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water mining
value for society

Deliverable 9.1

Market System Maps

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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

Additional note		This deliverable has been prepared based on information provided by case study partners in WATERMINING and stakeholders identified as key informants for the case study. This report, therefore, relies heavily on participatory research and less on peer-reviewed scientific findings.	
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[3] D 9.1 describes in great detail and critically the market opportunities for the processes developed as part of the project and the products generated in the European environment. Above all, the locations of the demonstration plants are considered. Market opportunities and market barriers are considered and regulatory and legal problems are discussed.

However, in Table 2-3 (CS 9) - the product scope "networking of sensors" should be specified. What is meant here - is it a sensor network? What is the focus here - wired or wireless sensor networks? Smart Connectivity Solutions? IoT?

Furthermore, the consortium should consider to develop relevant EU policy recommendations in terms of the end of waste criteria in Waste Framework directive, taking phosphate recovery as one example.

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Glossary

BAT	Best Available Techniques
$CaOH_2$	Calcium hydroxide
CoP	Communities of Practice
CSP	Concentrated Solar Power
EFC	Eutectic Freeze Crystallization
ESG	Environmental Social Governance
HCl	Hydrochloric acid
MBR	Membrane Bioreactor
MED	Multi-Effect Desalination
$MgOH_2$	Magnesium hydroxide
MSA	Market System Analysis
NaCl	Sodium chloride
NaOH	Sodium hydroxide
Na_2SO_4	Sodium sulfate
NF	Nanofiltration
TNA	Technology Needs Assessment
UNFCCC	UN Framework Convention of Climate Change
ZLD	Zero Liquid Discharge

Executive Summary

WATERMINING's case studies focus on developing technology systems for circular treatment of sea- and wastewater towards a level that these are ready for market deployment. However, successful market entry also depends on making markets ready for circular technology solutions and enabling these to successfully compete with conventional linearly processed products. The latter is the focus of WATERMINING's work on market analysis, development of circular business models and identifying enabling policies for that. This deliverable is focused on market analysis, as it describes relevant markets for circular technology systems and products and identifies opportunities for market improvements.

The tool used for the market system analysis is Market System Mapping, which is a concept developed by Albu and Griffith (2005, 2006) to take a systemic approach, including a focus on market actors and how they compete or collaborate, institutional aspects that can support or slowdown market entry of a product, and relevant policies for products, or lack thereof. This systemic approach enables case study partners and stakeholders to take a snapshot of the current market context and identify scope for improvement. As such, it can be learned what are the conditions and needs for a circular business model to successfully market WATERMINING solutions, not only in the regions of the case studies but also elsewhere.

With partners and stakeholders, six case studies in the WATERMINING project have been analysed with the Market Mapping tool; this has been complemented by analysis of four hypothetical case studies in partner countries of WATERMINING. The market system mapping has been carried out via the following general steps:

1. Identify stakeholders for each case study, both those that partake in traditional water management and those that have a stake in markets for resources and products mined from the sea- and wastewater.
2. Analyse, with stakeholders, relevant markets: what do current market systems in the case study contexts look like and where do we need improvements for the circular business potential of WATERMINING products and resources?
3. Identify, with stakeholders, actions for market improvement, including responsibilities and beneficiaries regarding improvement actions, policy instruments and funding strategies.

The case studies are shown in the following table.

Table 0-1: Overview of case studies, the case study owners, and facilitators

Case study	Source for WATERMINING	Case study partners
CS 1 – Lampedusa	Seawater	S.El.I.S., WEI
CS 2 – Spain	Seawater	CIEMAT
CS 3 – Portugal	Urban wastewater	TU Delft, ADA, Acciona
CS 4 – Cyprus	Urban wastewater	LARNACA, NTUA, MADISI
CS 5 – Catalonia	Urban wastewater	ACSA-Sorigué, UAB
CS 6 – Netherlands	Industrial wastewater	Hexion, WEI
CS 7 – Israel	Urban wastewater	JIIS
CS 8 – Greece	Seawater	NTUA
CS 9 – Germany	Industrial wastewater	DECHEMA
CS 10 – India	Industrial wastewater	VSI, Hexion

Based on the market maps a better understanding has been obtained of market actors, in terms of:

- Suppliers or raw materials, including the wastewater,
- Suppliers of technology system elements,
- Processors, such as the water treatment plants,
- Potential users of the products from the technology system, such as customers of purified water and other products mined by the circular technology system.

Moreover, the enabling policy and business environment have been spelt out for each case study to learn about potential barriers to be cleared for market deployment and enablers that already support this. Across the case studies, **barriers** have been found in terms of:

1. The currently insufficient **business models** for technologies and systems for circular treatment of sea and wastewater, so that pay back times are relatively long and ancillary environmental benefits not or insufficiently valued in monetary terms.
2. As markets are used to conventional, linearly produced products, in terms of **product characteristics and quality**, new products mined from the sea- or wastewater needs to gain trust among market actors.

3. Stakeholders argue that current **EU legislation** may prohibit the use of water-mined products as these are often considered a waste product, instead of end-of-waste.
4. Finally, stakeholders point at the need to enhance collaboration between research institutes and water treatment companies, as well as with **national governments,** to accelerate improvement of products, procedures, and cost-effectiveness of WATERMINING solutions.

Enabling factors in support of the market deployment of WATERMINING technology systems are:

1. Especially in the case study countries in Southern Europe, there is a growing concern about **water scarcity** which strengthens the need for producing water for consumption and use in industry and agriculture from sources such as sea or wastewater.
2. There is an increasing awareness of **environmental impacts** of conventional treatment of sea- and wastewater which can pave the way for, e.g., circular systems such as zero-liquid desalination.
3. The market value of environmental benefits can be further strengthened by formulating **stricter (environmental) legislation** on the use of conventional products.
4. Currently, there is already a **rather long list of potential EU policies and policy instruments** that could potentially incentivize circular sea- and wastewater treatment, and the policy momentum seems to be growing with the introduction of the EU Green Deal and other EU funding opportunities.

1. Introduction

Water access and its related energy, environmental and economic issues are among the greatest challenges for society today. According to the 2030 Water Resources Group of the World Bank, global water demand by 2030 is expected to exceed sustainable water supply (World Economic Forum, 2019). The WATERMINING project aims to face this challenge and help ensure access to clean water and sanitation by developing innovative solutions for the sustainable use of alternative water sources, including urban and industrial wastewater and seawater desalination.

Essentially, the technical focus of WATERMINING is on further developing technologies and techniques for clean water and mining other products and materials from seawater, urban and industrial wastewater (Figure 1-1). This will be done via a series of case studies in Cyprus, Italy, Portugal, Spain, and the Netherlands. The case studies will help to further improve techniques that have already been developed in earlier research projects and which are now in the stage of further development towards the market entry, including a demonstration in demo-plants in relevant environments with real-life circumstances.

