Deliverable 2.7

Info-sheet quick scan VSD for case studies

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Deliverable 2.6	Info-sheet quick scan VSD for case studies
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[1] **R**=Document, report; **DEM**=Demonstrator, pilot, prototype; **DEC**=website, patent fillings, videos, etc.; **OTHER**=other

[2] **PU**=Public, **CO**=Confidential, only for members of the consortium (including the Commission Services), **CI**=Classified

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Executive summary

This deliverable is associated with Task 2.2 – Value sensitive design and optimization, integrating moral values, social perceptions and behaviors. In Water-Mining, Value Sensitive Design (VSD) is aimed at incorporating the stakeholders' values, concerns and expectations into the early-stage design, development and implementation of novel circular water mining systems. VSD considers three phases: Setting the scene (M1-M10), Exploring opportunities and barriers (M11-M35) and Full-implementation study (M36-M48).

This deliverable aims at updating D2.6, in which social values and concerns identified in the first stage of the VSD process were presented, as well as the feedback collected from stakeholders in the first meeting of the respective Community of Practice (CoP).

The update includes the description of the second phase of VSD – Exploring opportunities and barriers – which is based on the development of technical scenarios to incorporate value tensions and uncertainties identified in Phase 1 to the development of the WATER MINING technologies. Scenarios have been developed in stages; one case study (CS) after another. Therefore, while for some CS scenarios are only described (CSs 4 and 5), in other cases (CSs 1 and 2) scenarios have been evaluated in quantitative terms and even presented and discussed with stakeholders.

This deliverable also includes the description and preliminary results of the behavioral studies, which are also part of T2.2.

Therefore, after briefly introducing the VSD process and its aims (Section 1), Section 2 presents the methodology followed to identify social values and concerns, and to translate them into design propositions for the different CSs (Phase 1: setting the scene) (Section 2.1). Then, the process to construct technical scenarios is described, and the aims and rationale behind behavioural studies are presented (Section 2.2).

Then, the main outcomes of Phase 1 are presented (Section 3.1): social values, value tensions and uncertainties. Overall, the main value tensions and uncertainties are related to the following issues:

- Different views of the ownership of raw materials, technology, property rights and products, and the distribution of benefits and costs they imply.
- Different sustainability concerns, such as the use of renewable energy for climate change mitigation, and their associated cost and land requirements.
- Economic sustainability expectations, like agricultural development from increased water availability, and their potential long-term sustainability impacts, such as increased water and land demand.
- Water and resource qualities with the proposed Water-Mining systems, and the energy, emissions and costs required to attain these qualities, as well as the local needs or priorities for water use.
- Different visions of a circular economy, which can be seen as, e.g., the local integration of resources for creating local impact, or as the valorisation of wastewater streams into high-value products that enter international value chains.
- Uncertainties about the safety of resources recovered from wastewater (and how to measure it), acceptable risk, and the applicable legislation to these resources (e.g. medicine residues or heavy metals in water).

The second part of Section 3 is aimed at presenting the technical scenarios in each case study, the results of the first survey of the behavioral studies in CSs 1 and 3 and the upcoming work in T2.2.

In CS1 and CS2, technical scenarios have been defined, evaluated and presented to stakeholders in the corresponding CoP meetings. For islands like Lampedusa, where there is limited energy availability and chemical use, a focus on water recovery (and not so much on zero liquid discharge) seems preferred by stakeholders.

Based on CS2, we can say that the only way to reach Zero Liquid Discharge (ZLD) is by implementing thermal technology or to add a thermal system to a reverse osmosis (RO) system. The RO-ZLD would perform better in terms of irrigation water production. But the thermal system (NF+MED+Thermal Crystallizer) would increase salts production and bring the possibility of recovering high value salts (e.g. Mg), decrease wastewater generation, with slight differences in the amount of irrigation water produced. This and other trade-offs have been investigated at the CoP meeting and through the behavioral studies. Then, it has been concluded that technical scenarios are not suitable for exploring the identified societal issues in CS3 and CS6 due to issues of project scope and stakeholder participation. In CS3, most of the value tensions identified can be translated into propositions that go beyond the Kaumera extraction system (e.g., end-use of post-processed Kaumera) and, therefore, beyond the scope of the project (i.e., optimizing Kaumera extraction in warm climate). Other issues such as the recovery of Phosphorus, Nitrogen or biogas are being developed at the theoretical and lab scale, which entails many unresolved and unknown issues that difficult the development of technical scenarios.

In CS6, the epoxy production process raises several sustainability concerns, such as the use of non-renewable resources and substances of concern. CS6 is mainly focused in closing the chlorine loop and developing a chemical leasing business case. Therefore, the replacement of raw materials and its sustainability impact are beyond the scope of the project and of the CS, and developing technical scenarios around the pilot system in WATER-MINING would not serve to address the issues mentioned above.

The next steps for the VSD process are bringing the results of the technical scenarios of CSs 4 and 5 to discussions with stakeholders at the respective CoPs. After these CoPs, the behavioral studies (remaining interviews and surveys) will continue in parallel to the Full-scale Study as Phase 3 of the VSD process.

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1. Introduction

This deliverable is associated with Task 2.2 – Value sensitive design and optimization, integrating moral values, social perceptions and behaviours. It presents feedback for the (preliminary) results of the value sensitive design process from the communities of practice to the case studies (WP3-6).

In Water-Mining, VSD is aimed at incorporating the stakeholders' values, concerns and expectations into the early-stage design, development and implementation of novel circular water mining systems. VSD is a suite of Design for Values approaches that have been developed to consciously incorporate societal values into emerging technologies (Hoven et al., 2015), which are often developed in processes that are blind to the context and the stakeholders' realities (Palmeros Parada et al., 2017).

Three phases are identified within the VSD process (Figure 1):

- Setting the scene (M1-M10). Technical and societal aspects of the WATER-MINING systems to be developed in the project are identified to support later stages of VSD. Technical aspects refer to design scope and main design variables of the different technical systems, while societal aspects refer to stakeholders and societal values relevant to the WATER-MINING systems.
- Exploring opportunities and barriers (M11-M35). The feedback on stakeholder values and design propositions from the 1st round of workshops for the different Case Studies will be used as input to re-define the design propositions intended to shape the development of the WATER-MINING systems; i.e., a process of value sensitive optimization based on stakeholders' values and expectations.
- Full-implementation study (M36-M48). Here, the research team will perform an analysis of real scale implementation of WATER-MINING systems. For this, the implications of the full-scale implementation of the systems will be investigated, to derive recommendations for their development considering the identified stakeholder values and the feedback from the previous rounds of workshops.

During the first year of the project, TUDELF and UAB teams, together with the CS partners, have identified social values, perceptions and value tensions (T2.2.1) and have carried out the first stage of the Value Sensitive Design Process (T2.2.2). During the second year of the project, T2.2.2 was continued through the second phase of the VSD process to explore opportunities and barriers. This stage has been conducted through the development of technical scenarios and behavioural studies, in collaboration with Case Study partners.

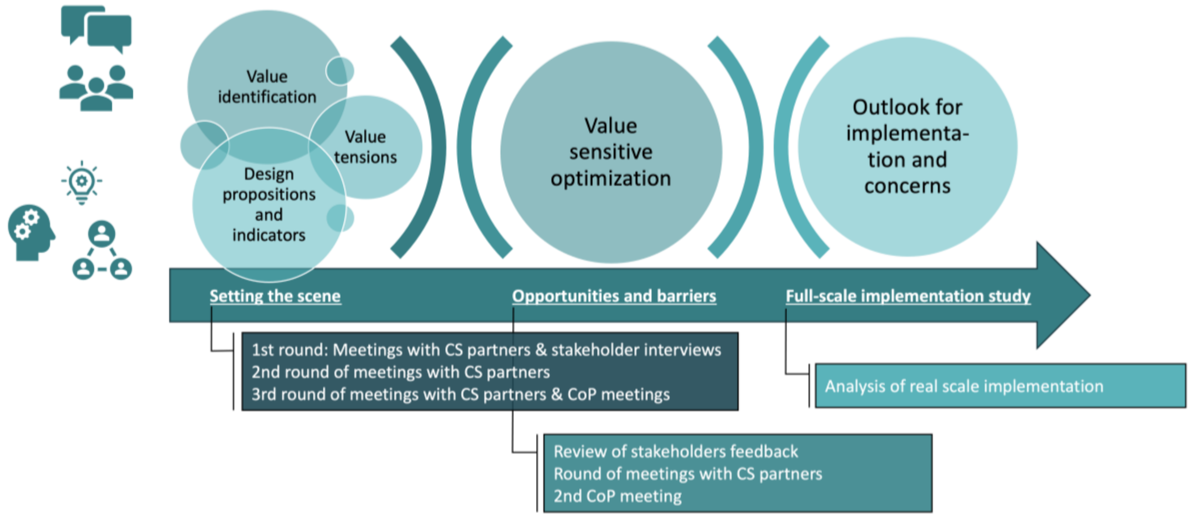

Figure 1. value Sensitive Design process

As part of phase 1 of the VSD process, technical aspects have been investigated internally through participant observation of WP 3 to 6 (case studies) kick-off meetings, and separate meetings for each Case Study with relevant project partners (mostly Case Study owners, facilitators and/or Work Package Leaders). Societal aspects were identified through a literature review (Palmeros Parada et al., 2022), and they were empirically investigated through stakeholder engagements as part of T2.1 (Figure 2).

Recall that T2.1 was aimed at establishing the Communities of Practices: "social learning systems that bring together people who share a concern or a passion for something they do and learn how to do it better as they interact regularly (Wenger-Trayner and Wenger-Trayner 2015, in Fulgenzi et al 2020). These stakeholder groups are the main communication space between the project and stakeholder groups regarding the VSD process.

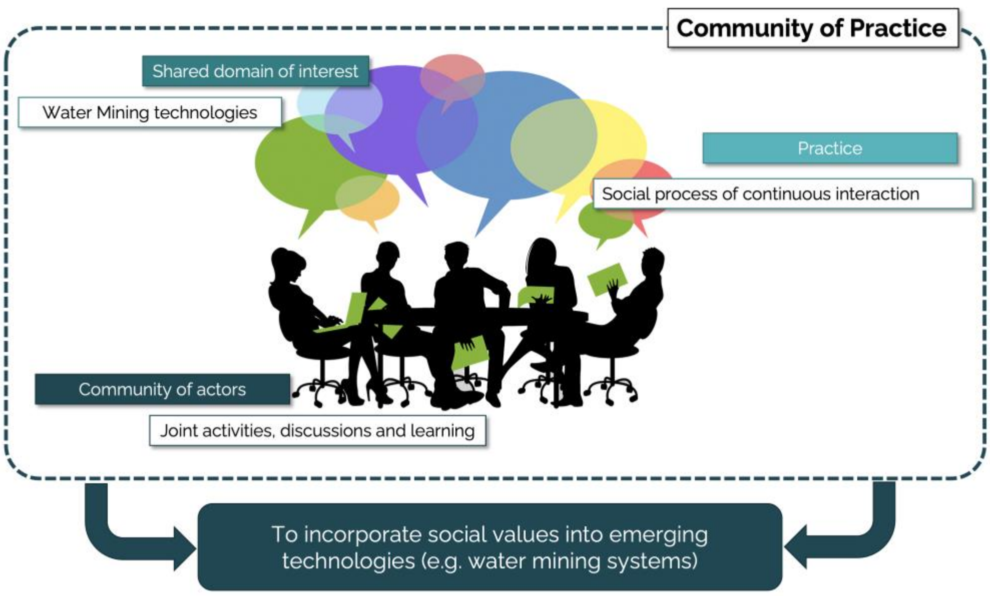

Figure 2. Value Sensitive Design and Communities of Practice

During Months 19 and 36, the work done in T2.2 included the following activities:

- Technical scenarios are being developed in four CSs. Technical scenarios are considered as different ways of implementing the WM technologies at large scale for each CS. The scenarios explore different technical configurations that could serve to explore the main societal aspects identified for each case (value tensions and uncertainties). Four large aspects or variables have been considered to develop the technical scenarios: 1) process and technology, 2) product and by-products, 3) scale and supply chain, 4) raw materials and utilities, based on (Palmeros Parada et al., 2018).
- Modelling and calculation of mass and energy balances of the different components of the scenarios in each case study. This work has been done in close collaboration between WP2, WP8 and a PhD student working in WP3.
- Validation of technical scenarios with technical project partners through an iterative process.
- Presenting technical scenarios to stakeholders of CSs 1 and 2, and discussing emerging societal issues with stakeholders.
- A survey to measure attitude change has been applied to participants of the CoP meetings in CS1 and CS3, as part of the behavioural studies considered in T2.2.

The following activities are considered for the rest of the project to finish the VSD process:

- Finalise the development and evaluation of technical scenarios in CSs 4 and 5, and present them to stakeholders, and discuss the performance of technical scenarios of CS4 and 5 and the emerging societal issues.
- Update the technical scenarios of CSs 1, 2, 4 and 5 according to the stakeholders' comments and feedback.
- Carry out the Phase 3 of the VSD process: full-scale implementation study, which will integrate outcomes of WP2, WP9 and WP10, to answer the following question: What is needed to implement at full-scale the technologies developed in the WM project?
- Finish the round of attitude change surveys in CSs 2, 4 and 5, and derive preliminary conclusions about the factors fostering attitude change. This will be the basis to plan the second step of the behavioural studies, which considers interviews with end-users in the different CSs.

In the following sections, we present the followed methodology for the first phase (to identify social values and value tensions, and to develop the design propositions for each case study) and second phase of the VSD project (technical scenarios and behavioural studies). Then, a summary of the main outcomes and the feedback received from stakeholders in the first and second meeting of the Communities of Practices (CoP) are presented.

A complete report on the identification of social values, value tensions and design propositions has been prepared with the information generated during this first year of the project (Palmeros-Parada et al., 2021), and that was the basis for this Deliverable 2.6.

2. Methodology

2.1. Phase 1: Setting the scene

In this section, we explain the process of translating social values into design propositions. In this report, ***social values refer to standards that social groups or stakeholders employ to define their goals and refer to what is important, considered desirable and acceptable***, in this case expressed by project partners directly involved in the development of the technologies or by stakeholders.

Values relevant to Water-Mining are identified by analysing the presentation of the project in the Grant Agreement (Part B, Section 1), as well from each case study (CS). To do so, a text analysis based on open coding was carried out (see below).

Aspects of importance for each CS were identified from two types of meetings with project partners within each CS (see the two bullets below) and the video script prepared by WP2 in collaboration with Case Study Owners (CSO) and Case Study Facilitators (CSF) for presenting the CSs to external stakeholders.

- Start-up Meetings: The first VSD meetings were held with CSO, CSF, and/or Work Package Leaders (WPL) from October 2020 to January 2021. These meetings were aimed at understanding the technical systems for subsequent activities in Task 2.2 (Value Sensitive Design, VSD). Also, these meetings were used to explore the aspects of importance to project partners with regards to their case studies. For this, in these meetings project partners were asked about their expectations, research focus, and concerns about the technical systems they were working on. Feedback from project partners on the meeting notes was used to clarify any misunderstanding or misinterpretation of their statements.
- VSD Meetings: Three rounds of VSD meetings were held with the technical project partners of each CS in the period March 2021 to October 2021. WPL, CSOs, and CSFs participated in these meetings and, in CS4 and CS5, also a project partner involved in Technology Development. In the first round of VSD meetings, project partners were introduced to the VSD approach in WATER-MINING. During the meetings a brief exercise about values was held, in which participants were asked to reflect on what they would consider a successful implementation of their system at full scale, and its desired impacts. In the 2nd round of meetings, project partners co-developed with the VSD researcher a map of the technical systems of each CS (main technical features and design rationale). In the 3rd round of meetings, project partners discussed and reflected over the identified stakeholder values, value tensions, and their relation to the CS system to derive design propositions.

Project values were first identified from the reviewed documents and the start-up meetings. The documents and meeting recordings were analysed with open coding focused on identifying aspects of importance to the project and case studies. At the end of the coding, the coded segments of the grant agreement were analysed to identify overall project values. Then, the codes for the specific case studies were contrasted to the overall project values to see how values are specified in the different case studies, and also to identify emerging CS-specific values and/or concerns.

In parallel to the first and second VSD meetings, a series of interviews were carried out with key informants: i.e. subjects that are well-informed, reflective, have first-hand knowledge about an issue and are willing to talk extensively with the researcher (Martín-Crespo Blanco & Salamanca Castro, 2007). The interviews were recorded, transcribed and qualitatively analyzed with open coding focused on identifying aspects of importance to the interviewees. A report putting together project values, social values and identifying value tensions was written and validated by CS partners. This validated report, together with a review of the literature on societal values and concerns around resource recovery, was the basis for the third VSD meeting with CS partners, which was aimed at developing a series of design propositions to deal with the main issues and concerns raised by project partners and key informants. (All value tensions can be seen in section 3.1)

Design propositions are recommendations for the development of the technology in the case study context (Palmeros Parada, et al. 2018). It is desirable that they are considered during the project duration (e.g. for further investigation, or to be discussed in a future Communities of Practice (CoP) meetings), but it may be that some are beyond the scope or the capacity of the project. Also, a series of policy proposals were identified to deal with issues that are beyond the technological development. The feedback from stakeholders and if/how design propositions can be approached in the project will be discussed in a 4th VSD meeting after the 1st CoP meeting.

A first round of CoP meetings took place in September and October 2021. For each CS, relevant stakeholders (as identified in Task 2.1) were invited to be part of the Community of Practice and join the first CoP meeting. CS owners and facilitators prepared the meetings' agendas, which included the presentation of the relevant CS (technologies, objectives), getting to know all participants, defining a common objective for the CoP, and to have an initial discussion of the preliminary results of VSD and Market Mapping (WP9). In some CS, however, there was very little or no time for a VSD discussion because priority was given to getting all participants familiarized with the CS and each other.

2.2. Phase 2: Exploring opportunities and barriers

2.2.1. Technical Scenarios

As part of the second phase, technical scenarios are being developed. Technical scenarios are considered as different ways of implementing the WM technologies at large scale for each CS. The scenarios explore different technical configurations that could serve to explore the main societal aspects identified for each case (value tensions and uncertainties). Such explorations could be through the design of technical options that directly address specific aspects (e.g. quality-cost or environmental trade-offs), or as a basis to investigate other implications (e.g. economic, environmental, policy, societal desirability). For such an exploration, the technical scenarios are to be presented to stakeholders with aid of the VSD indicators identified in task 2.2.1.

