across product types. Thus, product specific factors, such as performance (relevant for cleaning products), play a role in the acceptance of CO_2-derived products and should be assessed.
Further, the report describes a standardized questionnaire which was created in task 4.2.1 and which is currently being conducted in Germany and the Netherlands. Next steps include analysing results of the online questionnaire. It will be examined whether the first insights from consumer interviews, pre-study and literature are confirmed. It will be assessed which factors are particularly relevant for consumers' evaluation of CO_2-derived cleaning products and their expectations and priorities (e.g. wishes for information) will be identified.

As a result, a list of recommendations for communication and stakeholder engagement was included in D4.2. The recommendations can be picked up in task 3.5 ("Industrial-Urban symbiosis") of the WaterProof project. Recommendations can be taken into account in engagement activities around the topic of industrial-urban-symbiosis (I-US) and around the topic of the WaterProof concept. Insights into consumers' preferences can be picked up in work related to formic acid application in consumer products.

7 List of abbreviations

Abbreviation	Description
WaterProof	urban WAste and water Treatment Emission Reduction by utilizing CO_2 for the PROduction Of Formate derived chemicals
FA	formic acid
CO_2	carbon dioxide
CE	circular economy
I-US	industrial-urban symbiosis
ADES	Acidic deep Deep eutectic Eutectic solvents Solvents
EPC	Engineering, Procurement and Construction
CCU	Carbon Capture and Utilization
E.g.	exempli gratia (for example)
Et al.	et alii/ et aliae/ et alia (and others)

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9 Annex A

Figure 11: Flyer for online study in the Netherlands about consumer perspective on the conversion of CO_2 from wastewater into formic acid and the application of CO_2-derived formic acid in cleaning products

10 Annex B

Figure 12: Flyer for online study in the Germany about consumer perspective on the conversion of CO_2 from wastewater into formic acid and the application of CO_2-derived formic acid in cleaning products