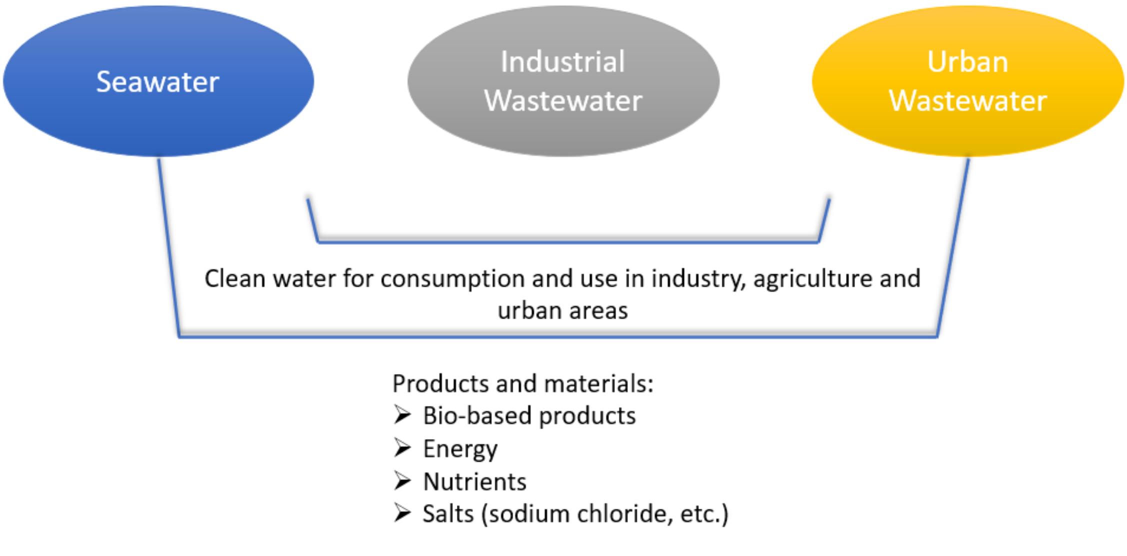

Figure 1-1: Clean water and products to be mined from sea water, industrial and urban wastewater in WATERMINING

Traditionally, sea water and urban and industrial wastewater treatment are based on linear processes with limited use of recovery of resources. In linear processes, wastewater from an industrial process often results in sludge streams and effluent into the environment, while resources and products from wastewater are not or only limitedly used and thus largely wasted.

Instead, the WATERMINING project aims at a **circular** approach of sea water and urban/industrial wastewater treatment with the objective to generate resources and products from wastewater for reuse in consumption and industrial and agricultural processes. In a similar vein, WATERMINING advances circular processes for sea water treatment. By producing clean water and mining several resources from sea water and urban/industrial wastewater for re-use and recycling, WATERMINING directly supports the development of a circular economy in Europe.

While currently, the WATERMINING solutions are in a demo-plant phase,[4] it is the goal of the project to make these ready for deployment in markets in the EU Member States and beyond the EU. For that, it is required to develop a circular business model for the solutions and make markets ready for their uptake, so that WATERMINING's solutions not only:

- Have a demonstrated technical potential with clear environmental benefits, but are also
- Financially viable investments, which furthermore,
- Improve societal well-being.

WATERMINING will thus also focus on identifying innovative approaches to make solutions for water mining market-ready, based on solid Circular Economy business models. For that, WATERMINING will:

- Attribute the circular economy benefits of water mining solutions in the case studies,
- Analyse relevant market systems for products resourced through water mining in the case study contexts, including the enabling policy and business environment and roles of market actors.
- Recommend market conditions that need to be improved or even created for successful circular processes.
- Identify innovative approaches to make markets ready for adoption of WATERMINING solutions, including public-private stakeholder partnership, finance innovations, policy instruments, raising public awareness, etc.

While the success of the demo application of WATERMINING solutions requires continued technical progress, success towards market readiness depends largely on insights obtained from stakeholders as actors in market systems for resources and products mined from seawater, and urban and industrial wastewater.

On the one hand, through engagement in the project, stakeholders benefit from the work, such as obtaining support for:

- Reaching policy and societal goals on sustainable water management.
- Addressing environmental concerns, such as climate change and pollution.
- Developing new market and business opportunities based on circular economy processes, products, and concepts such as chemical leasing.

[4] At Technology Readiness Level 3 or 4.

On the other hand, with the help of stakeholders, the WATERMINING project could improve its learning about what are the conditions and needs for a circular business model to successfully market WATERMINING solutions, not only in the regions of the case studies but also elsewhere.

The WATERMINING team thus invites stakeholders to co-create the market conditions for the water mining solutions as successful circular business opportunities. This has been done in the following general steps:

1. Identify stakeholders, both those that partake in traditional water management and those that have a stake in markets for resources and products mined from the sea- and wastewater.
2. Analyse, with stakeholders, relevant markets: what do current market systems in the case study contexts look like and where do we need improvements for the circular business potential of WATERMINING products and resources?
3. Identify, with stakeholders, actions for market improvement, including responsibilities and beneficiaries regarding improvement actions, policy instruments and funding strategies.

While step 1 is coordinated by work package 2, steps 2 and 3 are the topic of Task 9.2 and their outputs form the basis for this deliverable.

2. Method

2.1. Market system mapping

As part of Work Package 9 of the WATERMINING project, Task 9.2 focuses on the market system analysis (MSA) for new technologies and products that are further developed and demonstrated in the case studies of WATERMINING. While the case study analysis focuses on technical improvements for making the circular water treatment solutions technically ready for market deployment, this task focuses on actions to make markets, which are often focused on adopting linearly treated wastewater streams, ready for adopting circular WATERMINING solutions. For example, circular treatment of wastewater could result in the production of brine or phosphorous which can be usefully utilised in other (industrial) economic processes. However, in the market, these circularly produced products face competition from linearly produced (i.e. less environmentally friendly) goods, which may be cheaper or with which market actors are more familiar.

For meeting sustainability, climate and circularity goals, for each case study we have explored current market systems for products 'mined' from wastewater and seawater streams, in order to obtain a comprehensive understanding of the market ('market literacy'). Using the method of Market System Mapping (Albu & Griffith, 2005, 2006) a market system is analysed by mapping:

(1) **market actors** that are currently, or could potentially be, active in the market value chain, and they collaborate or compete with each other,
(2) the **policy and business enabling environment** which is the collection of policy, social, technical and other factors that either hamper or enable the deployment of WATERMINING technologies (e.g. legal restrictions on goods produced from waste streams could be a barrier to market entry of a WATERMINING product, while a subsidy scheme for circular processes can be an enabler),
(3) **supporting services** which are the institutions that support the market value chain such as a stable financial sector (e.g. willing to provide loans to circular solutions), an education system with a focus on circularity topics, or a stable legal system (e.g. to handle intellectual property rights).

Initially designed as a qualitative, participatory research tool for analysing markets for scaled-up implementation of technologies for improved sustainable livelihoods in Africa(Albu & Griffith, 2005, 2006), market system mapping has been applied successfully in, among others, the first two phases of the Global Technology Needs Assessment (TNA) Project under the UN Framework Convention of Climate Change (UNFCCC) (Chowdhury et al., 2010). It has also been applied in the Horizon 2020 project TRANSrisk (2015-2018), where addressing stakeholder engagement was an important pillar of successful technology deployment (Nikas et al., 2017; van der Gaast et al., 2016).

With help of the thus described market system analysis tool, it is possible to elaborate on the **desired market system**, i.e. a market system within which circularly produced sea- or wastewater products can be deployed successfully. Comparing the desired and current market systems enables us to identify factors that need to be improved, such as barriers or obstacles that need to be cleared for increased competitiveness of sea- or wastewater products. For example, for reaching the desired market system it is needed that wastewater products are eligible for subsidies so that circularly and linearly produced goods face a level playing field in the market. Another example could be an awareness campaign among end-users to demonstrate that the wastewater product is of equal or better quality. This is illustrated in Figure 2-1 which shows how market system mapping supports the objective of WATERMINING of scaling up water treatment solutions from research, development and demonstration to scaled-up implementation in European markets.