The development of the technical scenarios started with the consideration of four large aspects or variables: 1) process and technology, 2) product and by-products, 3) scale and supply chain, 4) raw materials and utilities, based on (Palmeros Parada et al., 2018). These variables as well as the identified societal aspects identified in the previous VSD stage were brought for discussion with project partners, in most cases being case study owners (CSO) and case study facilitators (CSF). Note that these variables were used as a starting point, but what is actually varied through the scenarios depends on each case study. The scenario development continued with data (e.g. operation conditions such as temperature, pression, inflows, outflows) obtained from the pilot system, and was brought for discussion with project partners in various instances including the Project Meeting in Palermo, in October 2022.

In the following sections, we include a summary of the proposed technical scenarios for Case Studies 1, 2, 4 and 5. For CS 3 and CS 6 no scenarios have been developed. For CS3, several possibilities for technical scenarios had been discussed with the project partners of CS3, particularly regarding scale and the post-processing of the extracted Kaumera. However, due to many uncertainties, the un-availability and confidentiality of data (especially regarding post-processing which falls beyond the scope of the

Water-Mining project), it was decided to not develop technical scenarios within the work of WP2. Therefore, looking at synergies between Work Package 9 and 2, for CS3 the second phase of the VSD task was combined with the Barrier Analysis task in WP 9. Particularly, the identified societal concerns from task 2.2 were translated as societal barriers and included in the barrier pool of task 9.2. In the third CoP, which took place on Oct 28th 2022, participants were given the pools of barriers identified from task 9.2 and VSD, and were asked to give a priority to all barriers and identify solutions to the top three barriers.

For CS6, the situation is also different than the rest of Case Studies considering that: (1) This CS is with mostly industrial actors as stakeholders in CoPs. (2) The CS6 technical solution is closed within an 'industrial loop' (i.e. raw material and products exchanged within an industrial loop). And, (3) there are technical variables that could be explored through technical scenarios (e.g. scale, combining different streams to process) but they do not relate to specific societal issues discussed within this CS. Based on these points above, the possibility of holding a discussion activity in the next CoP, without technical scenarios and focusing around identified societal issues, is being discussed with CS6 partners.

2.2.2. Behavioural Studies

The behavioural studies within WM have the aim to increase end-user adoption of WM technologies and focus on three notions: (1) Usefulness and ease of use of technology, (2) Behaviour, acceptance and attitude-change of end-users, and (3) Public attitudes and trust in institutions and technology. Surveys have been conducted that focus on aspects 1 and 2. Additionally, aspect 1 is investigated through discussions with stakeholders at CoPs, taking as reference the developed technical scenarios. Aspect 3 will be studied by means of the living lab Floating-Farm (Rotterdam).

The survey aims to cover the perceptions of end-users regarding the usefulness and ease of use of the WM technologies, and to observe any attitude changes in regard to these technologies. Work conducted by Alcon, de Miguel & Burton (2011), and within the WM infosheet quickscan on Value Sensitive Design (Deliverable 2.6), formed the foundation for the behavioural studies survey. This led to the following themes being covered in the surveys:

1. Basic information of the participants, i.e. education level, age, membership of relevant associations, gender and e.g. farmer characteristics for WM technologies' agricultural usage or the usage of products such as salts and chemicals.
2. Attitude change and perceptions on the innovation process, i.e. transparency and responsiveness.
3. Attitude change and perceptions on the usefulness and usability of the respective WM technology and derived products.
4. Factors of acceptance (local and global) for the WM technologies and products.

The surveys conducted at the CoP meetings in Lampedusa (CS1) and Faro (CS3) are provided in Appendices A and B. For processing of the data, Likert scales are included in the survey (ranging from 1 to 5, with 1 being that there is no association, and 5 being an extremely high association) and rankings (i.e. from 1 to 10, 1 being of the lowest importance, and 10 being of the highest importance). Lastly, each survey consists of 2 parts; one that has to be filled in at the beginning of each CoP meeting and one at the end of this meeting in order to be able to see changes in responses. For this, questions from bullet points 2, 3 and 4 are filled in twice by the respondents. Lastly, the surveys were translated from English to other languages, i.e. Portuguese and Spanish, depending on the location of the CoP meeting and participants. The surveys included in Appendices A and B are in English.

3. Results

3.1. Phase 1 of VSD Process

This section summarizes the identified values and the main issues emerging during the first VSD phase: setting the scene. This information is based on the analysis of observed concerns, expectations, objectives, etc., from documents, surveys and interviews within the project and from engagements with stakeholders as mentioned in Section 2. Note that specific market and policy issues emerging from the VSD process have been communicated to WP 9 and 10 respectively, where they have been further investigated.

3.1.1. Social values

The main values identified within the project and through the engagements with stakeholders are:

- **Resource security**: In the project and in the engagements with stakeholders, resource security emerges as the concern around a supply of resources for industrial production, prominently considering shortages of some materials, especially in Europe, arid regions, and in islands (e.g. phosphorus and other critical raw materials and energy). Resource security is seen as being achieved through a circular economy in which the supply of resources is secured by recirculating them through arrangements across industries, and by increasing the efficiency of the processes that use them. Therefore, key to the WM systems in the project is to achieve higher resource efficiency and re-use.
- **Water access**: The vision within the project is to contribute to overcome an emerging water availability crisis, and related socio-economic and political impacts. Fitting this vision, water within the project is seen as a resource that needs to be extracted as with desalination (CS1 and CS2), as a consumable that, after being discarded, can be recovered and re-used (CS3-5), and as a durable that can be used and reused within an industrial closed loop (CS6). Overall, water mining presents itself with the aim to contribute to the availability of water of different qualities, and project partners speak of improve water availability, provision, recovery and re-use, and taking into consideration its affordability. On the other hand, stakeholders, besides having concerns about water supply and availability, find its affordability a prominent aspect that can hinder water access. As well, some stakeholders argue in favour of having a 'sustainable' or reduced consumption vis-à-vis the current situation. Therefore, the distribution of benefits and costs, as well as the consideration of alternatives, are prominent for stakeholders.
- **Environmental sustainability:** WATER-MINING aims to contribute to creating sustainable production model, decoupling environmental impacts derived from production processes and water systems. Specific environmental impacts being addressed are related to the extraction of raw materials and waste production, and which are aimed to be reduced with WM innovations. Climate change mitigation emerges mostly as an overarching challenge in society that puts constraints on water efforts (e.g. energy and GHG emissions of desalination and resource recovery), and to which it aims to reduce contributions (e.g. emission reduction efforts). Stakeholders echo these concerns and emphasize the consequences on the status of aquifers, water consumption, land use, soil quality, climate change mitigation, the use of resources through the life cycle of products, as well as direct impacts on the environment (e.g. like potential smells and nuisance, the landscape) associated to

the implementation of the systems. They consider that these environmental impacts should be considered for societal acceptance.

- Socio-economic sustainability: Within the project, there are two main aspects of importance: 1) the contribution of recovered resources to local economies (e.g., employment and activities like agriculture and tourism), and 2) their impact on the profitability of the water systems to improve the business case's finances of water systems and their durability, or to reduce their societal costs. For the second point on profitability, there is a focus within the project on the valorisation of streams, cost minimization, the avoidance of future costs, as well the competitiveness and existence of markets for recovered resources as products. Stakeholders also spoke about these aspects and indicated that product pricing is a factor for user acceptance. Additionally, some stakeholders spoke on the importance of the distribution of costs and benefits across end-users of water, potential long-term socio-economic risks for the region (e.g., increased water and land demand, and effects on their price), as well as the potential for increasing local economic resilience through local production and use.
- Innovation: The circular economy is presented as a desirable overall system in which sustainable production is established, and for which technical and business innovations are needed. WATER-MINING is presented as contributing to the vision of Europe as a world leader in technology development and implementation for the circular economy. For this, in the project there is a focus on demonstrating the replicability of the systems, the integration with other actors (e.g. industries), and improving efficiencies and optimizing operating parameters of circular systems. This value has been expressed from the project's perspective, and there is no mention about it from the stakeholder's perspectives.
- Quality: The quality of the recovered resources is a focus throughout the case studies, particularly considering the various possible uses for the recovered water and other products, each with its own quality requirements. Prominently, water re-use is targeted for applications in agriculture, municipalities, industries, the environment, and regulations as well as user requirements are to be investigated (e.g., phosphorus content in water for agriculture). Stakeholders also spoke about these aspects and indicated that quality is a factor for user acceptance. Especially some stakeholders spoke of standardized quality, performance, the presence of contaminants, the smell of the product, the end-of-waste status, and processing flexibility to match various applications.
- Safety: Safety is prominent in the project concerning the health and environmental impacts risks associated with some waste streams. For this, monitoring and testing are measures in consideration. Some project partners, though, speak of the role of societal perceptions and risk acceptance, and the comparability of recovered resources with conventional products, emphasizing that conventional products are not as monitored as recovered resources are/can be required to be. Operational safety is discussed as workers safety especially with the handling of streams (biogas, sludge), and concerning the risk of overflow. For these operational safety aspects, measures are being taken into consideration (e.g. overflow lagoon, manuals and training for operators). Stakeholders also spoke about these aspects and the impact of the quality of the incoming waste streams on the safety of recovered products.
- Transparency: Stakeholders spoke about the importance of communicating with local stakeholders around the WM systems for their societal acceptance, especially regarding the project objectives, the distribution of benefits and costs around WM systems and the role of different stakeholders.

3.1.2. Value tensions and Uncertainties

The main issues identified throughout the case studies are related to the following value tensions and uncertainties:

Different views of the ownership of raw materials, technology, property rights and products, and the distribution of benefits and costs they imply.

This issue has emerged in different CSs in different ways. In CS2 desalinated water is considered a public good, which should be used to improve the quality of life of the population, which may collide with private benefits obtained from a public good (e.g., irrigation in agriculture). In that sense, some proposed to build different desalination plants for different uses. Also, different opinions were raised regarding the question of who should pay investment and increasing costs of water. Some argue infavor of subsidies, while others argue that who make profit of using desalinated water should pay higher prices.

In CS1 and CS5, some interviewees questioned the private ownership (and potential profits) of a technology developed with public funds. They ask for an equitable distribution of costs and benefits among private companies and society.

In CS3, the privatization of public resources and the profits made from them raise the question of who owns the waste streams. In that sense, it is argued that valorising stream by public companies may help to decrease the operation cost of wastewater treatment plants.

Different sustainability concerns, such as the use of renewable energy for climate change mitigation, and their associated cost and land requirements.

This tension mainly emerged in the seawater mining CSs, which are based on the use of waste heat and/or renewable energies to power the desalination systems. In CS1, there were some concerns regarding a potential lock-in effect to fossil fuels due to the use of waste heat from a diesel power plant. In this case, the possibilities of using renewable energy sources are constrained by land scarcity that characterizes the island.

In CS2, the aim of decarbonizing seawater desalination collides with the extensive land use of thermal solar energy. Land competition between economic activities in coastal areas (e.g., tourism, agriculture, housing, seawater desalination) would push thermal solar plants to inland, which would increase water transportation costs in energy and monetary terms.

Economic sustainability expectations, like agricultural development from increased water availability, and their potential long-term sustainability impacts, such as increased water and land demand.

Increases in water availability may lead to agricultural expansion and, in the medium- and long-term, increased water consumption and land use. This issue is very important in a water stressed region (CS2) whose aquifers are highly degraded and/or overexploited. Stakeholders agree that aquifers should be protected and improved. Seawater desalination should substitute aquifers, and not be complementary water source. To do so, adequate policies should be implemented to avoid illegal abstractions, improve control, and foster substitution of water sources.

Increases in water consumption can also take place in CS4. Decreasing salinity and increasing availability of irrigation water may lead to farmers to switch to more profitable crops and also an expansion of the agricultural activity. Even though new crops have less water requirements, the overall consumption of water will depend on the amount of production. This issue is also very important in a water stressed region such as Cyprus.

Water and resource qualities with the proposed Water-Mining systems, and the energy, emissions and costs required to attain these qualities, as well as the local needs or priorities for water use.

In CS5 there is the possibility of producing water for different purposes and with different quality standards. Some stakeholders raised some concerns about increasing water prices due to higher investment (e.g., equipment) and operational (e.g., energy materials) costs to reach higher qualities (e.g., for industrial use). There were also some concerns about whether higher qualities and the necessary technologies are really needed in the local context.

In CS4, farmers expressed some concerns regarding the extraction of Phosphorus from the effluent of the WWTP, which is used for irrigation purposes. According to them, they would have to increase fertilizers use if less phosphorus is contained in irrigation water. Incorporating the technologies to remove phosphorus from water would increase the investment cost of the WWTP and the operational costs of farmers. But it is not clear how the operational costs of the WWTP would change. Additional equipment would increase operational costs and, at the same time, would reduce costs associated to manage biofouling in pipes and membranes produced by phosphorus in water.

Different visions of a circular economy, which can be seen as, e.g., the local integration of resources for creating local impact, or as the valorisation of wastewater streams into high-value products that enter international value chains.

This tension was present in CS2 and CS3, mainly. In CS2 some people questioned the circularity of a system that uses local resources (seawater, sun) to produce irrigation water for export-oriented production. The same applies to CS3, where local sludge is processed to produce a high value product for the international markets. Then, the following questions arises, can these processes be considered circular water economy? Some stakeholders think they are not.

In CS5, reuse of water and recovery of phosphorus can increase the circularity of the system and potentially also its sustainability. However, the re-use of water and the recovery of resources can be seen as a net contribution of resources, which may lead to increasing consumption due to larger availability. In a river basin, for instance, one can increase the circularity of water use upstream, but an increase in resource consumption upstream may lead to lower availability of water downstream and also for recovering degraded aquifers.

Uncertainties about the safety of resources recovered from wastewater (and how to measure it), acceptable risk, and the applicable legislation to these resources.

The issue of producing a biopolymer for agricultural uses from wastewater sludge generates concerns among stakeholders of CS3. The potential content of medicines and heavy metals in Kaumera is uncertain and should be investigated. In the same line, there are concerns regarding legislation that is not up-to-date to regulate new products or technologies. In this situation, some people asked, how can safety be ensured? What would be an acceptable risk if regulations are not up-to-date on some of these issues? What would be considered safe in foreseen WM Kaumera applications?

Uncertainties around the allocation of responsibility in the circular economy, including safety, investment risk and liabilities.

Safety and liabilities is mainly related to CS6, where safety concerns related to the use and release of high salinity streams and substances of concern (e.g. toxic or cancerogenic) to the environment were expressed. In the case of using recovered salts for road de-icing, the distribution of risks and responsibilities related to the recovery, transport, and use of the brine product would be an issue. Also, some expressed concerns with regard operational risks (e.g. leakage and handling risks within the industrial loop), together with other potential safety risks in the chlor-alkali process, prominently the handling of chlorine.

As mentioned in the previous point, stakeholders of CS3 also expressed concerns about safety of Kaumera. In this case, and as current legislation would not be adequate for new products such as Kaumera, they asked, Who´s responsible for safety in this innovation process then?

Regarding investment risk, in CS5 there was discussion about who should run the risk, in economic terms, of developing the new technologies and at what price. On one side, both end-users and project partners consider that they should be the economic beneficiaries of these technologies, being the cost of the water (i.e. price) subsidized. Some regulators also think it is important to subsidize the use of recovered resources. On the other side, ecologist groups consider that if these technologies improve the impact on the environment, they should be implemented regardless the cost they have (which would also imply subsidies to make development and implementation cheaper and viable).

Tables 1 through 6 present the identified value tensions and uncertainties for each Case Study. The first column of the tables presents the general aspects to which the main issues identified (second column) relate. The third column presents the ideas expressed by stakeholders in the first CoP meeting. It is important to notice that the first CoP meeting was mainly aimed at establishing the CoPs, so most of the time was devoted to present the project and case study objectives, and to know each other. Some CSs were able to include discussions on VSD in the meeting, but most CS were unable to cover all issues that have merged in the previous steps of the VSD process. As the reader will see in section 3.2, some of these issues have been discussed with stakeholders in the last CoP meeting.

Table 1. Case study 1 – Lampedusa. Main issues and values identified in the VSD process, and responses from stakeholders.

Aspects	Main issues identified in VSD	Stakeholder response to main issues
Affordability, Distributive Justice and Societal Acceptance	Zero liquid discharge (ZLD) comes with energy and economic costs in an island with limited energy resources. However, the cost and energy impact of the ZLD system, and possibilities with waste heat integration are not fully known yet. They partly depend on the revenues coming from the purified salts and the implemented business plan.	*Not discussed in the CoP*
Efficiency and Long-term Sustainability	Integration with waste heat from fossil resources implies a risk of fossil energy lock-in effects. In Lampedusa there are limited areas for renewable energy sources (RES), and it is already expected that fossil resources are the only alternative in the short to medium term. If the system were to be integrated in another location with available RES, the thermal equipment could be integrated with renewable heat as in CS2.	Some stakeholders supported the importance of the sustainable development which means use of renewable sources, use of technology but in a sustainable way, especially in small islands as Lampedusa. Moreover, it should pay attention to avoid ecosystem alteration.

Aspects	Main issues identified in VSD	Stakeholder response to main issues
Sustainability Trade-offs	The avoidance of brine discharge through ZLD implies GHG emissions associated to energy requirements. About 60 to 70% of CS1 runs on waste heat, which would otherwise be wasted. Given the limited availability of land for RES, the energy requirement will add to the energy imports and GHG emissions of the island, and raises questions about the desirability of ZLD. There is a risk to increase water consumption due to higher efficiency in the provision of water, leading to larger environmental impacts (more energy for more water being consumed). Drinking water needs are already covered by seawater desalination (SWD) and it is unknown what the effects on water consumption will be (i.e., more water available would foster more water consumption).	*Not discussed in the CoP*
Water and Technology Ownership	Some question the private ownership of seawater, of desalinated water, and of the technology developed with public funds. They ask, who would be the beneficiaries of implementing the system? And ask for a fair distribution of costs and benefits of implementing these technologies. According to them, the investment of technology development is financed with public funds, but the economic benefits are privately owned.	*Not discussed in the CoP*

Table 2. Case study 2. Plataforma solar de Almería. Main issues and values identified in the VSD process, and responses from stakeholders.