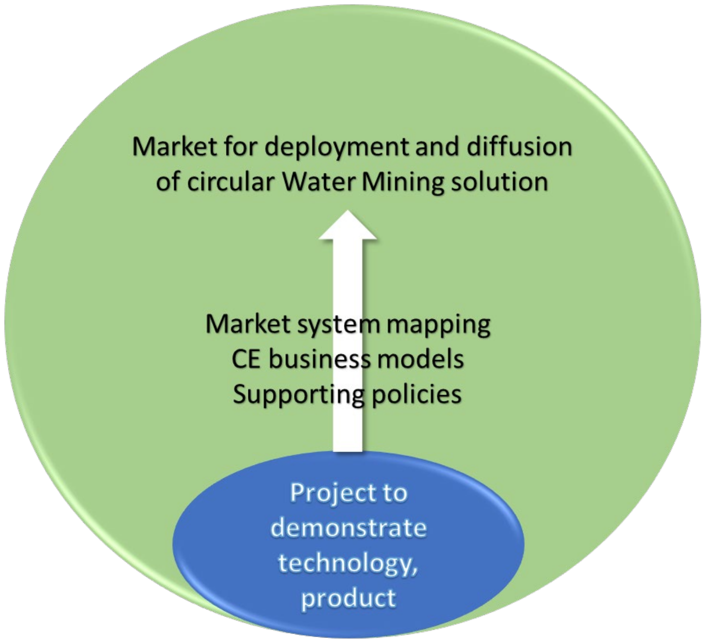

Figure 2-1. Assessing conditions for scaling up WATERMINING solutions through market system mapping

A critical factor in the market system analysis is stakeholder engagement as stakeholders bring a vast amount of practitioners' knowledge and market insights into the research project that are indispensable for a discussion on how to improve market systems for circularly produced sea- and wastewater products. This supports, on the one hand, identifying showstoppers for technology deployment at a later stage of the project. On the other hand, it helps to locate market actors and beneficial factors that can support the deployment and diffusion of WATERMINING technologies into markets.

Market system mapping has been applied in the six case study countries in WATERMINING where innovative sea, urban, and industrial wastewater mining solutions are demonstrated: CS1-6 (work packages 3-6). Subsequently, the analysis has been replicated for study cases in Germany, Greece, India, and Israel. In the latter countries, no actual case studies take place within WATERMINING, but for existing plants in these countries, it has been 'simulated' what their markets for WATERMINING solutions look like and what improvements could be made to enable market entry of circularly produced goods.

2.2. Steps

In terms of organization, together with partners from the WATERMINING case studies, the following steps have been carried out, during months 1 through 18, to map markets for circular sea- and wastewater treatment:

1. Together with Case Study partners (case study owners and facilitators), the **scope of analysis** for each case study has been determined by identifying which of the products to focus on in the MSA, given the resources within the project. Subsequently, case study partners participated in an **introductory training** session hosted by JIN to familiarise themselves with the concept of market system analysis and to receive instructions on the first MSA step of 'preliminary mapping'. This training was required as the MSA was to be carried out by Case Study partners given their familiarity with Case Study market contexts, stakeholders active in the markets and ability to communicate with stakeholders in the national languages.
2. The first product of MSA was a **rough version of a market system map**, which was drafted by the case study owners and facilitators on the basis of their expert knowledge.
3. These rough maps were subsequently extended with interviews with, per case study, a small group of **key informant stakeholders**. For that, case study owners and/or facilitators identified three to five stakeholders for their case study with detailed, expert knowledge of current market conditions. With help of their inputs, the rough market maps were extended towards **advanced market system maps**. Interviews with key informants have been recorded, where feasible and/or allowed, or summarised by the case study owners/facilitators, whereby summaries have been checked with key informants for correctness and completeness.
4. Based on the advanced market map, a first indication has been obtained of **market barriers** that could hamper the eventual deployment of a WATERMINING solution in the market. Such barriers could be market inefficiencies in terms of how market actors collaborate or compete in the market (e.g. competition between circular and linear processes), lack of policy incentives, legal barriers or knowledge gaps. The foreseen next step of inviting wider groups of stakeholders in the Case Study countries to validate the advanced market maps, possibly at meetings of the Communities of Practice (CoP) was complicated due to COVID-19 restrictions as these delayed CoP meetings. When CoPs were held during September-November 2021, there was too little time to also validate the advanced market maps. Hence, an amendment request has been filed to extend Task 9.2 to month 30 (instead of month 18), so that more time is available for a solid, wider stakeholder validation of the market system maps.
5. The result of that will be the **final market system maps**, showing a picture of what markets should look like in order to be ready for deploying and diffusing WATERMINING solutions. These maps will be presented at sessions of the Community of Practice in each case study environment and included in D9.6

2.3. Applied schedule

For effective inclusion of the stakeholders in the work on the case studies, also to avoid stakeholder fatigue, a research schedule has been applied for Task 9.2 as shown in Table 2-1 and Figure 2-2.

Table 2-1. Timetable market system mapping Task 9.2

Timing	Project activity	Actions
December 2020	Stakeholder identification	Who are the parties to benefit from WATERMINING solutions and whose input into the project is indispensable for improved market conditions and actions for scaling up solutions?
January 2021	Bilateral meetings with case study facilitators and owners	Finalisation of the scope of case study analysis, i.e. which WATERMINING product, resource or technology to focus on for exploring circular business models? Mock session on market mapping and identification of enabling actions. Planning agreement, i.e. when to reach out to stakeholders with questionnaires, interviews and meetings.
February – June 2021	Towards advanced market maps	Rough market maps by case study owners/facilitators Interviews with key informant stakeholders.
September – November 2021	Presentations at CoPs	This was done for a few Case Studies, for reasons mentioned in Section 4.2.
February 2022 – September 2022	Stakeholder meetings on market barriers	Validation of advanced market maps, barrier analysis and exploration of solutions.

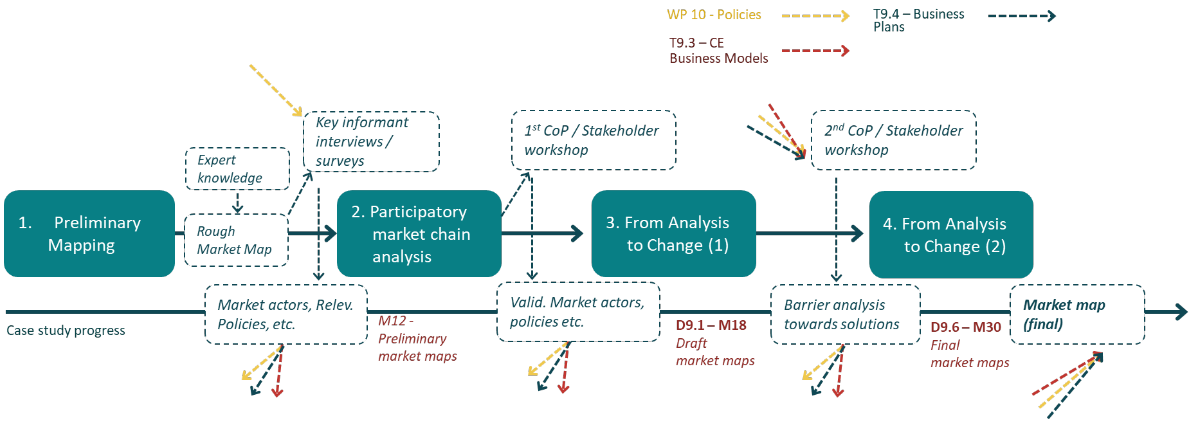

Figure 2-2: Schedule activities Task 9.2

Note: This deliverable covers the outcome of Steps 1, 2 and 3; Step 4 will be covered by D9.6

As explained in Section 4.2, in order not to overburden stakeholders, it was agreed with CS leaders/facilitators and CoP meeting organisers to move the wider stakeholder consultations and their validation of the advanced market maps to February – May 2022.

2.4. Market Systems Analysis for Case Studies

1. WATERMINING hosts six Case Studies in three categories of (waste) water treatment. Next to the six case studies in WATERMINING in WP3-6, Task 9.2 also conducts a market system analysis for 'replication' cases in four other countries (see Table 2-2)
2.). In these countries, we test the replicability of WATERMINING solutions in a different country context; what are commonalities and differences between markets for similar products in different countries and what is the scope for mutual learning. The replication cases are done in collaboration with WATERMINING partners in these countries.

Table 2-2: Overview of case studies, the case study owners, and facilitators

Case study	Source for WATERMINING	Case study owners	Case study facilitators
CS 1 – Lampedusa	Seawater	S.El.I.S.	WEI
CS 2 – Spain	Seawater	CIEMAT	CIEMAT
CS 3 – Portugal	Urban wastewater	TU Delft, ADA	Acciona
CS 4 – Cyprus	Urban wastewater	LARNACA	NTUA, MADISI
CS 5 – Catalonia	Urban wastewater	ACSA	UAB
CS 6 – Netherlands	Industrial wastewater	Hexion	WEI
CS 7 – Israel	Urban wastewater	JIIS	*The four replication cases do not have a case study facilitator since they are not linked to a Community of Practice as is the case in CS1-6.*
CS 8 – Greece	Seawater	NTUA	
CS 9 – Germany	Industrial wastewater	DECHEMA	
CS 10 – India	Industrial wastewater	VSI, Hexion	

The market system analysis scopes for these case studies are summarised in Table 2-3.

Table 2-3. Overview of scope for market system analysis of Case Studies

Case study	Product Scope	Geographic Scope
CS 1 – Lampedusa	- Recovered water for internal local use - Recovered waste heat - Salts	Mediterranean region
CS 2 – Spain	- Renewable energy production with Concentrated Solar Power (CSP) and residual heat for desalination - Desalinated water adequate for irrigation in agriculture	Almeria, Spain
CS 3 – Portugal	- Kaumera - Phosphorus recovery	Portugal; EU for phosphorus
CS 4 – Cyprus	- At least two products: - Water (agriculture), phosphorus (fertilizer), salt (mainly sodium chloride for industrial use)	Cyprus
CS 5 – Catalonia	- High-quality water (industrial use) - Water for agriculture - Phosphorus	Catalonia, Spain
CS 6 – Netherlands	- Purified industrial brine - Salts - Possibly hydrochloric acid (HCl) and sodium hydroxide (NaOH)	The Netherlands
CS 7 – Israel	The product scope is yet to be determined	Israel
CS 8 – Greece	- Recovered water for internal local use - Recovered waste heat - Salts	Greece
CS 9 – Germany	Digitalization for an integrated approach of water system planning, operation and maintenance, incl.: - Connecting sensors across the water system (using ICT, such as Internet of Things) for real-time data collection, as input for - Computer (forecasting) models, and - Real-time control systems.	Germany
CS 10 – India	The product scope is yet to be determined	India

In the next chapters, the Case Studies' advanced market maps are further elaborated, with Chapter 3 covering seawater mining, Chapter 4 covering urban wastewater mining and Chapter 4.4 focussing on Industrial wastewater. Included in these chapters are the market maps done for Germany, Greece, India, and Israel to replicate MSA done for the Case Studies.

3. Market System Analysis: Mining Seawater

3.1. CS1 – Lampedusa, Italy

3.1.1. Introduction

The case study at Lampedusa belongs to the category within WATERMINING where the focus is on the treatment of seawater streams to provide clean water and to recover valuable minerals and products (mining seawater). This case study combines techniques to remove all liquid waste from the process of seawater desalination (zero liquid discharge) to (internally) reuse recovered resources and to integrate waste heat in a demonstration project. Next to the municipal potable water, the treated water will be used as tap water for local internal consumption and cooling water for diesel engines of nearby power facilities. The salts that are recovered from the seawater can be sold to different end-users. The technology itself has a high replicability potential considering that it can be used across the islands within Europe and beyond. An overview of market chain actors that have been identified so far in case study 1 is provided in Table 3-1.

The scope of the market system analysis for the Lampedusa case study consists of two main product categories:

1. Water – The technology recovers usable water from seawater for internal use as a coolant, and ice as a by-product of the Eutectic Freeze Crystallization (EFC) process, and
2. Recovered salts – The technology includes the 'mining' of different salts such as sodium chloride (NaCl), magnesium hydroxide ($MgOH_2$), calcium hydroxide ($CaOH_2$), sodium sulphate (Na_2SO_4), hydrochloric acid (HCl), and Sodium hydroxide (NaOH).

As a first step in the market system analysis, the case study owner and facilitator drafted a map of the market system for the above product categories, based on their expert knowledge. This map was used for discussion (via a survey) with the seawater treatment plant operator SOFIP, and subsequently with the case study's key informant stakeholders ResourSEAs, SOSALT, and ARCA Sicilia. The results of this process have been used during the first Communities of Practice meeting in Italy to collect further feedback from a broader stakeholder group. Altogether, the expert knowledge of case study owners and facilitators and the knowledge of external stakeholders provided via interviews, the survey, and the first CoP meeting is integrated into the advanced market map for this case study (see Figure 3-1).

Table 3-1: Identified market chain actors in CS 1

Market chain actor category	Description	Stakeholders
Technology providers	Design and provide the technology.	- SOFINTER and TUDELFT, assisted by NTUA for the bench-scale tests - Nanofiltration: LENNTECH - Magnesium crystallizer and EDBM: UNIPA - Thermal crystallizer: TITANSALT - Eutectic Freeze Crystallizer (EFC): TUDELFT
Energy supplier	Supply of power to the seawater treatment plant operator, as well as waste heat and brine to the Zero-Liquid Desalination operator.	S.EL.I.S.
WWTP operator	Maintain and operate the technology.	SOFIP, PROTECNO, ACCIONA
Input supplier	Supply of NaOH.	N.a.
Packaging	Packaging of the products.	
Traders & logistics	Distribution of products to end-users.	
End-users	End-users for water and salts	Municipal end-users (potable water) Fishery (ice)
'Linear' salt producers	Existing producers of comparable products.	- Alca Chimica - ResourSEAs - Italkali - SOSALT

3.1.2. The advanced market map for Italy

The market value chain - market actors

Mapping the market, first, the composition of the **market chain** was identified, and key roles were attributed to specific examples of respective Italian market actors. The latter group can be broken down into the i) suppliers, ii) the operator of the technology, iii) the market actors involved in logistics & distribution, and iv) the end-users. The first part of the market chain is well represented in the project with the energy and technology supplier being part of the WATERMINING project consortium:

- **Technology providers:** As the overall process comprises different technologies, there are several technology providers involved per process:
  - Evaporator (MED): SOFINTER and TUDELFT, assisted by NTUA for the bench-scale tests;
  - Nanofiltration: LENNTECH;
  - Magnesium crystallizer and EDBM: UNIPA;
  - Thermal crystallizer: TITANSALT;

    - Eutectic Freeze Crystallizer (EFC): TUDELFT.
- **Energy Supplier:** The electricity supply company operating on the island of Lampedusa and case study owner of this case study (SELIS) supplies power to the seawater treatment plant operator (SOFIP). Moreover, it supplies waste heat and brine from reverse osmosis (RO) equipment to the zero-liquid desalination operator.