Aspects	Main issues identified in VSD	Stakeholder response to main issues
Affordability, Distributive Justice and Societal Acceptance	Adding a ZLD approach puts pressure on water access (affordability). Farmers call for subsidies, which is an ongoing issue in Spain. This raises the question of how far the CS system can go with salt recovery considering costs (and who is willing to pay them) and environmental impacts.	Some argue that small desalination plants used and paid by irrigation communities would make the management of brine easier. Most of the participants think that those who pollute or have unsustainable water uses should be penalized. It is perceived that public management creates mechanisms to manage brine, but there are some obstacles in the private sector. Some agreed that polluters should pay and to apply fiscal incentives for developing clean technologies, although others were more positioned in the line of subsidies and aid for clean technologies (e.g. subsidizing RES or taxing those desalinating water with fossil-fuels based electricity/heat).
Efficiency and Long-term Sustainability	Increasing the energy and water efficiency could reduce the costs of water desalination, and in the longer-term lead to lower water prices and lower costs for agricultural production. Cheaper irrigation water may foster agricultural expansion in terms of land use and increasing production. This would, consequently, may lead to higher water consumption and land prices.	Regarding the protection of aquifers, the consensus is that knowledge about the state of aquifers should be improved, and illegal abstractions should be fought. Specifically, control networks should be established to detect illegal water captures. In addition, it was suggested that farmers using desalinated water should have to give up the rights to the concessions (extraction from the aquifer) for as long as they use desalinated water.
Local vs. Global Circular Economy	For some a circular economy entails the use of local energy sources to process a local resource for local production. However, as desalinated water is for irrigation purposes and agriculture is mostly export-oriented, most of the recovered resources would exit the local context and break the expected local circularity.	In general terms, participants agreed that no circular economy exists when water is used to irrigate vegetables that ended up in the rest of Europe. But they agreed that it is more sustainable in energy terms and environmentally friendly to grow vegetables in Almería than in the Netherlands

Aspects	Main issues identified in VSD	Stakeholder response to main issues
Sustainability Trade-offs	RES for ZLD and SWD creates a tension between the placing of desalination plants close to the coast and the use of land (e.g. land cost and tourism, impacts on wild-life).	When talking about decarbonization of the desalination sector, participants were convinced that only a large-scale thermal desalination plant coupled with concentrated solar power (CSP) plant can achieve decarbonization, since RO with photovoltaic (PV) panels could not be possible due to the prohibitive cost of PV batteries. However, some consider that thermal desalination would have disadvantages compared to reverse osmosis technologies, because the former has a larger land use. There is the feasibility of using desalinated water blended with brackish water extracted from aquifers that are affected by marine intrusion or contamination by irrigation effluents. Brackish water of the upper aquifer that sometimes overflows in some places, flooding greenhouses, must be pumped into the sea, which implies a high energy cost. Brackish water could be desalinated at a lower cost, although the recovery of nutrients would not be recovered within the scope of the WM CS2 system.
Water Ownership	Some actors highlight the fact that desalinated water is a public good, which should be used to improve the quality of life of the general population. On the other side, several actors point out that (thermal) desalinated water can foster the agricultural sector in the South of Spain (due to its higher availability for irrigation), which entails private benefits from a public good.	There was considerable agreement on the need to build different desalination plants for different uses and avoid the same desalination plant supplies farmers and urban uses. It was commented that those who use the water should pay the desalination plants, except for depressed areas or areas at risk of depopulation, where the investment should be public to promote the local economy. As well, some argue that desalinated water costs should be fairly distributed among users; subsidies and taxation should be considered to arrive to a more equitable scheme across regions. Current uses of desalinated water in Almería are 80% agricultural and 20% urban. Some argue that the desalinated water should be preferably used in the urban domain, because urban users can afford it and it is a priority. Regarding the question, who pays the investment costs of the technology? It would have to be public and little by little

Aspects	Main issues identified in VSD	Stakeholder response to main issues
		give way to the private sector, so competitiveness is increased. Some agreed that the "polluters pay" principle should be applied, while others argue that fiscal incentives should be applied to developing clean technologies. Others were more positioned in the line of subsidies and aid for clean technologies (e.g. subsidizing RES or taxing those desalinating water with fossil-fuels based electricity/heat).
Market uncertainties, Profitability	The positive effects of the CS system would depend on the amount of desalinated water and brine generation. If NaCl production is larger enough and cannot be consumed, then it will become waste.	*Not discussed in the CoP*

Table 3. Case study 3. Faro-Olhao. Main issues and values identified in the VSD process, and responses from stakeholders.

Aspects	Main issues identified in VSD	Stakeholder response to main issues
Affordability, Valorization, and User Acceptance	The processing costs of Kaumera add to the costs of the wastewater treatment plant (WWTP). The marketization of Kaumera is seen as a way to compensate for the cost and make a business case, or to even lower the sanitation service costs. However, this valorization perspective comes into tension with the idea to introduce Kaumera at low prices to improve its acceptability by farmers.	The price of Kaumera-based products compared to conventional ones is an important issue for stakeholders. Some stakeholders propose to introduce Kaumera in the market at low prices and, when better performance is proved, increase prices. Regarding user acceptance, there were concerns about the odour of the final product. As well, there are some concerns in the gel consistency of Kaumera (humidity level) and its suitability for soil applications. Both issues will be evaluated by WP3 in later stages of the project.
Local vs. Global Circular Economy, and Quality	The valorization of sludge by extracting Kaumera is seen as promoting a circular economy (e.g. local raw materials, industries, and jobs). At the same time, the vision of producing and supplying Kaumera globally, exploring higher-value markets goes beyond the local and leads to a tension with the vision of a local circular economy. Also, the possibility of a standardized global Kaumera supply and its desirability (the same quality for different agricultural uses) remain a question.	The possibility of producing Kaumera for exports is preferred among the participants of the CoP meeting. However, there were few attendees that prefer to keep Kaumera within the local environment.

Aspects	Main issues identified in VSD	Stakeholder response to main issues
Sustainability Trade-offs	The life cycle of Kaumera, including its extraction and processing as part of a final fertilizer product, implies some environmental impacts. These impacts imply a trade-off with the avoided impacts associated to the use of conventional agricultural products, including the compositing of sludge.	Most of the participants of the CoP meeting consider that Kaumera production has to have a positive impact on the reduction of CO_2 emissions.
Water and Resource Ownership	While the privatization of public resources (waste streams) can be a discussion point, it is considered that valorizing residue streams from the treatment of wastewater can support the reduction of the (public) wastewater treatment costs or incentivize the adoption of CE approaches for (a public) environmental benefit.	*Not discussed in the CoP*
Safety uncertainties: Legislation and Responsibility	Safety is regulated based on what is known, but CE innovations introduce new concerns like medicine residues in sludge and potential impacts (such as antibiotic resistance). Current legislations on sludge may lead to have no concerns on these issues, while on the other side, some questions arise: How can safety be ensured? What would be an acceptable risk if regulations are not up-to-date on some of these issues? What would be considered safe in foreseen WM Kaumera applications? Who´s responsible for safety in this innovation process then?	It was suggested to make a special effort to test, prove and certify the suitability of using Kaumera in organic farming (WWTP sludge cannot be used as organic fertilizer, for instance) given the fact organic farming is promoted at EU and country levels. This aspect is highly valued by most of the participants (These issues would be investigated in later stages of the project, within the corresponding WPs (WP3, WP10)). Also, some asked about the real meaning of "biodegradable" in the case of Kaumera and about the time/years required to be degraded.
Impact uncertainty	There is uncertainty regarding the CS impacts such as waste reduction, resource recovery, safety, economic performance, health and welfare, job creation, energy use and consumption of chemical compounds.	Some asked about the percentage of sludge reduction that occurs with the production of Kaumera (20 to 30% of the sludge is converted into Kaumera), and about the quality of remaining slude (slludge that is not converted to Kaumera), which needs to be further investigated.
Viability of Kaumera	Issue not identified in the first VSD stage, and appeared in the first CoP meeting.	There were several questions regarding potential difficulties to apply Kaumera into the soil (e.g. need of special machinery, humidity level, ability to be incorporated into the soil), due to its consistency and humidity. These doubts were clarified by explaining that Kaumera would be an ingredient of the fertilizers. However, some asked about the possibilities of using products with high moisture as solid fertilizers coating.

Aspects	Main issues identified in VSD	Stakeholder response to main issues
		Some request that the Kaumera-based fertilizers have to be liquid, or at least stable colloid solutions, in order to be able to be applied in the fruit orchards through the drip irrigation system. While others mentioned that semi-solid fertilizers could be used in the initial phase of soil preparation for planting trees in fruit orchards or annual crops (e.g., cereals).

Table 4. Case study 4. Larnaca. Main issues and values identified in the VSD process, and responses from stakeholders.

Aspects	Main issues identified in VSD	Stakeholder response to main issues
Valorization and User Acceptance	Some farmers are concerned about the impact of removing phosphorus from the water they currently use for irrigation. It is unknown if the phosphorus recovery will have an impact and, how much, considering their overall fertilizer needs. However, there are no other foreseen alternatives to prevent eutrophication in the water treatment and distribution.	Regarding the removal of phosphorus, most of the farmers agreed that they haven't faced any issue in the irrigation system due to the presence of phosphorus in the water. If removed during the process, they would like Phosphorus to be injected into the irrigation network without any additional fee, so they will be able to control the quantity of the phosphorus applied to their crops.
Efficiency and Long-term Sustainability	A possible consequence of providing extra water for farming emerges as a concern: instead of preventing groundwater extractions, extra water can result in a water consumption increase. That is, the supply of water with low salinity implies the risk that farmers change to more profitable crops that cannot be irrigated with saline water, possibly leading to higher freshwater demand.	Stakeholders' express concerns regarding potential increase in the water use due to higher availability of water. These can be controlled by the government by allocated certain amount of water to each farmer depending on the area irrigated and the kind of crops. In Cyprus, profitable crops are the vegetables which are irrigated with advanced irrigation systems (drop irrigation) which leads to water saving. Now, they are mainly irrigating fodder crops using sprinkler irrigation system, which leads to higher water demand.
	There is a tension between those supporting the development of a new technology to improve the system and those proposing to solve the problem before water arrives to the WWTP: avoid infiltration of salty water in the sewage system.	For several years, the sewage board of Larnaca (the owner of the sewage network) has put a great effort to control infiltration of seawater into the network. Unfortunately, there are still some intrusions since the network is lying within the sea water table. The only way to alleviate the problem is to increase the number of the areas served by the network which are in the areas with more dry ground.

Sustainability Trade-offs	There are on-going efforts for the installation of solar panels on-site, which can cover a fraction of the WWTP energy requirements. However, there is a tension with the use of space for RES as the CS is in a Natura 2000 area and close to an airport.	All the stakeholders agreed that the use of renewable energy sources will be a very good and attractive solution. There is the possibility of installing the RES far away from the WWTP, near the reservoir where the water will be stored. This possibility is to be explored.
Reliability-Flexibility	The system is designed to treat current salinity concentrations in the wastewater. However, other measures are proposed to solve the problem, such as avoiding seawater intrusion to the system.	See previous answer.
Water affordability	Issue not identified in the first VSD stage, and appeared in the first CoP meeting	The main problem that would arise during the promotion of the water treatment system in the market is its cost. The current price of water, which is distributed for agricultural use, is very low. But by adding the proposed process the cost of water would rise, so the government should subsidy the WWTP's.

Table 5. Case study 5. La Llagosta. Main issues and values identified in the VSD process, and responses from stakeholders.

Aspects	Main issues identified in VSD	Stakeholder response to main issues
Distributive Justice	There is a question about how costs and benefits should be distributed between, e.g., the industry, the end-user and the general population, considering potential uses of the recovered water and regional water plans.	The water treatment costs and the water price is a very relevant issue for the stakeholders. Some argue that costs must be translated into the price of water, raising awareness on its importance. Also, it is considered that water price should vary depending on its use (domestic, urban, industrial, etc.). Although prices do not have to be equally distributed, it is desirable that all the costs are translated to the users. But this is seen as something that will cause a lot of social resistance and opposition. As end-users are not the only beneficiaries of using these technologies, the costs can be distributed between actors considering the use given to water.
Efficiency and Long-term Sustainability	The reuse of water and recovery of phosphorus can increase the circularity of the system and potentially also its sustainability. However, it can also be seen as a net gain of resources, with the risk to lead to higher resource consumption and a worse environmental balance than before implementing the innovative technologies.	Regarding the potential increase in water use, stakeholders propose to implement discount bonus on sustainable consumption (in contrast with classic measures based on penalizations), raise awareness on the effect of high consumption levels and implement adequate regulation and control schemes; for instance, not renewing existing water allocations when a new source is available.

Aspects	Main issues identified in VSD	Stakeholder response to main issues
	WWTP are seen by some as an end-of-pipe solution, and there are demands for pollution prevention.	*Not discussed in the CoP*
Local vs. Global Circular Economy	A question emerges on the limits of what circular means. For example, is it considered circular to have a fertilizer produced from recovered phosphorus in La Llagosta and being used or exported in agricultural products around the world?	To boost local circularity, legal changes are needed to allow the reuse of sludge coming from WWTP as fertilizer. Also, there is a generic recommendation on adapting the technologies to the local context where they are implemented, so they will be much more "useful".
Water and Resource Ownership	There are some tensions in the expectations of on who is going to manage and benefit from the recovered resources, as well as intellectual property, especially considering that the WWTP is a public utility and the project received public funds.	*Not discussed in the CoP*
Quality-Cost	Higher qualities imply higher production costs, and because the required amounts and qualities for water re-use is not fully known, it is uncertain if all process steps (to improve water quality) are necessary.	Technologies must be adapted to their local context, need to know the qualities required by the different end-users.
Conflicting duties	Recovering water is seen as a potential driver to boost circular economy, but at the same time it is noted that the main objective of the WWTP must be, according to the Water Framework Directive, helping achieve good qualitative and quantitative status of all water bodies. This is a tension about where the main efforts are put.	Need to raise awareness on the role of the WWTP.

Table 6. Case study 6. Rotterdam. Main issues and values identified in the VSD process, and responses from stakeholders.

Aspects	Main issues identified in VSD	Stakeholder response to main issues
Efficiency and Long-term Sustainability	The epoxy production prosses raises several sustainability concerns, and there is potential for lock-in effects with the CS, slowing the uptake of renewable resources, and/or the prevention of the use and/or disposal of substances of concern. While project partners foresee no risk about switching to renewables, and chlorine would be recirculated in an almost-closed industrial loop, uncertainties remain on the effects of the proposed system on changing the epoxy process and its long-term sustainability impacts.	*Not discussed in the CoP*
Safety and Quality Uncertainties	There are safety concerns relate to the use and release of high salinity streams and substances of concern (e.g. toxic or cancerogenic) to the environment. With the brine product entering in an industrial loop, safety concerns seem mostly operational. Other concerns are about the quality of the product for industrial use, and relate to the type, fate, and concentration of organics.	*Not discussed in the CoP*
Safety and Responsibility	In the case of using recovered salts for road de-icing, the distribution of risks and responsibilities related to the recovery, transport, and use of the brine product would be an issue. Some have concerns with regard operational risks (e.g. leakage and handling risks within the industrial loop), together with other potential safety risks in the chlor-alkali process, prominently the handling of chlorine.	An alternative brought forward by stakeholders was that the transport costs (and, in that case, leakage risks) could be reduced by bringing the brine use (i.e. electrolysis) into the Hexion site.

3.2. Phase 2 of VSD Process

In this section, the technical scenarios developed for each CS are described. As mentioned before, the scenarios are built to incorporate value tensions and uncertainties in the development of WATER MINING technologies.

This section also presents the feedback to technical scenarios from stakeholders, collected in the CoP meetings (CS1 and CS2), and the preliminary outputs of the behavioral studies (CS1 and CS3) and the upcoming work within T2.2.

3.2.1. Case study 1. Lampedusa

a) Technical Scenarios

Considering the identified tensions and the scope of the CS1 WM system, it was decided to develop the technical scenarios around the tension between water security, resource security and sustainability. Therefore, while all scenarios aim to use waste heat to increase water recovery and reduce brine discharge (compared to typical seawater desalination, SWD), they do so differently.

Table 7. Technical Scenarios developed for Case Study 1 in Lampedusa

Scenario	1	2	3	4
	RO-Integrated Scenario	WATER-MINING Scenario	Water Recovery Scenario	Mg Scenario
Technologies	RO + Scenario	NF, MED, ThCryst, MFPR, EFC, EDBM	NF, MED, ThCryst	NF, MED, EvPond, MFPR, EDBM
Products	Ca(OH)2, HCl, Ice, Mg(OH)2, NaCl, NaOH, Na2SO4, Water	Ca(OH)2, HCl, Ice, Mg(OH)2, NaCl, NaOH, Na2SO4, Water	Water, Mixed salts	Ca(OH)2, HCl, Mg(OH)2, NaCl (lower purity), NaOH, Water

EDBM: Electrodialysis with bipolar membranes; EFC: Eutectic freeze crystallization; EvPond: Evaporation Pond; MED: Multi-effect distillation; MFPR: Plug-flow reactor; NF: Nanofiltration; RO: Reverse Osmosis, ThCryst: Thermal crystallizer

Scenario 1

This scenario is aimed at maximizing water and resource recovery as integrated to a typical desalination plant (with Reverse Osmosis, RO).

The mainstream entering the treatment chain is seawater. This seawater stream first goes to the RO unit which represent the existing RO plant in Lampedusa. RO unit recovers 40% of the water and the RO concentrate goes to NF unit. The NF unit separates the inflow into two different streams: the permeate high in monovalent ions, and the concentrate that is high in multi-valent ions. The former is directed to a process line of conventional units, including the MED unit that obtains water from the evaporation process. Following this unit, the stream goes to a thermal crystallizer to finally obtain NaCl crystals. The latter stream from nanofiltration, high in multi-valent ions, is directed to a treatment line comprising three innovative units: selective magnesium and calcium crystallizer (MF-PFR), the EFC and EDBM units.