At the core of the market map is the **Zero-Liquid Discharge desalination operator** being a separate entity from the desalination plant itself. The products generated by the WATERMINING technology are the following:

- **Sodium hydroxide** (NaOH), is internally produced by one of the installations but also bought from a supplier. The internally produced NaOH is sold to the seawater treatment plant operator but could also be reused directly in the future if the quantity and the quality were sufficient.
- **Hydrochloric acid (HCl)** is supplied to the seawater treatment plant.
- **Water** is supplied to the energy company (SELIS).
- **Salts** (NaCl, MgOH2, CaOH2, Na2SO4) are produced and can be supplied to different end-users in the market.
- **Ice** is a by-product of the process and could also be sold and distributed to the local fishery sector (see also below).

Concerning logistics and distribution, stakeholders have highlighted during the CoP that a company dealing with the packaging of the products could be relevant in the market chain. There is possibly also the need for a market actor who can trade and distribute the different products further on into the market. However, potential companies to undertake this role and thereby enable the market deployment of the solutions have not been specified yet in the advanced market map.

Conducted interviews with key informants led to the recognition that the specific **end-users** per product vary and are yet to be determined in most cases:

- **Magnesium hydroxide** end-users could be industries that use this resource for fertiliser products in the agricultural sector,
- **Ice** produced by the EFC unit could be used by the fishing sector which is very prominent in Lampedusa; fishermen could use the ice to keep the fish fresh during its transportation.
- **Sodium chloride** could be used both in the non-food or food market. In the non-food market, sodium chloride is needed for some chemical and pharmaceutical applications. Besides, lower quality salt could be used for melting ice. Concerning the food market, EU regulation prohibits sodium chloride by-products from chemical processes which may be an overall barrier to using it for food market applications. Which specific EU regulation/directive applies for human dietary consumption of NaCl still needs to be investigated, as part of the wider stakeholder consultation foreseen in the project and collaboration with work package 10 (WATERMINING's policy work package).
- End-users for **sodium sulphate** (Na_2SO_4) and **calcium hydroxide** ($Ca(OH)_2$) could not be identified yet during the first stage of market system analysis.

Barriers and enablers

In terms of barriers, it has been frequently mentioned during the key informant interviews that the market price for the produced salts is a critical component. Especially for sodium chloride and calcium hydroxide, the market is currently supplied by providers that have an advantage by mining these salts in a conventional and low-cost way. Traditional market suppliers, using conventional linear techniques, can produce, e.g., sodium chloride at very low costs and saltworks. Also, calcium hydroxide is already produced (linearly) at low costs and in high quantities in mines. The market for magnesium hydroxide and sodium sulphate in terms of prices and potential customers yet needs to be explored, which will be progressed in collaboration with Task 9.3 and 9.4 of WATERMINING.

Next to the uncertainties of market prices, there are also high costs of transporting waste and products to the mainland (shipping costs). This can be one of the main issues for islands, in general, to compete with products that may be produced in a conventional way on the mainland.

From a *technical point of view*, there are yet a few uncertainties among stakeholders about the quality of the products. It is hoped that more certainty on product quality can be provided based on the data from the demonstration plants in the WATERMINING case study.

Furthermore, the market mapping has resulted in the identification of important drivers for the deployment of this WATERMINING technology, among which is the contribution to the environment. On the one hand, sustainable desalination processes can address **water scarcity issues** in some Italian regions. Another aspect is that the technology produces **less waste** compared to conventional seawater desalination, e.g., the brine which is not disposed of in the sea.

In terms of *policies*, a potential enabler is that the new technology anticipates stricter discharge norms, e.g., about salt concentrations of effluents since it already eliminates effluents. This can be a major advantage in the future over conventional technologies. Next to this expected competitive edge, the Lampedusa case study solution is fully in support of the EU Green Deal perspective, including the reuse of waste heat and the recovery of products from waste. As such the case study contributes to one of the main Green Deal building blocks which is the circular economy (new circular economy action plan). On a more local/regional level, there are further opportunities since the Sicily region currently drafts a new white paper which also addresses how to attract and use European Funds e.g., from the EU Green Deal to develop the region over the next five years. The process includes the involvement of stakeholders such as institutions, start-ups, the industrial sector that can contribute to the white paper by participating in focus groups. WATERMINING could benefit by participating in the focus group on energy, and the focus group on smart cities, whereas these groups can benefit from WATERMINING results.

The market mapping process, however, has also shown that there are difficulties to involve Italian governmental authorities in these circular processes. This may prove to be a significant barrier for scaling up since the authorities can commission permission/trial processes for the new technology. According to one of the interviewees, this investigation of the new process and products in terms of among others environmental aspects and product specifications may take several years during which no production might be possible.

From the perspective of **facilitating services** for the case study, the advanced market mapping led to the identification of several cooperation opportunities. Some of these evolved from two interviews conducted with ‘linear’ salt producers, one with a saltwork company and another one with a company producing magnesium hydroxide. Both revealed that the linear salt producers do not necessarily have to harm new innovative technologies but could even support their development and deployment. The interviews were very valuable for the identification of all market map components, and especially for barriers and enabling factors. In the case of the saltworks company, the WATERMINING technology is seen as supplementary to the current production process and the company representative indicated a high interest in cooperation. The same was the case for a producer of magnesium hydroxide production. The sort of cooperation and the underlying required agreements yet need to be determined, and insights derived from that could be input for the WATERMINING work on circular business models in work package 9.

What yet also needs further exploration is the consultation of environmental NGOs due to the potential **extraction of seawater from protected areas** around islands or elsewhere.

Furthermore, the interviews highlighted three actors (ARCA, the National Association of Green Energy for little islands, and the Enel innovation hub) that could further support the development of the whole market chain. ARCA for instance offered to establish connections between WATERMINING and the other facilitating services, but also the regional government. It is highly recommended to make use of this contact, particularly since the involvement of the public sector has been proven to be difficult.