In particular, the concentrate is sent to the MF-PFR in which magnesium and calcium are recovered in the form of hydroxide precipitates via a chemical reaction between the NF concentrate and an alkaline reactant. Then brine stream free from Mg^{2+} and Ca^{2+} goes to the EFC unit where Na_2SO_4 and water in form of ice are recovered. The remaining solution is a NaCl rich stream and is fed to EDBM. Overall, this treatment chain represents a ZLD desalination (ZLDD) system aiming to maximize freshwater recovery and to recover valuable resources from brine, such as NaCl, $Mg(OH)_2$, $Ca(OH)_2$, Na_2SO_4, HCl, NaOH. The recovered HCl and NaOH are reused in the treatment chain. NaOH is the alkaline reactant is MF-PFR and HCl is used to neutralized the pH.

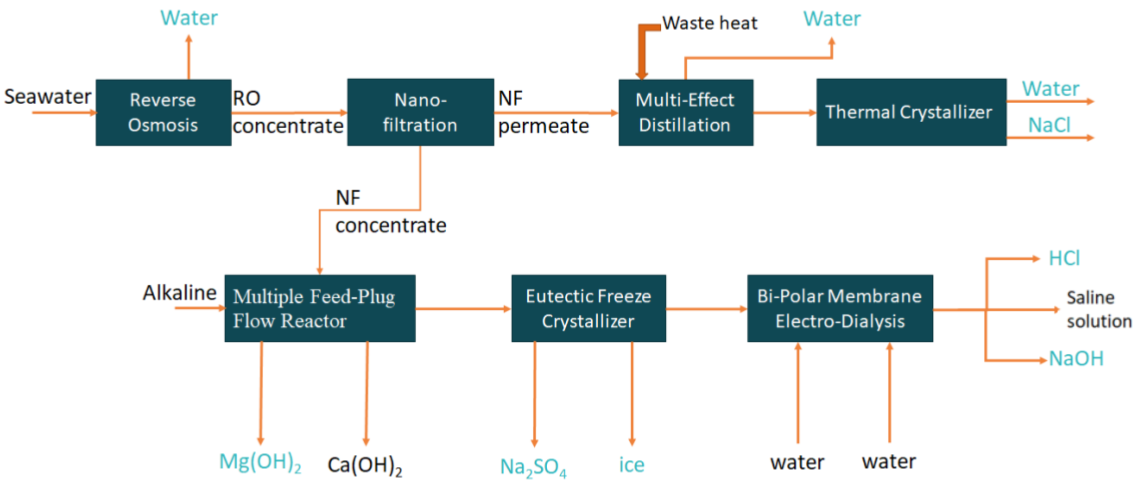

Figure 3.Process flow diagram of Scenario 1.

Scenario 2

This scenario does the same than Scenario 1, but as a stand-alone facility (no RO). The mainstream entering the treatment chain is seawater. This seawater stream first goes to the NF unit to be separated into two different streams: the permeate with high in monovalent ions, and the concentrate that is high in multi-valent ions. The former is directed to a process line of conventional units, including the MED unit that obtains water from the evaporation process. Following this unit, the stream goes to a thermal crystallizer to finally obtain NaCl crystals. The latter stream from nanofiltration, high in multi-valent ions, is directed to a treatment line comprising three innovative units: selective magnesium and calcium crystallizer (MF-PFR), the EFC and EDBM units. In particular, the conentrate is sent to the MF-PFR in which magnesium and calcium are recovered in the form of hydroxide precipitates via a chemical reaction between the NF concentate and an alkaline reactant. Then brine stream free from Mg^{2+} and Ca^{2+} goes to the EFC unit where Na_2SO_4 and water in form of ice are recovered. The remaining solution is a NaCl rich stream and is fed to EDBM. Overall, this treatment chain represents a ZLDD system aiming to maximize freshwater recovery and to recover valuable resources from brine, such as NaCl, $Mg(OH)_2$, $Ca(OH)_2$, Na_2SO_4, HCl, NaOH. The recovered HCl and NaOH are reused in the treatment chain. NaOH is the alkaline reactant in MF-PFR, and HCl is used to neutralized the pH.

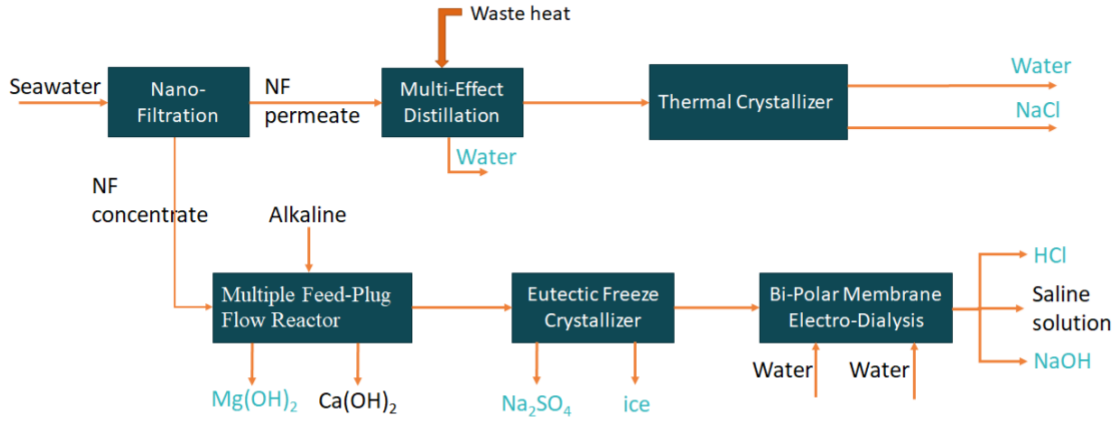

Figure 4. Process flow diagram of Scenario 2.

Scenario 3

This scenario focuses only on water recovery to keep energy requirements low. The mainstream entering the treatment chain is seawater. This seawater stream first goes to the NF unit to be separated into two different streams: the permeate with high in monovalent ions, and concentrate that is high in multi-valent ions. The former is directed to a process line of conventional units, including the MED unit that obtains water from the evaporation process. The NF unit is used to as pre-treatment for MED to increase the performance of the unit. Following this unit, the stream goes to the thermal crystallizer and mixed with the latter stream from nanofiltration, high in multi-valent ions to finally obtain water and mixed salt (low purity NaCl crystals).

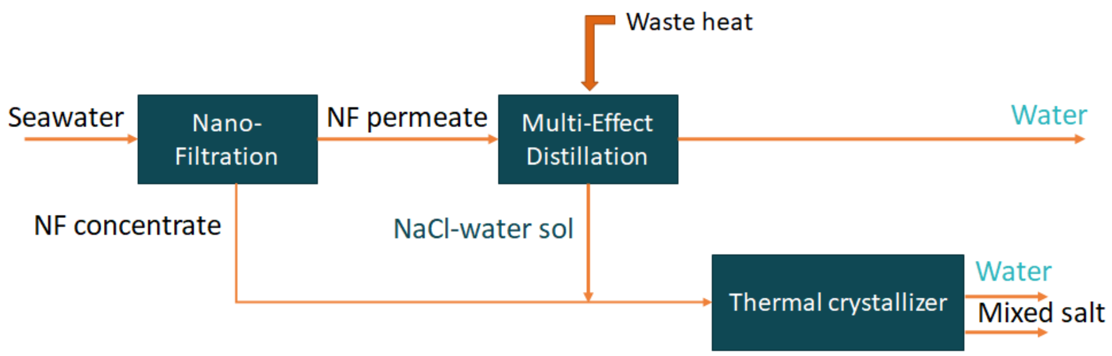

Figure 5. Process flow diagram of Scenario 3.

Scenario 4

This scenario balances water and resource recovery with electricity requirements. The mainstream entering the treatment chain is seawater. This seawater stream first goes to the NF unit to be separated into two different streams: the concentrate that is high in multi-valent ions, and the permeate with high in monovalent ions. The former is directed to a treatment line comprising three innovative units: selective magnesium and calcium crystallizer (MF-PFR) and EDBM units. In particular, the concentrate is sent to the MF-PFR in which magnesium and calcium are recovered in the form of hydroxide precipitates via a chemical reaction between the NF retentate and an alkaline reactant. Then brine stream free from Mg2+ and Ca2+ goes to a nanofiltration unit where he remaining solution is concentrated further. The NaCl rich stream is fed to EDBM and the permeate goes to the MED unit.

Regarding the EDBM unit, lower molarity chemicals are recovered and the saline solution is recycled to the thermal crystallizer. The latter stream from nanofiltration, high in monovalent ions is directed to a process line of conventional units, including the MED unit that obtains water from the evaporation process. Following this unit, the stream goes to a thermal crystallizer to finally obtain NaCl crystals. Overall, this treatment chain represents a ZLDD system aiming to maximize freshwater recovery and to recover valuable resources from brine, such as NaCl, $Mg(OH)_2$, $Ca(OH)_2$, HCl, NaOH. The recovered HCl and NaOH are reused in the treatment chain. NaOH is the alkaline reactant is MF-PFR and HCl is used to neutralized the pH.

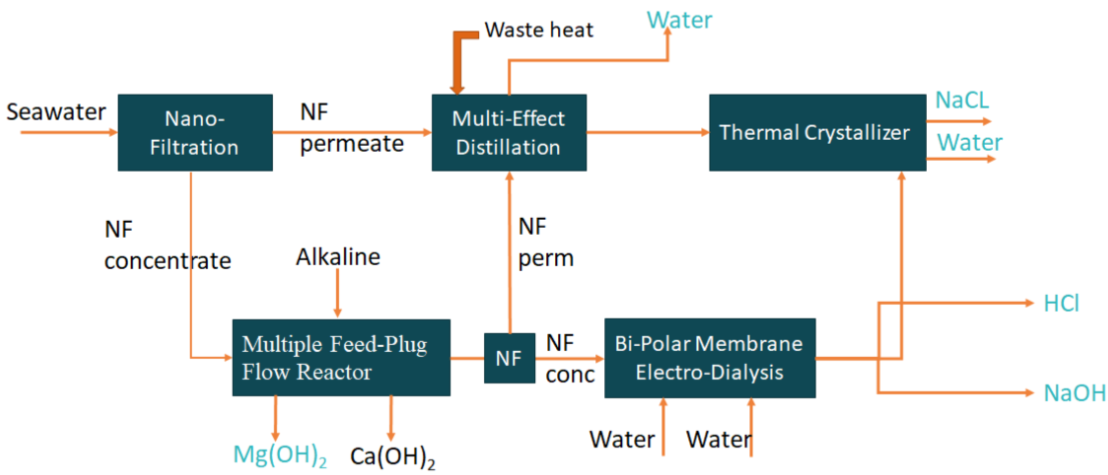

Figure 6. Process flow diagram of Scenario 4.

b) Estimated performance of Technical Scenarios

The following Table 8 presents the estimated performance of the technical scenarios according to a set of indicators derived from the social values and value tensions identified during the VSD process (Palmeros-Parada et al., 2021).

. As it can be seen, Scenario 3 performs better under most of the indicators, but on water production, which is the main objective of this scenario (together with keeping energy consumption low). However, its specific energy consumption and CO_2 emissions (per m^3 of distilled water) present the lower values among the scenarios.

Scenario 1 produces the higher amount of desalinated water. The RO system consumes higher amounts of electricity and lower amounts of thermal energy, which implies larger CO_2 emissions. And despite the lower OPEX, its economic margin relegates it to the least profitable.

Scenario 4 presents the largest CAPEX and OPEX. Despite the high investments required, this scenario is the more profitable with the higher economic margin thanks to the possibility of recovering and selling Mg.

Overall, Scenario 2 presents a more balanced performance, with a large thermal energy consumption, due to the reliance on waste heat to power the thermal technologies.

Table 8. Summary of results of the evaluation of technical scenarios in CS1.

Indicator	Unit	Direction	Scenario 1: Integrate RO plant with brine treatment	Scenario 2: Water mining case study	Scenario 3: Water recovery	Scenario 4: Mg recovery
Water production	kg/year	↑	1,35E+05	1,31E+05	1,23E+05	1,28E+05
Electricity consumption	KWh/year	↓	1,39E+03	9,89E+02	6,91E+02	1,15E+03
Thermal energy consumption	KWh/year	↓	2,11E+05	3,44E+05	2,11E+05	3,58E+05
CO_2 emissions*	kg/year	↓	2,76E+06	1,96E+06	1,37E+06	2,28E+06
OPEX	€/year	↓	1,38E+07	1,76E+07	1,51E+07	2,09E+07
CAPEX	€	↓	3,45E+07	3,02E+07	2,93E+07	5,17E+07
Economic margin	€/m^3 distillate water	↑	0,08	0,10	0,11	0,15
Specific energy consumption	kWh/m3		10,3	7,5	5,6	9,0
Specific thermal energy consumption	MWh/m3		1,56	2,63	1,72	2,80

*Note: Direction has two options: For maximizing higher is better, and for minimizing lower is better. *Emissions associated to energy use within the process and transportation of brine.*

The figures of specific energy consumption should be considered with caution. As the overall energy consumption of the scenarios is a result of the energy consumption of individual components of the system, non-linearity may exist when up- or downscaling water production.

c) CoP Discussion

The scenarios and its preliminary evaluation (in collaboration with WP3 project partners) was brought for discussion to the CoP hosted online on Tuesday January 31st. Discussion groups were formed with participants, and the feedback per discussion group was:

Group 1: from an energy efficiency point of view, **scenario 1** is the most practical one. Using reverse osmosis to produce fresh water is the safest option in terms of known technology and performance, and best with respect to efficiency. Considering the plant is at Lampedusa, however, this plant does not need to produce much chemicals as there are no large industries. So, a low scale desalination plant, with small land usage, is best for Lampedusa – like **scenario 3**. Taking into account other stakeholders' perspectives, e.g. civil servants or environmental protection agencies, they would prefer plants with an environmentally friendly approach with an application of the notion of the circular economy. This could also be an advertisement for Lampedusa itself.

Group 2: two scenarios were considered, **1 and 3**. These were considered the best due to economic factors and CO_2 emissions. But after discussion, **scenario 3** was considered the best, lowest CO_2 emission so from an environmental perspective this would be the best one. But, considering economic margins, this scenario does not provide the best economic revenues and resources – capital and operating costs. Furthermore, the treatment chain of this scenario lends itself best for installing outside of Lampedusa, mostly due to the economic factors and CO2 emissions.

Group 3: **scenario 3** was considered the best due to energy efficiency. Also, **scenario 1** was considered. **Scenarios 4 and 5** were also interesting but because of the lack of industry on Lampedusa, these were not considered viable options.

Overall, participants seemed to agree that in the context of Lampedusa, where there are no industrial users for chemicals, scenario 3 is preferred, and it could include RO to improve its energy efficiency (need depending on the amount of waste heat available). In other locations, scenarios 1, 4 and 5 with the recovery of chemicals (and integrated to RO) are considered a good alternative in terms of economics and environmental impacts (circularity and emissions).

It is interesting to notice that, thorough the discussion of the technical scenarios, stakeholder discussed about some issued not tackled in the first CoP meeting (See Table 1), such as the tension between ZLD, energy and economic costs, and the possibility of valorising recovered salts. As well, the possibilities of increasing water consumption by increasing water availability was discussed and some policy measures were proposed.

The issue of the ownership of seawater was not raised in the discussion, and it will be brought up in the last CoP meeting.

d) Usefulness and Attitude Change Survey

Participants to the CoP meeting in Lampedusa were invited to fill in the survey (see Appendix A). However, despite multiple requests to fill in the survey and providing participants time to do so during the online meeting, only 8 participants filled in part 1 of the survey, and 1 person filled in part 2. Based on the derived data, no changes in behaviour or attitude can be observed.

Respondents were asked to what extent they associate this project and/or the derived products with certain aspects (see Table 8). These included, amongst others, to what extent stakeholders associate CS1 with circularity, local production and consumption, equal sharing of revenues and use of renewable energy. As already mentioned in Section 2.2.2, these aspects were derived from literature and deliverable 2.6. In order to observe any changes in stakeholders' perceptions and associations with CS1, respondents were asked to fill in this part of the survey both at the beginning of the CoP meeting (part 1), and at the end of the meeting (part 2). This way, any differences could be identified in terms of the weight assigned to either of the listed aspects as a Likert Scale was used with 1 being no association, and 5 being an extremely high association. Unfortunately, as only 1 person filled in part 2 of the survey, no significant changes in stakeholders' associations could be observed.

However, when only taking into account part 1 of the survey in which respondents provided their initial associations, we can observe differences in terms of stakeholders' associations of CS1 with regard to several aspects (Table 9). In this Table, the total weight and average of each aspect is indicated. The total weight represents the extent stakeholders associated an aspect with CS1, with 40 being the maximum (8 respondents x 5 - having an extremely high association), and 8 (8 x 1 - no association). So, Table 8 illustrates which aspects are the most and least associated with CS1. This shows that a circular product is associated the most (total weight of 24) and equal sharing of revenues the least (total weight of 9). This is also illustrated by the average weight of 1.8 for equally shared revenues and 4.0 for it being circular products.

The results provided above seemingly contrast to the conclusion from the CoP discussions (Section C above) that highlights the importance of the context of implementation. That is, despite the importance that respondents give to circularity and environmental impacts and how much they associate the WM system (pilot) to these aspects, for the Lampedusa context they nevertheless suggest a water recovery focus as in Scenario 3.

Table 9. Overview and averages from the Usefulness and Attitude Change survey for CS.1 For the evaluation, a Likert scale has been used to show the extent of association of CS 1 with the following aspects. Thereby, 1 = not at all, 2 = slightly, 3 = somewhat, 4 = very, and 5 = extremely.

Associations of CS1 with several aspects	Circular Product	Local production and consumption	Environmental impact	Consistent quality	Safety of sec. processes
Total weight	24	20	22	22	16
Average	4	3.3	3.7	3.7	2.7
	Sustainable water use and management	Equal sharing of revenues	Affordable price of rec. water	Affordable price of rec. product	Use of renewable energy
Total weight	21	9	16	18	19
Average	3.5	1.8	2.7	3.0	3.2

3.2.2. Case study 2. Almeria

a) Technical Scenarios

The following value tensions emerged during the first steps of the VSD process, which have been considered to develop a set of technical scenarios. According to these tensions, we have developed the technical scenarios in Table .