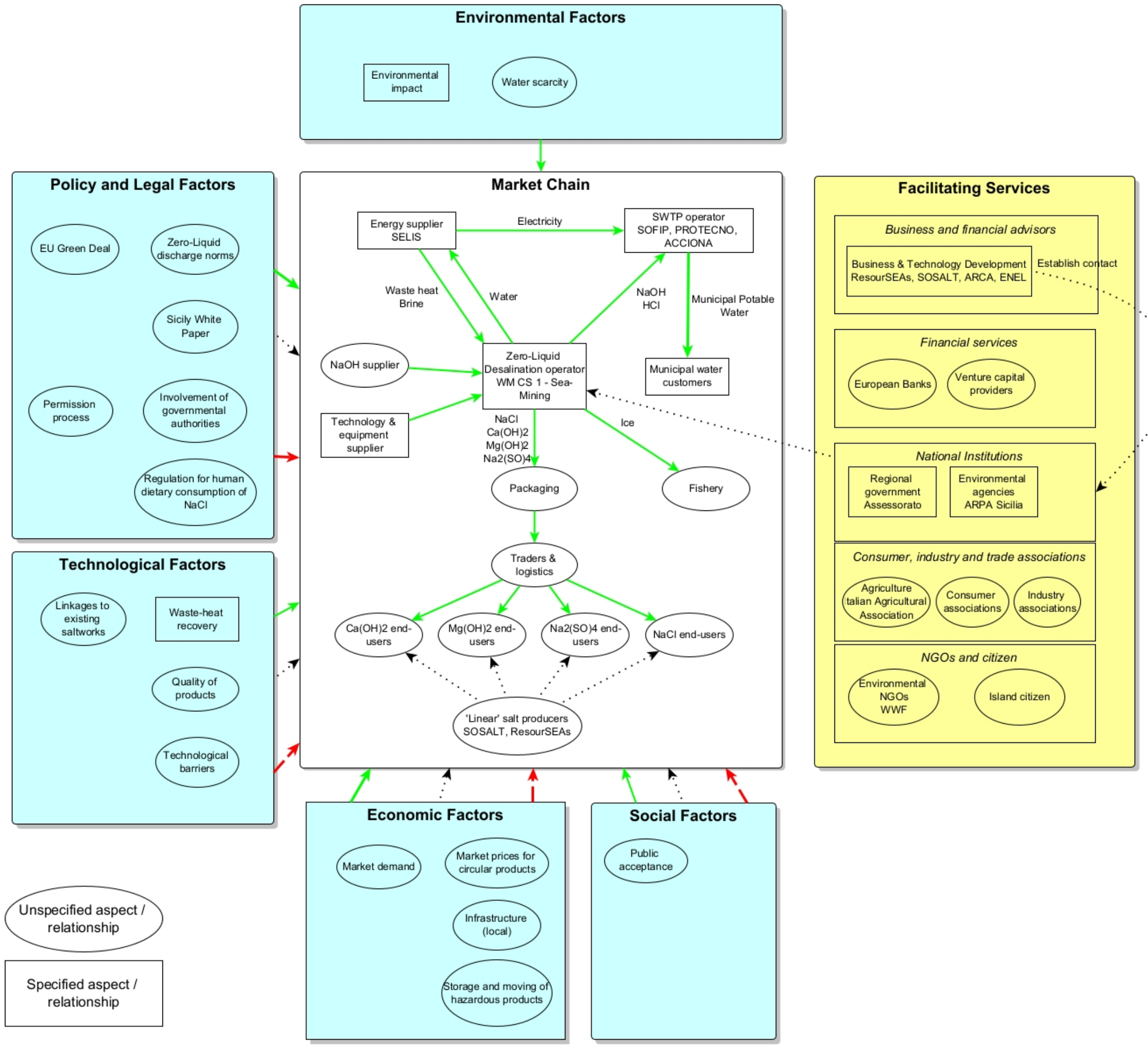

Figure 3-1: Advanced Market Map – Integration of waste heat and recovery of salts in Italy

3.2. CS2 – Almeria, Spain

3.2.1. *Introduction*

In WATERMINING's Case study 2 at Almeria (Spain), the focus is on the desalination of seawater with help of renewable energy sources. For this circular treatment of seawater, a demonstration plant will be manufactured and operated under the project, using techniques such as nanofiltration, a multi-effect solar thermal evaporation plant and a crystalliser that is powered by solar thermal energy. Setting up the demonstration plant is done in work package 3, with a 'light' focus on thermal desalination and a 'heavier' focus on the integrated system of renewable energy production and using residual heat for water desalination. The purified water will be applied for irrigation in agriculture. A brief overview of market chain actors that have been identified so far in case study 1 is provided in Table 3-2.

The market system analysis, undertaken in Task 9.2, is aimed at describing the relevant markets for the outputs of the circular process for desalination of seawater. The resulting market map, taking a system-level perspective with market actors, relevant policies and customer needs and habits, and relevant institutions to support circularity, etc., enables case study partners and stakeholders to explore how well the relevant market for the technology will be able to adopt the technology and supply its products to potential users, i.e., agricultural sector. Based on the market system analysis, barriers can be identified that need to be cleared to provide circular and profitable seawater desalination plants and their outputs a level playing field in comparison with other, less sustainable products in the market.

As part of an initial capacity building step, bilateral discussions were held between the case study and the task leaders to determine the scope of the market system analysis. In consultation with the case study partners, it was decided to focus the market system analysis on:

- An integrated system of renewable energy production, using residual heat for water desalination,
- Thermal desalination, and
- Supply of treated water to the agricultural sector.

According to the methodology of Task 9.2 for market system analysis, case study partners have prepared a first draft of the market system based on their practitioner's, expert knowledge. This draft map has subsequently been discussed with a limited group of key stakeholders within the market to check for completeness and correctness. Interviewed stakeholders represented regional business associations and consulting services (ASEMPAL, Protermosolar, EFFERGY), technology associations (ASIT, SOLPLAT, CAJAMAR), as well as one representative of the agricultural sector (Vicasol).

The combined findings have been integrated into an advanced market map (see Figure 3-2). The outcomes are going to be communicated to the respective tasks in WP9 & 10 to develop a desirable market system that builds further on existing enabling factors and tackles the previously identified barriers.

Table 3-2: Identified market chain actors in CS 2

Market chain actor category	Description	Stakeholders
Technology suppliers	Provide the technology for desalination and crystallization.	CIEMAT
Energy supplier	Supply of power and heat (thermal collectors/CSP) to the seawater treatment plant operator.	
WWTP operator	Maintain and operate the technology.	
Environment	Supply of seawater	N.a.
Distributors	Agricultural water suppliers	
End-users	End-users for water and salts	Farmers, irrigation communities, fruit & vegetable handling companies

3.2.2. The advanced market map for Spain

Market chain actors

The core of the market map is the actors who together form the value chain for the Integrated system of renewable energy production, using residual heat for water desalination. Among these, the first group of identified market actors are the technology suppliers for:

- Solar technology to produce thermal energy and electricity. These actors can be divided into suppliers of thermal solar collectors and concentrated solar power technologies.
- Operating the desalination process, and
- The crystallization process.

Prominently in the market map is the inflow of seawater as the main water source with stakeholders responsible for collecting seawater and operating the infrastructure for that (pumps, pipelines).

The seawater is processed via the WATERMINING demonstration plant operated at Almeria resulting in three main products:

- Water for use in irrigation in agriculture: including actors in the agricultural sector,
- Drinking water for households: including, e.g., consumer organisations and local water boards,
- Salts 'mined' from the desalination process including divalent salts and sodium chloride

Based on the conversation with key informants it is therefore important to add the **water distribution companies** to the map, as well as **end-users** (farmers and irrigation communities) as it would help build awareness that purified water increasingly is a scarce good that needs to be protected. Also, these actors are relevant because of their behaviour as water demanding (their opinions and preferences do influence the final water mix), and as participants in the governance of agricultural water providers.

Concerning the policy enabling environment, the market map has identified three main policy areas as relevant for this case study:

- Water consumption in the agriculture section: regulations for the origin and quality of irrigation water to be used in the agricultural sector,
- Use of desalinated water in sectors other than agriculture, and
- Stimulating the use of renewable energy sources during seawater treatment.

Based on interviews with key informants it was suggested to **add actors from the Public Administration entities** that influence the legal framework and can create incentives to stimulate circular water treatment in the market.

One key informant explained that the use of renewable energy and the use of desalinated water must be empowered through the companies in the fruit and vegetable sector, as well as other industries of Almeria, with support from the Ministries of Agriculture, Environment, and Ecological Transition, the Provincial Council, and Town Halls, until reaching the irrigation communities. This would require streamlining of bureaucratic obstacles when applying for subsidies for the installation of the necessary infrastructures.

Facilitating services

The advanced market mapping identified the logistical and technical infrastructure support from **the water distribution network** as a supporting service for the case study. In addition, a key informant recommended adding the **Center for Industrial Technological Development (CDTI)** which is a public business entity dependent on the Science and Innovation Ministry and in charge of drawing the specific lines for financing. A key informant highlighted the importance of improving the municipalities' water distribution networks (with financial support to invest from both the private and business sector).