- Affordability, distributive justice and societal acceptance: ZLD is expensive, and it raises the question of who pays it.
- Sustainability trade-offs: tension between the placing of desalination plants close to the coast (land competition with other economic activities) and extensive land use of renewables. As well, there are some tensions between ZLD, land use (of thermal energy) and the use of fossil fuels based electricity (and CO_2 emissions) to desalinate water.
- Market uncertainties, profitability: If NaCl production is larger enough and cannot be consumed, then it will become waste. As well, low price of water and NaCl can hinder the economic viability of the proposed technology.

Table 10. Technical Scenarios of Case Study 2 in Almeria

Scenario	1	2	3	4	5
Process	ZLD	MLD	MLD	RO-MLD	RO+Thermal-ZLD

Scale & location	large scale, inland	large scale, inland	small scale, seaside	Typical SWD scale, seaside	Typical SWD scale, inland

MLD: Medium liquid discharge, in this case it refers to not recovering NaCl; ZLD: Zero liquid discharge, in this case it refers to the recovery of NaCl from the MED brine; RO: Reverse Osmosis, ThCryst: Thermal crystallizer

To develop the scenarios, the following issues were also considered:

- Large-scale desalination plants are more suitable inland to be coupled with a concentrated solar power plant.
- Small scale plants would be scattered in the landscape, so it can be considered one big transport system to a common seawater storage tank and a distribution system to e.g. three desalination plants.
- Scenarios do not consider the pretreatment processes before the NF. In terms of comparison with the benchmark scenario, it is considered that both the RO and the NF+MED processes would need similar pretreatment of seawater.

Scenario 1. ZLD – Large scale – Inland

This scenario (Figure 7) is aimed at processing 30.000 m^3/day of seawater. Water would be transported 20 km inland, and 100 meters above the sea level (a.m.s.l). The scenario considers a nanofiltration process to extract divalent ions from seawater. This allows the MED to increase the operation temperature and reach a recovery ratio of 86%. Then, a thermal crystallizer would treat the MED concentrate (followed by a filtration process) to produce pure NaCl. A mixer would add part of the NF rejection to the MED distillate to produce irrigation water (containing divalent ions which perform as crops' fertilizers). The scenario does not consider the treatment of NF wastewater, which is assessed in terms of waste generation (i.e., amount of released wastewater from the NF).

In this case, the energy consumption of the NF unit based on the osmotic pressure needed to pass through the NF membrane was calculated. As this energy consumption can be reduced by incorporating energy recovery devices, as in RO systems (Mirza 2008), a net energy consumption of about 40% of the calculated values was considered (See section Scenario 4. Benchmark RO).

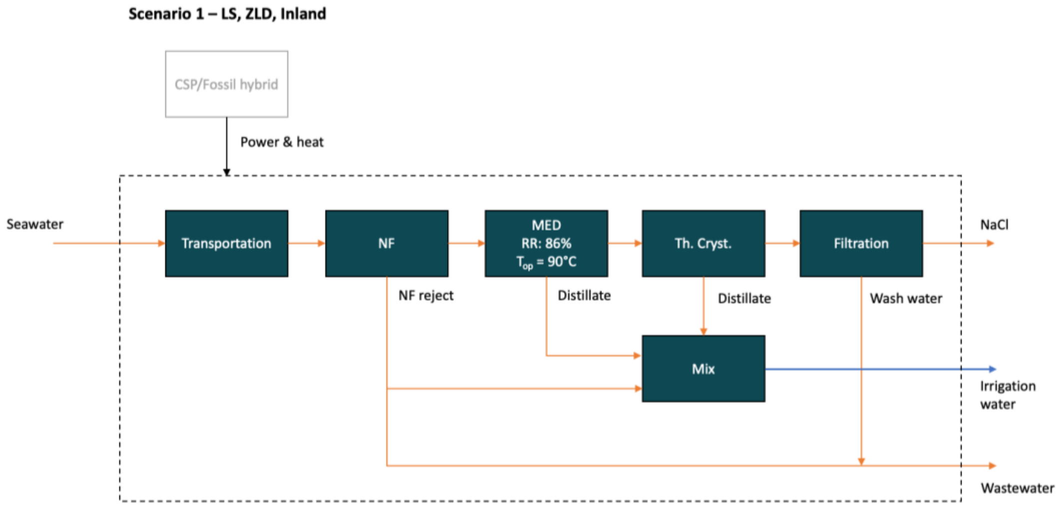

Figure 7. Scenario 1, CS2.

Scenario 1.1. Large scale – Thermal ZLD – Inland

As the reader will see in the results section, Scenario 1 generated an important amount of wastewater (i.e. NF reject), therefore ZLD is not met. To do so, based on thermal technology, it would be necessary to add a second "MED + Thermal crystallizer" step. This scheme is shown in Figure 8. There, large part of the NF rejection goes to the second MED system. The second MED operates at 38% of recovery rate, @70°C, due to the presence of divalent ions that can produce scaling in the MED. As the NF rejection contains salts other than NaCl, the rejection of the filtration process is a water with high content of mixed salts, but NaCl.

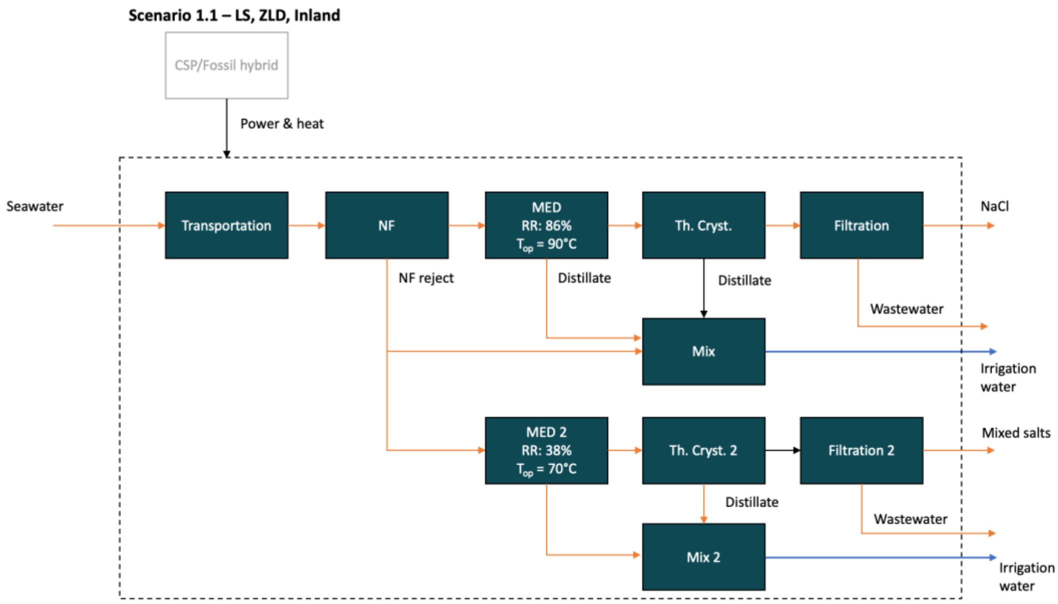

Figure 8. Flow diagram Scenario 1.1.

Scenario 2. Large scale – Inland

This scenario (Figure 9) would also process 30.000 m^3/day of seawater. Water would be transported 20 km inland, and 100 meters a.m.s.l. The scenario considers a nanofiltration process to extract divalent ions from seawater, so the MED would reach a recovery ratio of 86%. A mixer would add part of the NF rejection to the MED distillate to produce irrigation water, and the brine from the MED and NF rejection would be managed afterwards. The brine treatment process is not considered in the evaluation of the scenario, which is assessed in terms of waste generation (i.e., amount of released brine and wastewater from the NF).

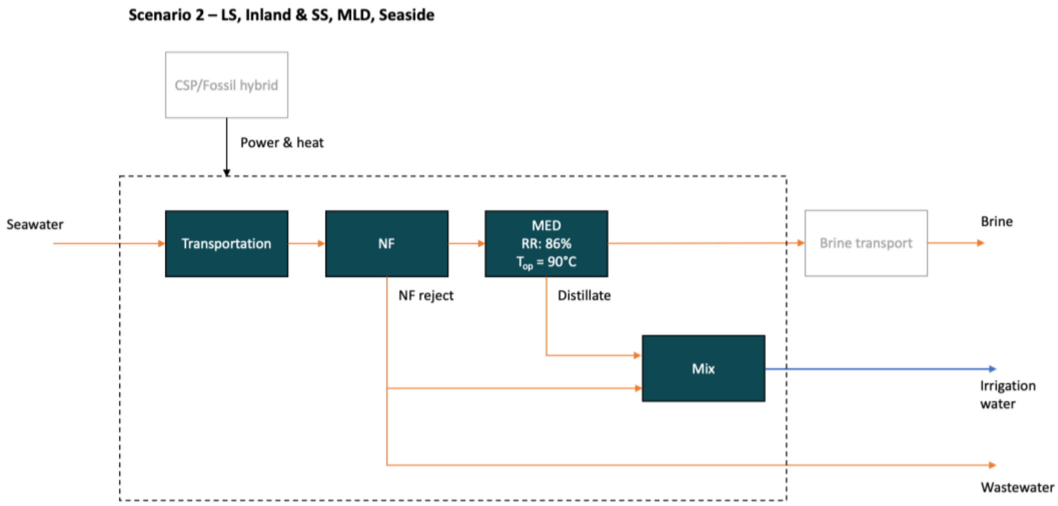

Figure 9. Flow diagram Scenario 2

Scenario 3. Small scale – Seaside

This scenario (Figure 10) would also process 30.000 m^3/day of seawater, distributed in 3 desalination plants. Water would be transported an average of 5 km inland, and 50 meters a.m.s.l. The scenario considers a nanofiltration process to extract divalent ions from seawater, so the MED would reach a recovery ratio of 86%. A mixer would add part of the NF rejection to the MED distillate to produce irrigation water, and the brine from the MED and NF rejection would be managed afterwards. As in the previous scenarios, the brine treatment process is not considered in the evaluation of the scenario, which is assessed in terms of waste generation (i.e. the amount of released brine and wastewater).

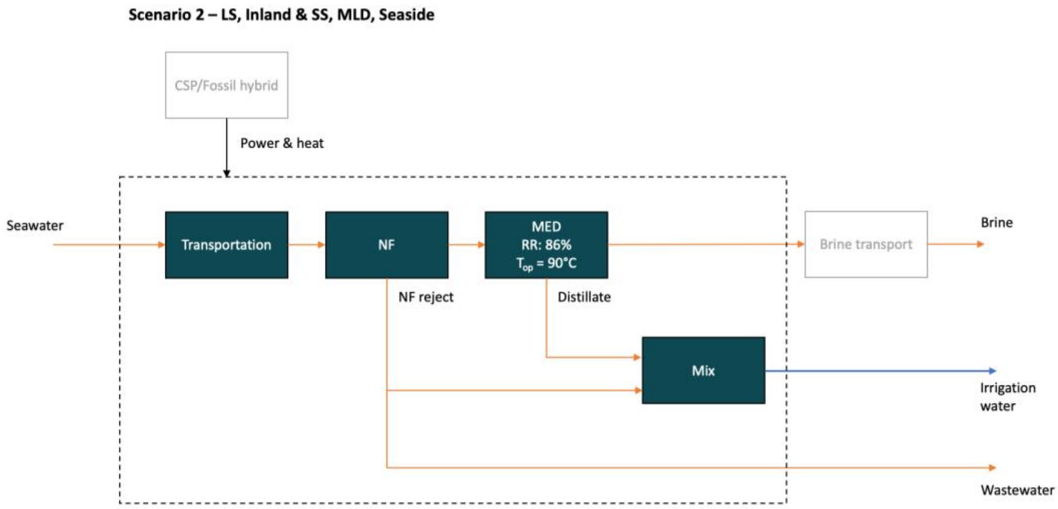

Figure 10. Flow diagram Scenario 3

Scenario 4. Benchmark RO

This scenario considers a RO desalination process located seaside, without brine treatment. It also considers processing 30.000 m^3/day of seawater, which would be transported 5 km inland, and 50 meters a.m.s.l. According to the literature, an RO process has an energy consumption of about 4,4 kWh/m^3 and a recovery rate of 50% (Antonyan 2019). The energy consumption of the RO itself is about 60-85% of the energy consumption of the whole process. Pumping, pre-treatment and brine discharge account for about 15-40% of energy consumption. These values of RO energy consumption are the results of implementing energy recovery devices, which can reduce energy consumption of the plant from 6-8 kWh/m^3 to 4-5 kWh/m^3 (Khawaji et al., 2007). According to Kim et al. (2019), the specific energy consumption of SWRO plants with high efficiency energy recovery devices is about 3,5 – 4,6 kWh/m^3, and the SEC of the plant is about 1 kWh/m^3 higher than the SEC of the RO system. Therefore, it can be considered that the SEC of a high efficiency RO system would be about 2,5 – 3,5 kWh/m^3.

As in other scenarios, brine treatment process is not considered in the evaluation of the scenario, which is assessed in terms of waste generation.

Scenario 5. RO – ZLD

This scenario (Figure 11) incorporates a MED and Thermal Crystallizer to avoid brine release. The RO plant would be located inland to be coupled with the thermal technologies. After some simulations, it has been realized that including a NF process to increase the MED recovery ratio to 86% would produce high salinity slurry, which would surpass the processing capacity of the Thermal crystallizer. Therefore, it was decided not including the NF and considering a MED recovery rate of 38% (@70°C). Then, part of the RO rejection would be mixed with the MED distillate to produce irrigation water.

Scenario Benchmark RO – ZLD

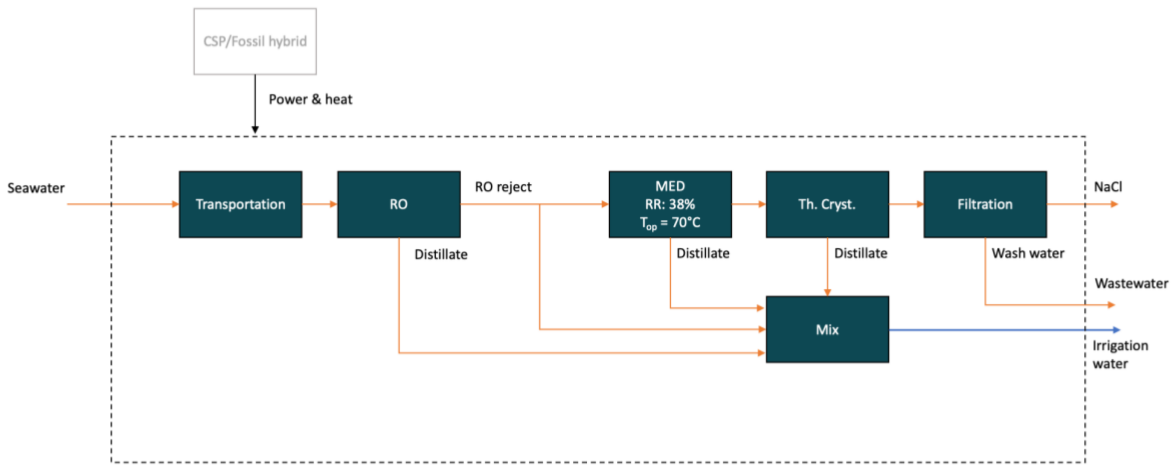

Figure 11. Flow diagram Benchmark scenario RO – ZLD

b) Estimated performance of Technical Scenarios

In this section the results of Scenario 1 are explained. Then, the main variations in the other scenarios are highlighted.

As the NF efficiency is 80%, 24.000 m^3 out of 30.000 m^3 goes to the MED. The NF would consume about 0,2 GWh (8,3 kWh/m^3). But considering the energy recovery devices, the energy consumption can be decreased to 3,3-3,5 kWh/m^3. Then, the MED would produce 20.500 m^3 of distillate, by consuming 1,22 GWh of thermal energy (~59 kWh/m^3). Then, the thermal crystallizer would produce 3.100 m^3 of distillate (@20°C) and about 1,3 tones of NaCl. Finally, the mixer would produce 23.200 m^3 of irrigation water, which incorporates ~3% of the NF reject. That means there would be about 6.000 m^3 of wastewater with a salinity of about 8%. This NF reject could be treated in a MED, but at different operating conditions (e.g. @70°C and recovery rate of 38%) to avoid scaling that would be produced by divalent ions (Scenario 1.1).

Table 10 presents the outcomes of the different scenarios. Scenario 3, small scale near the seaside, is not included here. The outcomes of that scenario are similar to those of scenarios 1 or 2 (depending if ZLD is considered or not) in terms of energy consumption. The main differences would be when calculating the capital investment (CAPEX) and operational investment (OPEX), since what really changes is the number and size of necessary equipment (pipes and pumps of distribution and storage system, for instance).

As it can be seen in Table 9, Scenario 1 performs well in most of the indicators, but in the production of wastewater. This is because a small fraction (~3%) of the NF reject is necessary to produce irrigation water. In general terms, and as can be expected, ZLD implies higher energy consumption, which translates in CO_2 emissions and land use (Scenarios 1.1 and 5). CO_2 emissions have been calculated considering the Spanish electricity mix, and could be reduced by implementing solar electricity production, which would increase land use.

In any case, if one wants to achieve ZLD, the thermal technology (scenario 1.1) presents some advantages with regard the RO-ZLD scenario (5). As electricity consumption, CO_2 emissions, thermal requirements and land use are somewhat similar, Scenario 1.1 would produce less NF rejection and large NaCl. This would reduce costs of managing wastewater and increase income by selling NaCl, improving the economic performance of the thermal technology.