As relevant institutions the following policy-related actors have been identified:

- The Ministry for the Ecological Transition and Demographic Challenge, with its associated institutions:
    - Waters of the Mediterranean Basin (ACUAMED, contracting, construction, acquisition, and operation of hydraulic works)
    - Institute of Energy Saving and Efficiency (IDAE)
    - The hydrographic confederation (for water resources management),
    - Council for agriculture, farming, fishing, and sustainability (water resources management),
    - Provincial deputy bodies for the above institutes.

These actors can support the market value chain with help of policy instruments, such as:

- market-based instruments, such as a feed-in tariff for water produced with renewable energy,
- command and control policies, such as ensuring quality levels of the water distributed to end-users, and

- investment-related support, such as government investments in longer-term circular seawater treatments, thereby considering the water-energy-food nexus.

These suggested policy instruments will be further discussed in the next stages of the market mapping in conjunction with policy packaging analysis in WP10.

Barriers and enablers

The advanced market system map has been completed in collaboration with five key informant stakeholders. As such, it forms a basis for further discussion with wider stakeholder groups in the next stages of WATERMINING, such as via the meetings of the Community of Practice. A key objective of the next steps is to identify actions for successful market deployment of the circular WATERMINING solution developed in the Almeria case study. Based on the current advanced version of the market map, the following barriers can be identified as well as a potential enablers to clear these.

One of the major barriers to circular seawater desalination is that current **illegal water catchment** takes place. As a consequence, existing aquifers become increasingly depleted which leads to water scarcity, but it also results in insufficient income from water supply so that costs of circular water treatment are more difficult to be covered. Key informants have pointed out groups of end-users consider water a public good that belongs to everyone and therefore should not be paid for. There are considerations among the stakeholder to counter this issue. On the one hand, stricter monitoring of the local authorities may help prevent the illegal water catchment, though it is also agreed that enforcing prevention laws is hardly possible as in many cases the illegal wells are hidden in secret locations.

Another point of concern is that for finding sustainable water supply, innovative technologies are increasingly needed, especially in Spain. Possible measures that have been suggested in the market mapping analysis are integrated (policy) actions such as strategies with action plans to be implemented by governmental agencies, as well as the elimination of bureaucratic obstacles concerning governmental funding. The latter would particularly make the funding more accessible for small and medium-sized enterprises.

Another barrier to circular seawater desalination treatment with renewable energy relates to the relatively high costs of that when compared to linear processes. Key informant stakeholders mentioned the following reasons (which can be input for Task 9.3 and 9.4 concerning improved business models for the circular water treatment):

- The relatively high investment costs for circular water treatment can now only be borne by large water distribution companies. Stakeholders also mentioned that the electricity costs of multi-effect desalination (MED, specific energy consumption of ~2.6 kWh/m^3) combined with Nanofiltration could be higher than the benchmark with reverse osmosis (~2.9 kWh/m^3 in the Carboneras desalination plant).
- High upfront investment costs for renewable energy can be prohibitive, especially when compared with using conventional energy. This barrier can be cleared with renewable energy investment support, including the possibility of selling the energy produced. During the first

CoP stakeholders also mentioned the possibility to develop fiscal incentives, e.g., subsidies, to support renewable energy systems and thereby the business case of the desalination plant.

- At the same time, comparing the innovative technology in the Almeria case study to conventional seawater desalination is not accurate. Key informants explained that since the CO_2 emissions resulting from fossil-fuel based desalination are not priced or penalized, conventional technologies have a cost advantage. Should, instead, CO_2 emissions be costed this would give preferential treatment to renewable energy-based desalination. At the first CoP for Almeria, stakeholders suggested taxing desalination water produced with fossil-fuel-based energy.

In a contrast, some **enablers** have been mentioned throughout the market mapping in this case study. Key informants pointed at scientific reports and a growing public awareness that sustainable water supply is among the key challenges for humanity during the next decades. This could be considered an important driver for supporting policies for seawater desalination with circular techniques. Moreover, key informants pointed at the increasing support for sustainable technologies from society and also end-users of water such as the irrigators in the southeast of Spain. Growing awareness within society about sustainability and climate change impacts, due to the increasing scarcity of rainfall in regional latitudes, could increase market demand for water produced in circular, renewable ways, thereby stimulating further innovations in renewable seawater treatment technologies. The irrigators in the southeast of Spain are potentially important enablers since they are particularly aware of the urgency of accessing additional water sources.

Finally, policy instruments such as the Next Generation Funds which focus on the environmental and digital transformation of the agri-food and fishing system may be an opportunity to attract funding.

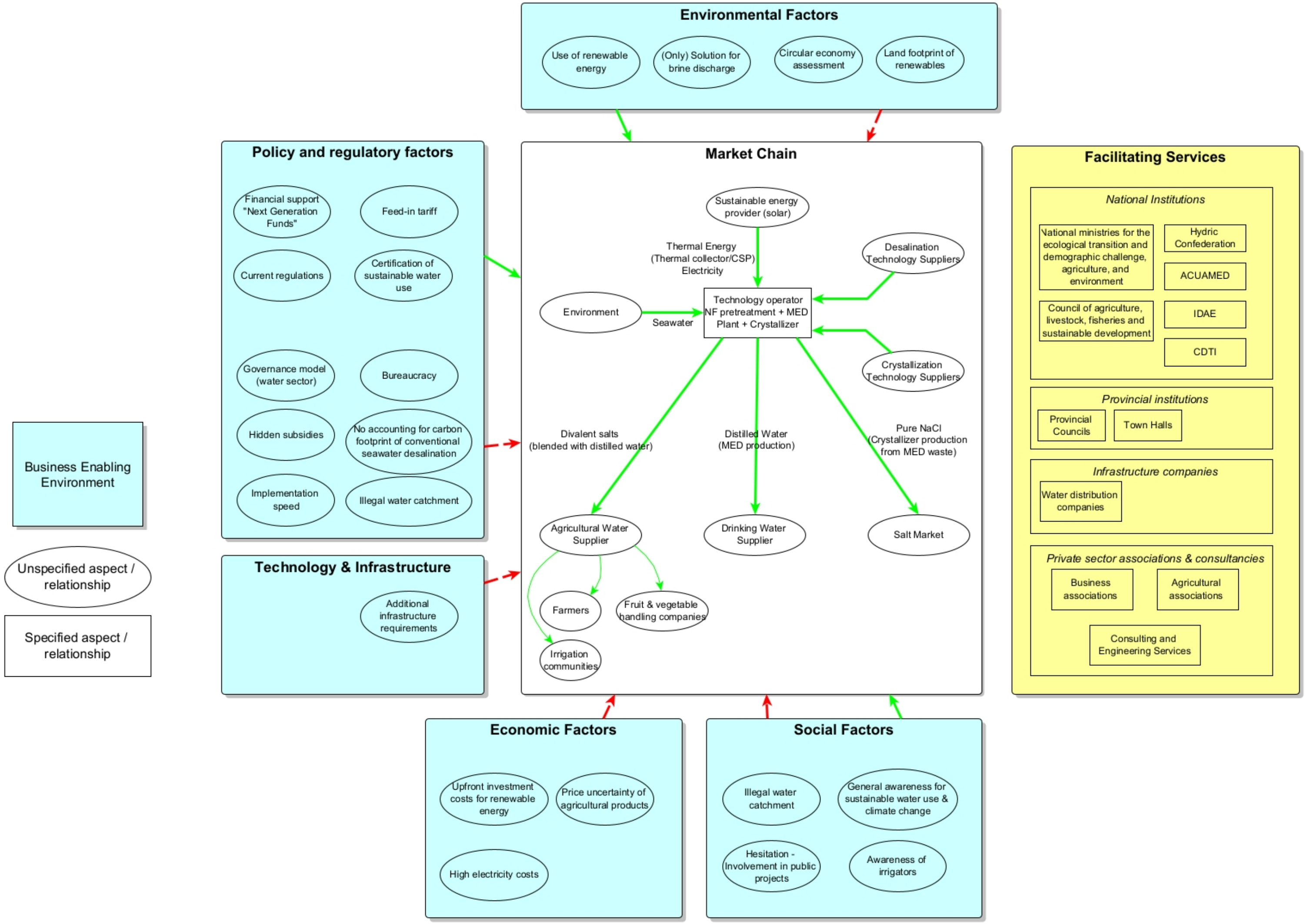

Figure 3-2: Advanced Market Map - Zero Liquid Discharge Desalination & integration of renewable energy in Spain

3.3. CS8 – Greece

3.3.1. Introduction

The Greek case study (case study 8) belongs to the group of replication case studies and focuses on SEA-Mining, i.e., the treatment of seawater and recovery of materials from it.