Table 91. Performance of different scenarios of CS2

Indicator	Unit	Direction	1.- LS / Thermal / NaCl / Inland	2.- LS / Thermal / Inland	4.- RO / Seaside	5.- RO / ZLD / Seaside	1.1.- LS / ZLD / Inland
Amount of treated water	[m³/d]		30.000	30.000	30.000	30.000	30.000
Volume of irrigation water	[m³/d]	↑	23.200	20.200	15.400	28.950	28.000
Thermal energy consumption	[GWh/d]	↓	2,24	1,22	0	2,96	3,23
Land use	[Km²]	↓	0,45	0,24	0,00	0,59	0,65
Electricity consumption	[MWh/d]	↓	128	127	121	129	131
CO_2 emissions	[TCO_2 eq]	↓	33,2	32,9	31,3	33,4	33,9
Brine generation	[T/d]	↓	0	4.300	15.450	0	0
Wastewater	[m³/d]	↓	6.000	5.800	0	350	180
NaCl production	[T/d]	↑	1.280	0	0	1.530	1.785
Specific energy consumption	kWh/m³		**5,52**	**6,29**	**7,86**	**4,46**	**4,68**
Specific thermal energy consumption	MWh/m³		**0,10**	**0,06**	**0,00**	**0,10**	**0,12**

The figures of specific energy consumption should be considered with caution. As the overall energy consumption of the scenarios is a result of the energy consumption of individual components of the system, non-linearity may exist when up- or downscaling water production.

c) CoP discussion

These results have been brought to discussions with stakeholders in the last CoP meeting in Almeria, on the 21st of February, 2023. The main ideas raised in the discussion are the following:

- The technical scenarios are too generic. The evaluation of desalination systems depends on specific context in which they will be installed. For instance, different altitudes of the location of the inland SWD plant should be studied.
- Brine and wastewater generated in inland systems should be treated to avoid costs associated to disposal in the sea (which is the current practice).
- The cost of extensive land use by thermal energy can be unacceptable. Above all, in coastal areas. This would increase investment costs of the plant, which would make if unviable in economic terms. If that is the case, it would become very important to valorize the streams by, for instance, recovering Mg to make a business case of thermal systems.
- Small SWD plants would provide flexibility and resilience in case of failures in a plant. If one plant stops, there would be more plants to supply water. This alternative would have higher

CAPEX due to the use of more and smaller equipment, and to invest in storage and distribution systems.

- The amount of NaCl produced is too large and can become a waste to be managed. In fact, NaCl production of the proposed scenarios would be about 40-60% of total amount of sea salt produced in Spain.
- The higher cost of the water should be paid by who uses it. In this case, the farmers. Subsidies to private companies should be limited and the polluter pays principle should apply. That means that the cost of avoiding or managing brine should be included in the price, as well as the higher cost on implementing thermal technologies. However, some stakeholders mentioned that farmers work with little economic margin, and this may imply a risk to the economic viability of their businesses.
- As Almería is a water stressed regions, there should be a balance btween covering water demand and minimize impacts. In some cases, disposal of brine into the sea is not seen as a problem if the regulations are met. In this sense, some stakeholders do not consider brine discharge to be an issue if well managed. They argue that releasing brine far out into the sea and using well designed diffusors would avoid impacts of marine life and ecosystems. Other stakeholder consider brine release as a potential problem for the future, in the sense that brine discharge may imply accumulative impacts on the marine environment with effects at long term.
- Membrane distillation should be considered as an alternative to MED. These systems can reduce the requirements of thermal energy and land use compared to the systems considered in this CS.
- As land use is too expensive in coastal areas, thermal SWD plants should be constructed inland. In this sense, some argue that SWD plants can be powered with renewable electricity coming from large inland PV plants. In that case, SMD plant can be located on the coast reducing transportation costs, and electricity can be transported from inland to the plant or even using floating PV farm. However, ZLD wouldn't be achieved by only using conventional desalination systems (e.g., RO).
- In places where land is already valorized, like in Almeria, the inland option has prominence. Nevertheless, current arguments around land competition assume a constant land economic value. If current uses are unsustainable – especially with regards to agriculture -, the value/usefulness of land for production may be different.
- Altitude for transporting seawater is a prominent aspect to consider in the evaluation of scenarios. Flat areas are easier for implementation inland. Unfortunately, this is not the case of south Spain.

Thanks to the development and evaluation of technical scenarios, most of the issues discussed in the first CoP meeting (Table 2) were discussed with more available information and in greater depth. Also, the issue of huge amounts of NaCl production, which was not discussed in the first CoP meeting, was discussed third CoP meeting. But proposals were given to deal with this potential problem: NaCl production would be about 40-60% of current sea salt production of Spain.

d) Upcoming work

Next step is to check the technical scenarios and update them according to the feedback collected from stakeholders. Also, the answer to the Usefulness and Attitude Change Survey will be analysed and incorporated to the behavioral study.

3.2.3. Case study 3. Faro-Olhao

a) VSD-Barrier Analysis Integration

In the CoP that took place on Oct 28th, stakeholders were given the pool of barriers identified from task 9.2 and VSD, see Figure 12. Stakeholders were asked to prioritize all barriers and identify solutions to the top three barriers. The prioritized barriers were:

(1) Market price/competing alternatives,
(2) Quality control and guarantee of Kaumera,
(3) Reluctance to use product originating from WWTP sludge.

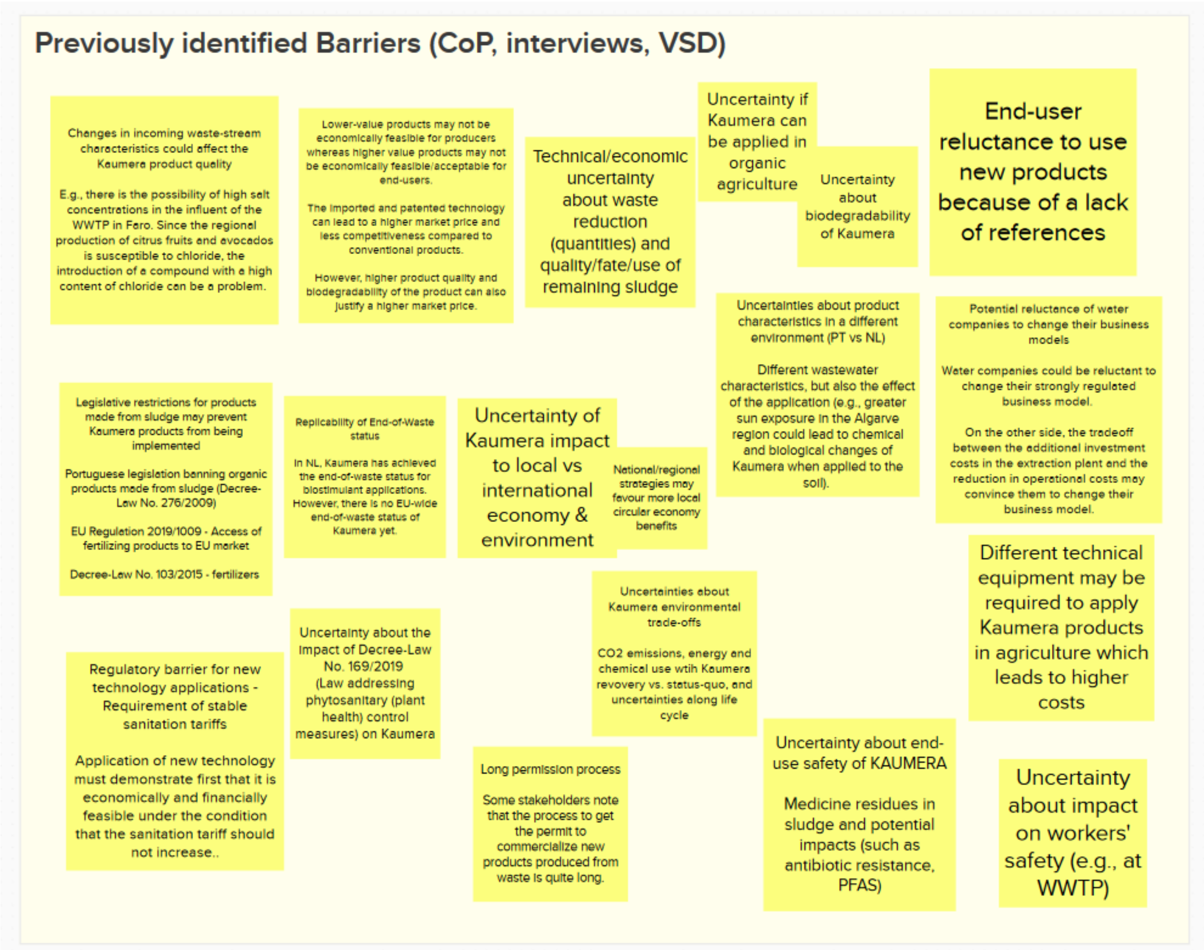

Figure 12. Identified barriers from the Barrier Analysis, including VSD-derived barriers.

Although none of these barriers were the ones directly defined from the VSD exercise, they do validate some of the VSD findings reported in deliverable D2.6. Particularly, the top barrier (1) relates to the affordability, valorization and user acceptance tension as well as concerns over the ownership of technology; the other two barriers (2 and 3), resonate with the uncertainties around safety and the technical viability of Kaumera in D2.6. From this exercise, proposed solutions that come in the technical design scope are listed below[3], and they will be further investigated.

- Increase the efficiency of the production process
- Concentrate Kaumera to improve its transportation [reduce cost]
- On-site energy production
- Adapting the product to agricultural technical equipment
- Scientific research to demonstrate safety with the use of the product

b) Usefulness and Attitude Change Survey

Part 1 of the survey was filled in by 16 respondents; part 2 by 5. Comparing results from both parts indicates "no to very little" changes in terms of attitude towards the WM technologies and Kaumera – the respective product of CS3. Furthermore, in general, respondents seem to have a positive association with Kaumera and it is considered useful and easy to be used for agricultural purposes. However, some respondents seemed to question its ease of use and compatibility with farming equipment. Other benefits of Kaumera that were mentioned are that it is being made out of waste, it is locally produced, it is biodegradable, designed to be circular, as well as its absorbent and slow-release properties. No to little changes in stakeholders' perceptions and attitudes were observed. This can be explained by only 5 respondents having filled in part 2 of the survey (compared to 16 respondents on part 1), which provided only little data for comparison. Furthermore, the technologies developed in CS3 are already of a higher Technology Readiness Level (TRL). That is, a pilot is already being run and product applications are being investigated, which corresponds with a TRL 7 – 8. With level 9 being the highest, this indicates that at these levels, the technology is already quite matured and therefore, no to only little changes in attitude and perceptions are to be expected.

In terms of stakeholders' associations of CS3 with several aspects ranging from circularity to safe production and other characteristics of Kaumera, again a Likert Scale was used (as with CS1). In the survey's respective part, respondents were asked to what extent they associate this project and/or the derived products with certain aspects, with assigning a weight of 1 indicating no association at all, and 5 indicating an extremely high association. Given the number of respondents, this would mean that an aspect could have a maximum assigned weight of 80 (16 respondents x 5 – highest association), and a minimum of 16 (16 respondents x 1 – no association).

This resulted in the following total weights assigned to each aspect: Circular Product (71), Regional application (65), Safe production process e.g. use of chemicals, waste disposal (56), Safe product e.g. effects on land/soil (58), Environmental impact of product and production (50), Affordable price of Kaumera (40), Unpleasant smell of Kaumera (34), Consistent quality of Kaumera (42), Adaptability of Kaumera to different applications e.g. soils and crops (46), and Kaumera's stability, i.e. degradation (46). This illustrates that circularity of the product is the most highly associated aspect, and an unpleasant smell the lowest. This is also illustrated by the aspects' average of 4.4 (circular product) meaning that there is a very high to extremely high association, and 2.7 (unpleasant smell) a slight to average association. Considering the latter, out of 12 respondents, 2 indicated an extremely high association (5) of Kaumera to an unpleasant smell, 1 respondent a very high association (4). Other respondents' associations varied between 1 (not at all) and 3 (somewhat), resulting in a right-skewed distribution.

[3] The overall results of the Barrier Analysis are reported within WP9.

Table 102. Overview and averages from the Usefulness and Attitude Change survey for CS3

	Circular Product	Regional applications	Safe production	Safe product	Environmental impact
Total weight	71	65	56	58	50
Average	4.4	4.2	3.5	3.6	3.2
	Affordable price	Unpleasant smell	Consistent quality	Adaptability to other applications	Stability
Total weight	40	34	42	46	46
Average	2.9	2.7	3.0	3.3	3.3

c) Upcoming work

As it can be derived from the previous sections, value tensions and uncertainties, and the derived design propositions for the Kaumera production systems are beyond the scope of the project. Most of these issues are related to processes that take place after Kaumera extraction (e.g., transport issues). Currently, the CS is aimed at optimizing Kaumera extraction in warm climate, and other issues such as the recovery of Phosphorus, Nitrogen or biogas are being developed at the theoretical and lab scale. **Therefore, the next step in the VSD process of CS does not consider the development and evaluation of technical scenarios.**

Instead, the value tensions identified in CS3 (including those not discussed in the first CoP meeting. See Table 3) will be discussed in more depth, together with the barriers to attitude change, within the behavioral studies.

3.2.4. Case study 4. Larnaca

a) Technical Scenarios

To develop technical scenarios, it was considered that the main target use for the reclaimed water has been for irrigation, as this is the main use of reclaimed water in Cyprus (besides some municipal services). As the CS4 system aims to reduce the salinity of the treated water, it would allow using it for a broader variety of crops than in current practice (beyond salinity tolerant crops), which can be of more interest to farmers. Currently, the Cyprus Code of Good Agricultural Practice (GAP) (No. 263/2007) allows for water reuse for irrigation broadly speaking (Fatta-Kassinos and Karaolia, n.d.). Cost is an important issue and keeping a low treatment cost is in the interest of the public as the government pays for its treatment and additional distribution infrastructure if required (Wencki et al., 2020).

There is interest in showing that the reclaimed water with the WM CS4 technologies could be used for other purposes demanding higher water qualities, such as for specific industrial uses or urban services. Particularly considering costs, if the recovered water will come at higher costs than alternatives, it is considered interesting to explore higher-quality water uses as the CS system already includes a reverse osmosis step. It is expected that the type of water (quality) and its possible use will have an impact on the acceptability by farmers or other users, and their willingness to pay if the recovered water comes at a higher cost. However, to the knowledge of the authors, there is no Cypriot regulation nor guideline for water reuse beyond irrigation purposes. Along the development of this case study, specific requirements will be investigated through stakeholder engagements.

A question from stakeholders in CS4 (from Phase 1 results) has been about the impact of removing phosphorus from the treated water effluent of the WWTP on farming practices. An internal WM study was performed to address the issue: it was estimated that the amount of Phosphorus provided through the irrigation water was about 8 times lower than the Phosphorus required for clover production in the irrigated water. That is, it was estimated that there were about 9t P2O5/year in the irrigation water *vs.* about 74 t P2O5/year used for clover production (Rey Furio and Gamboa, 2022). Based on that estimation, it is suggested that the impact of Phosphorus recovery on farming practices with treated water for irrigation would not be significant, and led to focus on the quality-cost and affordability tension identified for this Case Study.

In Table 11, an overview of the proposed technical scenarios is presented. The main aspects that change between scenarios are the target water use, which determines the quality (for industrial or irrigation purposes), the removal of Phosphorus with BioPhree, and the crystallization of the divalent ions. The plan is to explore the attainable quality of water with different process set-ups and to present them to stakeholders vis-à-vis the related costs. Such discussion is aimed to inquire about specific requirements by potential water users. The benchmark is the point of comparison for the proposed scenarios, and it is to be retrieved from available data for Cyrpus water desalination, or a similar region.

Table 11. Overview of proposed scenarios for Case Study 4

Scenario	1	2	3	4	Benchmark
Technology and Process	All Pilot + remineral.	All Pilot	No BioPhree + remineral.	No low T evap. + remineral.	RO
Products: Phosphorus	P-product	P-product		P-product	
Products: Water	Irrigation Water	Water for nearby users*	Irrigation Water	Irrigation Water	Industrial Water
Products: Salts	NaCl and Mg and Ca salts	NaCl and Mg and Ca salts	NaCl and Mg and Ca salts	NaCl	
Scale	WWTP	WWTP	WWTP	WWTP	WWTP
Others:				NF reject discharge	Brine discharge
To consider impact of:	RES and salinity changes				

*Near-by users refer to airports, hotels (garden irrigation), and golf fields owners, could be the potential clients of CS4 recovered water.

Scenario 1. All pilot for irrigation water

In this scenario, all technologies from the pilot plant and a remineralisation step are considered to deliver water at qualities adequate for irrigation, as presented in Figure 13. Besides water, other products considered are salts of NaCl, Mg and Cl, as well as the Phosphorus product obtained from BioPhree.

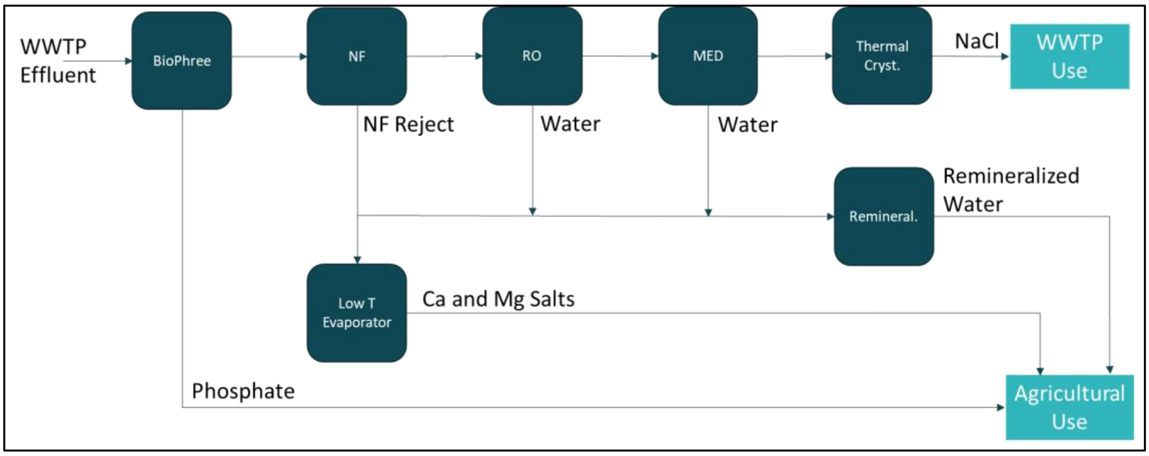

Figure 13. Scenario 1, CS4

Scenario 2. All pilot for industrial water

In this scenario, all technologies from the pilot plant are considered to deliver water of high quality without a remineralisation step, which is typically needed for agricultural purposes and not for industrial purposes. Specific water uses and their requirements by near-by users are to be discussed in future engagements with stakeholders, in CoPs or through the behavioural studies. That means that the system is comprised of all CS4 pilot technologies, as presented in Figure 14. Besides water, other products considered are salts of NaCl, Mg and Cl, as well as the Phosphorus product obtained from BioPhree.

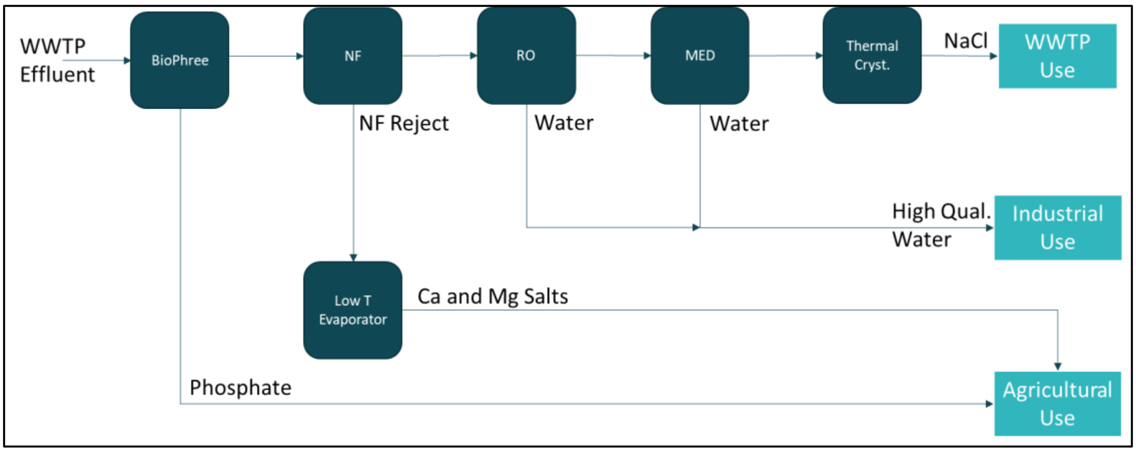

Figure 14. Scenario 2, CS4

Scenario 3. Irrigation water

In this scenario, all technologies from the pilot plant excluding BioPhree and including a remineralisation step are considered to deliver water at qualities adequate for irrigation, as presented in Figure 15. BioPhree is not included in this scenario and therefore, this scenario is expected to show the impact of this technology on capital and maintenance cost (a trade-off), on the possible products to obtain (a phosphorus product) and on the overall sustainability impacts. To note that as Phosphorus is not removed at the beginning of the process, it is expected to lead to higher cleaning requirements of the membrane equipment, and possibly affect the quality. Besides water, other products considered are salts of NaCl, Mg and Cl.

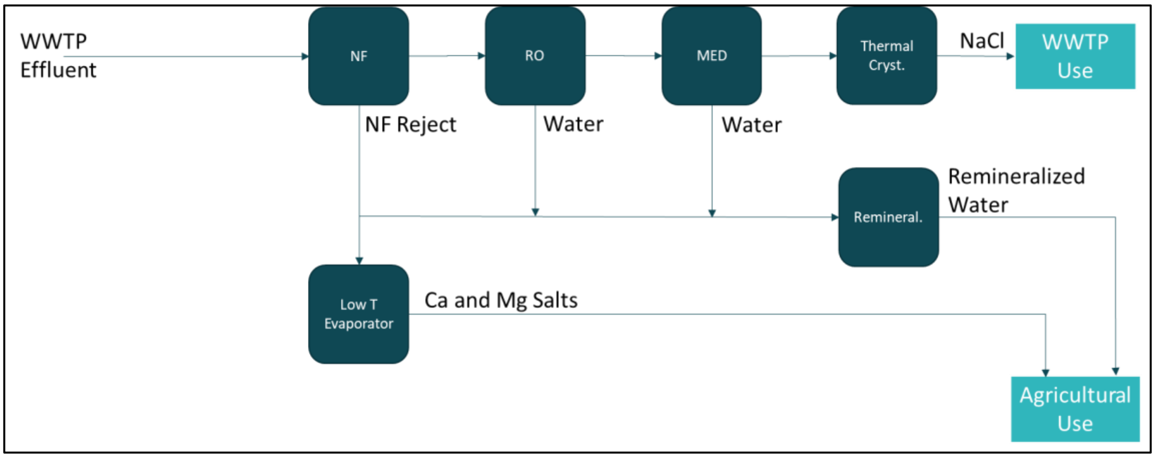

Figure 15. Scenario 3, CS4

Scenario 4. Irrigation water

In this scenario, all technologies from the pilot plant excluding the low Temperature evaporator and including a remineralisation step are considered to deliver water at qualities adequate for irrigation, as presented in Figure 16. The low temperature evaporator is not included in this scenario and therefore, this scenario is expected to show the impact of this processing step on capital cost and revenues, on the possible products to obtain, and in perspective of the sustainability impacts of the system (much lower energy needs without an evaporator, but a waste effluent is produced).

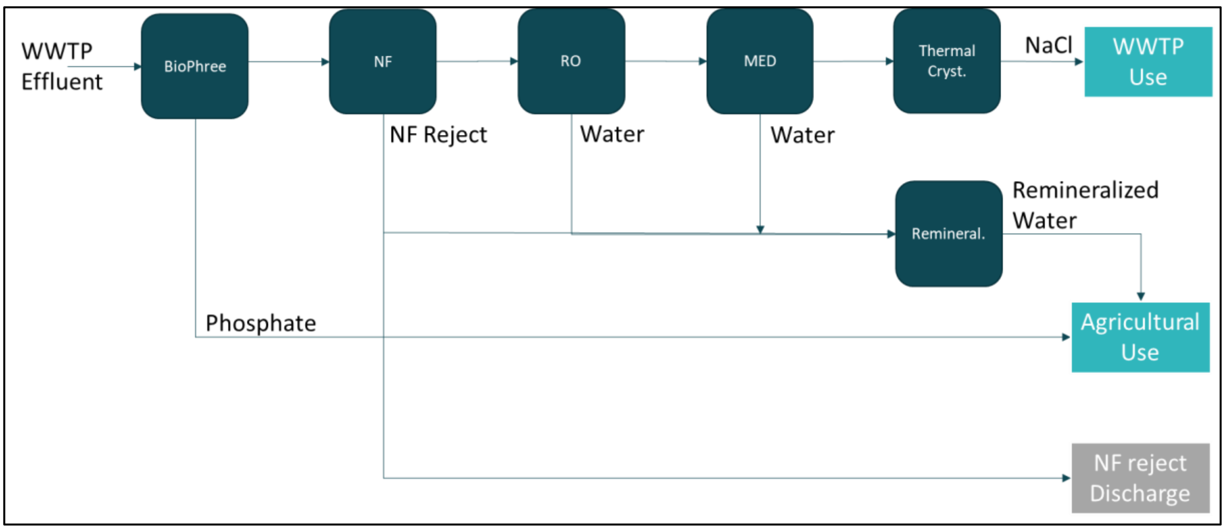

Figure 16. Scenario 4, CS4

b) Upcoming work

The performance of these scenarios is currently being estimated in collaboration with WP8 partners from Brunel University. The results will be brought to discussions with stakeholders in the upcoming CoP meeting in taking place on March, 2023. In the same meeting stakeholders will be invited to fill in the Usefulness and Attitude Change Survey.

All value tensions and uncertainties identified in phase 1 of VSD were discussed in the first CoP meeting and incorporated in the development of the technical scenarios. In the third CoP meeting, we will explore the preferences of stakeholders regarding the desirability and viability of technical scenarios,

3.2.5. Case study 5. La Llagosta

a) Technical Scenarios

Based on the discussion with the CSO, CSF and the received input from a local regional water authority, the main variable to consider for the generation of the technical scenarios was the target water quality (product) and the existence of secondary treatment in place. Overall, the development of technical scenarios focused on minimizing the number of operations, the energy use and subsequently the cost. Therefore, three different scenarios were considered: (1) Greenfield, flexible for irrigation; (2) Greenfield varied qualities at La Llagosta; and (3) Integration with La Llagosta WWTP.

Table 12. Technical Scenarios of Case Study 5 in La Llagosta

Scenario	1	2	3
	Greenfield, flexible for irrigation	Greenfield, varied qualities at La Llagosta	Integration at La Llagosta
Process	Flexible Water-Mining: AnMBR, and 50% split to PN-Annamox and ViviCryst	Full Water-Mining: AnMBR, PN-Annamox, ViviCryst, BioPhree (optional), RO (optional)	P removal and polishing: ViviCryst, BioPhree (optional), RO (optional)
Products	Irrigation water, biogas, vivianite (depending on setting)	Water suitable for diverse uses (e.g. environmental, municipal), vivianite, with BioPhree and RO as optional	Water suitable for diverse uses (e.g. environmental, municipal), vivianite, with BioPhree and RO as optional

Scenario 1

In scenario 1 (Figure 17), it is considered that the WM system will be up-scaled and installed assuming there is no treatment in place, as a greenfield scenario. Scenario 1 considers a flexible facility that can deliver irrigation water without nutrients, but that can also deliver all or part of the agricultural water with nutrients. Considering that: (1) a demand for irrigation water with nutrients may vary seasonally and from user to user, that (2) WWTP are already designed with some processing flexibility due variabilities in incoming influent quality and quantity, and that (3) there is a possibility to dilute nutrient-rich water in case of discharge. Hence, we propose to present this scenario as producing water targeted for irrigation in two qualities at a given proportion that can be considered flexible. Similar systems, in which different types of water for irrigation can be produced and respond to demand are being or have been recently studied in other EU contexts ("Run4Life Project - Articles and Scientific Publications" 2021; "Life - Zero WasteWater Project" n.d.; Jiménez-Benítez et al. 2020). Therefore, of the total water treated in the system, it is proposed to target 50% of irrigation water before nutrient removal and 50% from Vivicryst.

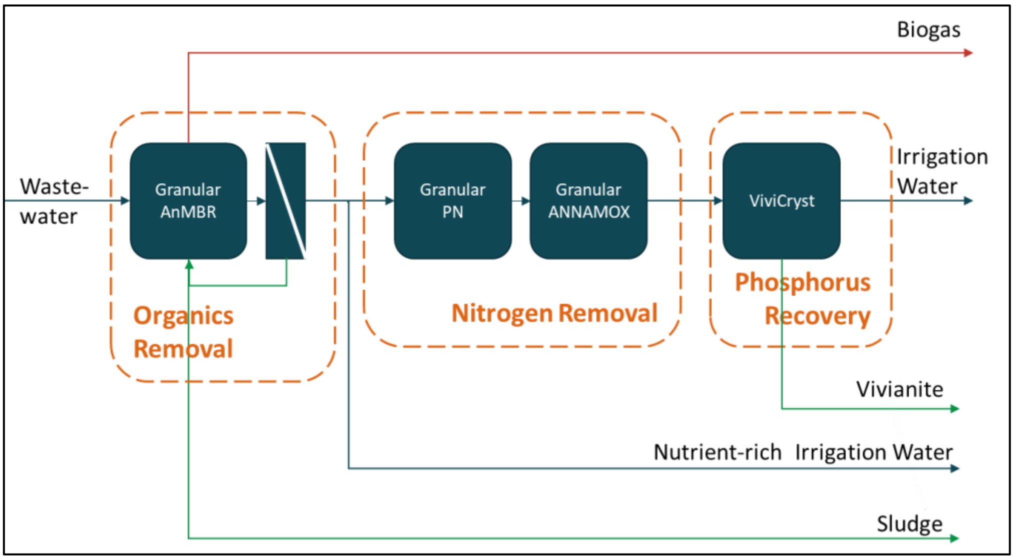

Figure 17. Scenario 1, with the majority of the water being directed for agricultural uses. HQ Water: High-quality water, which could be targeted for municipal or industrial uses.

Scenario 2

This scenario considers that the WM system will be up-scaled and installed at La Llagosta, not considering the existing WWT processing already in place. Water qualities taken as basis for this scenario are based on the investigated water demands by the contacted regional water authority for La Llagosta: Water for environmental use mainly, particularly aquifer injection at about 97%, with the rest for unspecified industrial and municipal uses. Therefore, Scenario 2a (Figure 18a) is proposed where all water is recovered after a ViviCryst step with reduced nutrient content, making it suitable to meet the regulatory requirements for aquifer discharge, and some municipal and industrial uses. In contrast to the original scheme, no water product is drawn from the AnMBR, nor after the Nitrogen removal step.

Additionally, given the uncertainty in the salinity requirements for aquifer recharge mentioned in the previous section, and potential higher quality demands for water for industrial and municipal uses, it is proposed to run this scenario with a variant where BioPhree and RO are included (Figure 18b). In this case, the cost of higher quality water will be made visible, and the willingness to pay for such quality could be investigated. To note that the process scheme of this Scenario 2 is similar to that of Scenario 1 when all water is taken nutrient-free, however presenting these schemes in different scenarios can serve different purposes. Scenario 2 is intended for investigating the quality-cost trade-off (polishing vs no polishing, and usefulness for potential applications), while scenario 1 focuses on the suitability and acceptability of the system delivering nutrients for irrigation water.

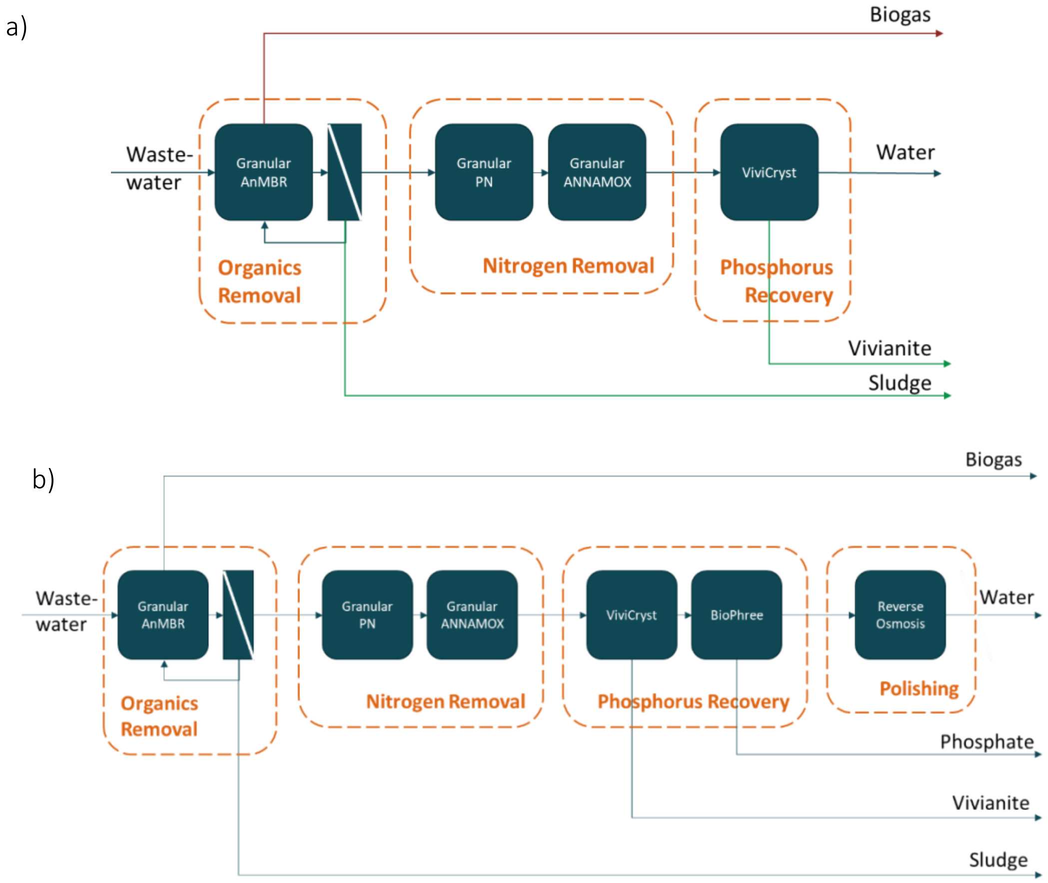

Figure 18. Scenario 2, where water could be suitable for aquifer recharge, and some industrial and municipal uses. a) indicates a relatively lower water quality suitable for aquifer injection following Spanish regulation and some industrial and municipal applications, whereas b) indicates a higher water quality.

Scenario 3

This scenario considers that the WM system will be up-scaled and installed at La Llagosta, taking into account that there is secondary treatment already in place, and to compare with current proposals for upgrading the plant for water re-use. Therefore the scheme for this scenario is much simpler, as presented in Figure 19. However, to make a fair comparison, the existing WWTP secondary treatment contribution must be taken into account in the evaluation of the scenario. Water qualities are set to meet the requirements of local water demands, water for aquifer injection mainly, with the rest for unspecified industrial and municipal uses. As the target is to investigate the interest/usefulness for nutrient recovery for existing plants, only the initial Phosphorus recovery step is proposed for this scenario. Depending on stakeholder responses, this scenario can include BioPhree and RO in later stages, or Vivianite recovery from the sludge of the existing WWTP (In the current biological process at la Llagosta phosphorus is not removed. However, this may not be the case in other plants and, if of interest, phosphorus could be recovered from the sludge stream).

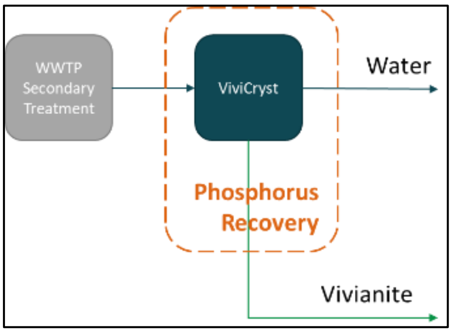

Figure 19. Scenario 3. Gray box indicates the processing step is already in place, and thus outside of the battery limits.

b) Upcoming work

The performance of these scenarios in economic, technical and environmental terms is currently being estimated in collaboration with WP8 partners from Brunel University. The results will be brought to discussions with stakeholders in the upcoming CoP meeting in taking place in the first semester of 2023. In the same meeting, stakeholders will be invited to fill in the Usefulness and Attitude Change Survey.

As in the previous case, most of the value tensions and uncertainties identified in phase 1 of VSD were discussed in the first CoP meeting and incorporated in the development of the technical scenarios. In the third CoP meeting, we expect that some of the issues not discussed during the first CoP meeting will emerge during the discussion of the technical scenarios. If that is not the case, we will come back to these issues in the last CoP meeting.

3.2.6. Case study 6. Rotterdam

As it can be seen in section 3.1.2 Value tensions and Uncertainties,

Table 6, none of the few value tensions identified in the preliminary steps of the VSD have been addressed in the CoP meetings. In fact, the interaction with stakeholders has been limited to actors closely related to the industrial chlorine cluster and the port of Rotterdam, and the CoP meetings has been focused on the issue of making this case a business case.

As mentioned in

Table 6, the epoxy production process raises several sustainability concerns, and there is potential for lock-in effects with the CS, slowing the uptake of renewable resources and/or the prevention of the use and/or disposal of substances of concern. While project partners foresee no risk about switching to renewables, and chlorine would be recirculated in an almost-closed industrial loop, uncertainties remain on the effects of the proposed system on changing the epoxy process and its long-term sustainability impacts. While these uncertainties have been identified within the WATER-MINING project, the epoxy production process, including the replacement of raw materials and its sustainability impact, is beyond the scope of the project and of the CS.

For these reasons, the development of technical scenarios has been also very limited. That is, developing technical scenarios around the pilot system in WATER-MINING would not serve to address the issues mentioned above. **Therefore, CS6 is not considered in the next steps of the VSD process (i.e., technical scenarios and full-scale implementation study).**

4. Conclusions

The VSD process along Phase 1 and Phase 2 has allowed the identification of values, value tensions and uncertainties surrounding the WATER-MINING Systems, as well as the development of scenarios to address or further explore these issues. Through the development of technical scenarios trade-offs have been quantified, uncertainties have been explored or defined in more detail, and some assumptions have been evaluated. For example, in CS2 it has been shown that the assumed mixing of divalent ions to produce water for irrigation would not work in reality – mixing all NF reject would lead to a water with conductivity/salinity above recommendations. This finding led to the identification of a wastewater stream previously un-recognized, and that contributes to the trade-off between wastewater production and energy requirements. For CS5, there exists some uncertainties surrounding the technical feasibility and the social desirability of a flexible system that can provide water for irrigation with and without nutrients on demand (see Scenario 1 of CS5).

Additionally, in the more advanced case studies up to the moment of writing this report (CS1 and CS2), some leads have been identified about desirable paths for the development the technology. Particularly:

- From CS1 it is concluded that for islands like Lampedusa, where there is limited energy availability and chemical use, a focus on water recovery (and not so much on zero liquid discharge) seems preferred by stakeholders.
- In CS2, trade-offs have been quantified indicating that to achieve ZLD, the thermal technology presents some advantages with regard to RO-ZLD in terms of overall energy consumption. But RO-ZLD would perform better in terms of irrigation water production and wastewater generation.

It has also been concluded that technical scenarios are not suitable for exploring the identified societal issues in CS3 and CS6 due to issues of project scope and stakeholder participation, as discussed in detail in sections 2.2 and 3.2.

The next steps for the VSD process are bringing the results of the Technical Scenarios of CS4 and 5 to discussions with stakeholders at the respective CoPs. After these CoPs, the behavioral studies (remaining interviews and surveys) will continue in parallel to the full-scale implementation study as Phase 3 of the VSD process.

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Appendix A:
Survey Behavioural Studies CS1 Lampedusa, Italy

Survey on Usefulness and Attitude Change | Lampedusa

Dear,

Please find enclosed a survey that will provide us insights into your perception on usefulness of the products and processes we're developing in Case study 1. Filling in this survey will help us to understand what is needed for us to help *you* to benefit from these products and technology. This survey contains of two parts of which survey 1 should be filled in *before* the start of the CoP meeting, and survey 2 *afterwards*. This will provide us insights into attitude change in response to the CoP meeting.

Based on the surveys, we might want to contact you for an interview in which we can discuss matters more in-depth. If you are okay with us possibly contacting you, you can leave your email address and contact information below (optional). We also ask you to first provide some basic information (required).

All information provided in the surveys will be treated confidential and will not be shared beyond the research team. For questions or remarks, you can contact the responsible researcher: Britte Bouchaut (TU Delft) via B.F.H.J.Bouchaut@tudelft.nl. We thank you very much in advance for filling in this survey.

Optional: only when you give consent to us possibly contacting you for an interview.

Name: Email Address: Telephone number (optional):

Required:

What is your main occupation? What is your age? What is your highest completed level of education? (primary school, high school, bachelor/ Master, PhD) With what gender do you identify? (woman, male, non-binary, other, prefer not to state)

Please indicate the following:
Are you a partner using any of the WM system products, i.e. chemicals/salt products? Yes/No

What product(s) do you use? What is your country of origin? Where do you use the product(s) from the WM system?

Part 1: Please fill in this survey BEFORE the start of the CoP meeting

Attitude Change – Innovation Process (transparency and responsiveness)
1. Please indicate to what extent you agree with each of the following statements from 1 – 5 (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree, 0 = not applicable) _ I feel that I have sufficient access to information concerning the project _ I feel involved in the project's innovation process and trajectory _ I feel that issues of importance to me are being addressed during the project _ I feel that the project communicates its goals clearly to me
Comments (optional)

Attitude change – Acceptance
2. Please indicate to what extent you agree with each of the following statements from 1 – 5 (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree, 0 = not applicable) - I am willing to (support the) use the recovered water by means of the WM system for drinking - I am willing to (support the) use the recovered water by means of the WM system for industrial applications - I am willing to (support the) use the recovered water by means of the WM system for other commercial usage - I think that the recovery of salt (NaCl) is beneficial for the local economy - I think that the recovery of chemicals is beneficial for the local economy - I think that releasing brine into the sea has negative consequences for the local ecosystem/environment - I think that the WATER-MINING system has no negative effects on local marine life - I think the integration of the WATER-MINING system with waste heat from a power plant is beneficial for seawater desalination in Lampedusa - I would prefer seawater desalination powered by other renewables (e.g. solar energy) than by integration with waste heat from a diesel power plant in Lampedusa
Comments (optional)

Attitude change – Usefulness & Usability
3. Please indicate to what extent you agree with each of the following statements from 1 – 5 (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree, 0 = not applicable) - I think that desalination of water should, in general, be subsidized by the local government - I think that desalination of water should, in general, be subsidized by the central government - I think that the recovered water in this project would provide an equal quality of water compared to the old system - I think that this specific research project/ case study contributes to all people on Lampedusa having equal access to water for a variety of purposes. - I think that having higher availability and an equal price of water leads to higher usage of water in the island (e.g. other, more water-consuming activities can take place) - I think that having higher access and an equal affordability of water would increase misuse and spoilage of water.
Comments (optional)

Factors of Acceptance (1)
4. Please put the following aspects in order of how important these are, in general, to you (from 1 to 10 , thereby 1 being of the lowest importance, 10 being of the highest importance). _ Circular economy _ Local production and consumption _ Environmental impact of product and production (e.g. energy consumption, greenhouse gas emissions, preservation of (local) nature) _ Consistent quality of the recovered water _ Safety of secondary processes for local ecosystem/ environment, i.e. brine disposal _ Sustainable water use & management (i.e. no increase in consumption of water for commercial, agricultural and drinking purposes) _ Equal sharing of revenues _ Affordable price of recovered water by means of the WM system _ Affordable price of recovered products such as chemicals and salts _ The use of renewable energy and its impacts
Other aspects? (Please specify below)

Factors of Acceptance (2)
5. Please indicate to what extent you associate the desalination of water by means of waste heat integration with the following aspects? (1= not at all 2= slightly, 3= somewhat, 4= very, 5= extremely) _ Circular economy _ Local production and consumption _ Environmental impact of product and production (e.g. energy consumption, greenhouse gas emissions, preservation of (local) nature) _ Consistent quality of the recovered water _ Safety of secondary processes for local ecosystem/ environment, i.e. brine disposal _ Sustainable water use & management (i.e. no increase in consumption of water for commercial, agricultural and drinking purposes) _ Equal sharing of revenues _ Affordable price of recovered water by means of the WM system _ Affordable price of recovered products such as chemicals and salts _ The use of renewable energy and its impacts
Other aspects? (Please specify below)

Part 2: Please fill in this survey AFTER the CoP meeting

Attitude Change – Innovation Process (transparency and responsiveness)
1. Please indicate to what extent you agree with each of the following statements from 1 – 5 (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree, 0 = not applicable) _ I feel that I have sufficient access to information concerning the project _ I feel involved in the project's innovation process and trajectory _ I feel that issues of importance to me are being addressed during the project _ I feel that the project communicates its goals clearly to me
Comments (optional)

Attitude change – Acceptance
2. Please indicate to what extent you agree with each of the following statements from 1 – 5

(1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree, 0 = not applicable) - I am willing to (support the) use the recovered water by means of the WM system for drinking - I am willing to (support the) use the recovered water by means of the WM system for industrial applications - I am willing to (support the) use the recovered water by means of the WM system for other commercial usage - I think that the recovery of salt (NaCl) is beneficial for the local economy - I think that the recovery of chemicals is beneficial for the local economy - I think that releasing brine into the sea has negative consequences for the local ecosystem/environment - I think that the WATER-MINING system has no negative effects on local marine life - I think the integration of the WATER-MINING system with waste heat from a power plant is beneficial for seawater desalination in Lampedusa - I would prefer seawater desalination powered by other renewables (e.g. solar energy) than by integration with waste heat from a diesel power plant in Lampedusa
Comments (optional)

Attitude change – Usefulness & Usability
3. Please indicate to what extent you agree with each of the following statements from 1 – 5 (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree, 0 = not applicable) - I think that desalination of water should, in general, be subsidized by the local government - I think that desalination of water should, in general, be subsidized by the central government - I think that the recovered water in this project would provide an equal quality of water compared to the old system - I think that this specific research project/ case study contributes to all people on Lampedusa having equal access to water for a variety of purposes. - I think that having higher availability and an equal price of water leads to higher usage of water in the island (e.g. other, more water-consuming activities can take place) - I think that having higher access and an equal affordability of water would increase misuse and spoilage of water.
Comments (optional)

Factors of Acceptance (1)
4. Please put the following aspects in order of how important these are, in general, to you (from 1 to 10 , thereby 1 being of the lowest importance, 10 being of the highest importance).

_ Circular economy _ Local production and consumption _ Environmental impact of product and production (e.g. energy consumption, greenhouse gas emissions, preservation of (local) nature) _ Consistent quality of the recovered water _ Safety of secondary processes for local ecosystem/ environment, i.e. brine disposal _ Sustainable water use & management (i.e. no increase in consumption of water for commercial, agricultural and drinking purposes) _ Equal sharing of revenues _ Affordable price of recovered water by means of the WM system _ Affordable price of recovered products such as chemicals and salts _ The use of renewable energy and its impacts
Other aspects? (Please specify below)

Factors of Acceptance (2)
5. Please indicate to what extent you associate the desalination of water by means of waste heat integration with the following aspects? (1= not at all 2= slightly, 3= somewhat, 4= very, 5= extremely) _ Circular economy _ Local production and consumption _ Environmental impact of product and production (e.g. energy consumption, greenhouse gas emissions, preservation of (local) nature) _ Consistent quality of the recovered water _ Safety of secondary processes for local ecosystem/ environment, i.e. brine disposal _ Sustainable water use & management (i.e. no increase in consumption of water for commercial, agricultural and drinking purposes) _ Equal sharing of revenues _ Affordable price of recovered water by means of the WM system _ Affordable price of recovered products such as chemicals and salts _ The use of renewable energy
Other aspects? (Please specify below)

Thank you very much for filling in this survey. You can now return both forms to one of the organizers. If you would have any questions or remarks on this survey, please contact the responsible researcher: Britte Bouchaut (TU Delft) via B.F.H.J.Bouchaut@tudelft.nl.

Appendix B:
Survey Behavioural Studies CS3 Faro, Portugal

Dear,

Please find enclosed a survey that will provide us insights into your perception on usefulness of the products and processes we're developing in Case study 3. Filling in this survey will help us to understand what is needed for us to help *you* to benefit from these products and technology. This survey contains of two parts of which survey 1 should be filled in *before* the start of the CoP meeting, and survey 2 *afterwards*. This will provide us insights into attitude change in response to the CoP meeting.

Based on the surveys, we might want to contact you for an interview in which we can discuss matters more in-depth. If you are okay with us possibly contacting you, you can leave your email address and contact information below (optional). We also ask you to first provide some basic information (required).

All information provided in the surveys will be treated confidential and will not be shared beyond the research team. For questions or remarks, you can contact the responsible researcher: Britte Bouchaut (TU Delft) via B.F.H.J.Bouchaut@tudelft.nl. We thank you very much in advance for filling in this survey.

Optional: only when you give consent to us possibly contacting you for an interview.

Name: Email Address: Telephone number (optional):

Required:

What is your main occupation? What is your age? What is your highest completed level of education? (primary school, high school, bachelor, master, PhD) With what gender do you identify? (woman, male, non-binary, other, prefer not to state)

If you are a farmer; could you please indicate the following:
Are you a member of an association? (Yes or No) What is the size of your association? (How many members?) What is the scale of your farm? (For example in hectares, economic output)

What do you currently use as your main source of water? Do you use soil conditioner? (Yes or No - if yes, which one?)

Part 1: Please fill in this survey BEFORE the start of the CoP meeting

Attitude Change – Innovation Process (transparency and responsiveness)
1. Please indicate to what extent you agree with each of the following statements from 1 – 5 (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree, 0 = not applicable) _ I feel that I have sufficient access to information concerning the project _ I feel involved in the project's innovation process and trajectory _ I feel that issues of importance to me are being addressed during the project _ I feel that the project communicates its goals clearly to me
Comments (optional)

Attitude change – Acceptance
2. Please indicate to what extent you agree with each of the following statements from 1 – 5 (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree, 0 = not applicable) _ I am willing to use Kaumera in my practices _ I am willing to support/recommend the use of Kaumera
Comments (optional)

Attitude change – Usefulness & Usability
3. Please indicate to what extent you agree with each of the following statements from 1 – 5 (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree, 0 = not applicable) _ I think that Kaumera is useful for farming practices _ I think that Kaumera can be used easily _ I think that Kaumera is compatible with current farming equipment _ I think that Kaumera is compatible with current distribution channels _ I think that Kaumera has benefits compared to other available soil conditioners
Comments (optional)

Open question: What benefits of Kaumera do you see compared to other available soil conditioners?

Factors of Acceptance (1)
4. Please put the following aspects in order of how important these are, in general, to you (from 1 to 10 , thereby 1 being of the lowest importance, 10 being of the highest importance). _ Circular product _ Regional application _ Safe production (e.g. use of chemicals, waste disposal) _ Safe product (e.g. effects on land/soil, composition) _ Environmental impact of product and production (e.g. energy consumption, greenhouse gas emissions) _ Affordable price _ Unpleasant smell of product _ Consistent quality _ Adaptability to different applications/ soils and crops _ Stability i.e. quality does not degrade
Other aspects? (Please specify below)

Factors of Acceptance (2)
5. Please indicate to what extent you associate Kaumera with the following aspects? (1= not at all 2= slightly, 3= somewhat, 4= very, 5= extremely) _ Circular product _ Regional application _ Safe production (e.g. use of chemicals, waste disposal) _ Safe product (e.g. effects on land/soil, composition) _ Environmental impact of product and production (e.g. energy consumption, greenhouse gas emissions) _ Affordable price _ Unpleasant smell of product _ Consistent quality

_ Adaptability to different applications/ soils and crops _ Stability i.e. quality does not degrade
Other aspects? (Please specify below)

Part 2: Please fill in this survey AFTER the CoP meeting

Attitude Change – Innovation Process (transparency and responsiveness)
1. Please indicate to what extent you agree with each of the following statements from 1 – 5 (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree, 0 = not applicable) _ _ I feel that I have sufficient access to information concerning the project _ I feel involved in the project's innovation process and trajectory _ I feel that issues of importance to me are being addressed during the project _ I feel that the project communicates its goals clearly to me
Comments (optional)

Attitude change – Acceptance
2. Please indicate to what extent you agree with each of the following statements from 1 – 5 (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree, 0 = not applicable) _ I am willing to use Kaumera in my practices _ I am willing to support/recommend the use of Kaumera
Comments (optional)

Attitude change – Usefulness & Usability
3. Please indicate to what extent you agree with each of the following statements from 1 – 5 (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree, 0 = not applicable) _ I think that Kaumera is useful for farming practices _ I think that Kaumera can be used easily _ I think that Kaumera is compatible with current farming equipment _ I think that Kaumera is compatible with current distribution channels _ I think that Kaumera has benefits compared to other available soil conditioners

Comments (optional)

Open question: **What benefits of Kaumera do you see compared to other available soil conditioners?**

Factors of Acceptance (1)
4. Please put the following aspects in order of how important these are, in general, to you (from 1 to 10 , thereby 1 being of the lowest importance, 10 being of the highest importance). _ Circular product _ Regional application _ Safe production (e.g. use of chemicals, waste disposal) _ Safe product (e.g. effects on land/soil, composition) _ Environmental impact of product and production (e.g. energy consumption, greenhouse gas emissions) _ Affordable price _ Unpleasant smell of product _ Consistent quality _ Adaptability to different applications/ soils and crops _ Stability i.e. quality does not degrade
Other aspects? (Please specify below)

Factors of Acceptance (2)
5. Please indicate to what extent you associate Kaumera with the following aspects? (1= not at all 2= slightly, 3= somewhat, 4= very, 5= extremely) _ Circular product _ Regional application _ Safe production (e.g. use of chemicals, waste disposal) _ Safe product (e.g. effects on land/soil, composition) _ Environmental impact of product and production (e.g. energy consumption, greenhouse gas emissions) _ Affordable price _ Unpleasant smell of product _ Consistent quality

_ Adaptability to different applications/ soils and crops _ Stability i.e. quality does not degrade
Other aspects? (Please specify below)

Thank you very much for filling in this survey. You can now return both forms to one of the organizers. If you would have any questions or remarks on this survey, please contact the responsible researcher: Britte Bouchaut (TU Delft) via B.F.H.J.Bouchaut@tudelft.nl.