There is a large demand for desalination units in Greece, particularly for the many island communities where small desalination plants are located. At the same time, access to fresh water is one of the main problems that the population of these islands faces. There are also links to tourism since the problem becomes worse during the summer when many tourists arrive on the islands. At this moment, the only solution to this problem seems to be the desalination plants. However, conventional desalination units have an important environmental impact (brine discharge) which in turn affects the important tourism sector.

One way to counter this issue is the application of Zero Liquid Discharge (ZLD) desalination, therefore eliminating the brine. Since this technology is also going to be demonstrated in the Italian WATERMINING case study (CS 1), the case study in Greece can benefit from information about their demonstrated technology and the preliminary findings of the Market System Analysis in CS 1.

This report provides an overview of the MSA methodology, an introduction to the Greek case study as well as the documented results that have been obtained so far.

Based on their expert knowledge, the case study owner drafted a rough market map. The rough market map was presented to key informants to identify missing market actors (see Table 3-3), barriers and enablers. The following key informants provided their feedback to the map:

1. The Capital Water Supply and Sewerage Company
2. The Mayor of Corfu
3. CHEMiTECH (Water and Environmental Technologies)
4. A consultant to the Cyprus Ministry of Agriculture, Rural Development, and the Environment

The combined findings have been integrated into a preliminary market map (see Figure 3-3). The outcomes are going to be communicated to the respective tasks in WP 9 & 10 to develop a desirable market system that builds further on existing enabling factors and tackles the previously identified barriers and blockages.

Table 3-3: Identified market chain actors in CS 8

Market chain actor category	Description
Equipment provider	Supply of NF, RO, MC, and MED systems to the WWTP operator.
Energy supplier	Supply of power and if available waste heat to the seawater treatment plant operator.
Chemicals supplier	Supply of NaOH and Na_2CO_3 for the membrane crystallizer process
WWTP operator	Maintain and operate the technology.
Environment	Supply of seawater
End-users	End-users of produced water and salts

3.3.2. *The advanced market map for Greece*

Market actors

The application of ZLD desalination in Greece involves different market actors which in this case can be categorized as those that supply materials and the technology to the desalination plant, the operator of the plant itself, and end-users of different products.

The key component of the market chain is the ZLD desalination system installed in a desalination plant**.** The desalination plant operator extracts seawater from the environment and feeds it into the ZLD system. The proposed ZLD system includes a set of membrane and thermal processes aiming at the recovery of valuable and marketable products. The first unit of the proposed system is a Nanofiltration (NF) unit separating the seawater influent into two streams, the permeate and the retentate. The retentate stream, rich in CO_3^-, Mg_2^+, Ca_2^+, is fed into a membrane crystallization (MC) unit where **magnesium hydroxide** ($Mg(OH)_2$) and **calcium carbonate** ($CaCO_3$) minerals are selectively recovered. The crystallizer effluent mixed with NF permeate is forwarded to the Reverse Osmosis (RO) unit. The RO concentrate is directed to a Multi-Effect Distillation (MED) unit where distillate water and a concentrated brine (24% NaCl) are produced. The RO permeate can be blended with the distillate water to **produce potable water**. The concentrated brine is finally driven to solar drying for the recovery of **high purity sodium chloride** (NaCl) after water solar evaporation.

Next to the desalination plant operator, more market chain actors were identified, and their main roles are presented below.

Suppliers, including:

- *Energy suppliers* are needed to satisfy the electricity demand of the seawater desalination plant. Waste heat sources (e.g., in case there are nearby electricity generation plants based on combustion and/or (cement) industry), as well as energy from renewable energy sources, can be supplied to the process to increase the overall sustainability performance and decrease external electricity requirements. Particularly the Greek small islands have a high potential for solar and wind generation.
- *Chemical companies* ensure the supply of required chemicals for the Membrane Crystallizer (MC) process. Solutions of sodium hydroxide (NaOH) and sodium carbonate

(Na_2CO_3) are needed for the recovery of calcium carbonate ($CaCO_3$) and magnesium hydroxide ($Mg(OH)_2$) minerals.

- *Equipment provider:* The NF, RO, MC, MED systems need to be supplied by different companies. Several companies supply desalination systems in Greece, such as CHEMiTECH, Sychem, TEMAK, and Aqua-Genesis.
- *Seawater Supply:* Existing RO units operate based on extracted seawater from the environment.

For the use of these 'recovered' products, the case study owner and key informants identified different end-users per product:

- *Sodium Chloride (NaCl):* The recovered salt can be used in large quantities in the industrial processes to produce plastic, paper, rubber, glass, chlorine, soaps, detergents, dyes, and animal food. Also, large amounts of salt can be used for road de-icing
- *Magnesium Hydroxide ($Mg(OH)_2$):* The recovered salt is a critical raw material that could be used for roofing, isolation materials, plastic articles and coatings.
- *Calcium Carbonate ($CaCO_3$):* Building materials, ceramic tiles, blackboard chalk, iron and paints are some of the most common uses for calcium carbonate. Also, it is used in glass, and pulp and paper manufacturing processes.
- *Potable water:* Municipal water companies are the main consumer of potable water. They are also responsible for the supply of water for human consumption, industry, and irrigation in Greece.

In the next phase of market mapping, it is important to specify the different end-user groups. This relates particularly to which the industrial sector could make use of sodium chloride, magnesium hydroxide, and calcium carbonate. Besides industry, the scope of the water application needs to be specified to answer the question of whether the water should/could be used for irrigation purposes, municipal water supply, and/or industry.

Barriers and enablers

The main drivers of the proposed ZLD system can be summarized as follows:

- The minimization of the *environmental impact* caused by the avoided brine discharge to the aquatic environment.
- *Applicability:* The technology can be applied not only to seawater but also to other types of water such as brackish water and treated wastewater with high salinity. This is a specific advantage in cases where industry and municipalities deal with seawater infiltration of their infrastructure.
- *Availability:* The vast availability of seawater in Greece as the main source for providing clean water is an important enabler.
- *Diverse demand for salts*: There are multiple uses of the recovered salts in the industrial sectors (as shown above).

Besides those general enablers, this case study so far has recognized several policy aspects that could enable the deployment of ZLD in Greece. First, the following EU-level policies have been considered, as identified as relevant policies for sea-water mining:

- *Directive 2000/60/EK* - This directive is about the establishment of a framework for community action in the field of water policy.
- *Council Directive 98/83/EC* – This is a European policy on drinking water standards. If the treated water was used for human consumption, this policy needs to be consulted in further detail.
- *Directive 2000/60/EC* – This is the EU Water Framework Directive with the objectives to protect surface water and groundwater from pollution. The suggested technological solution has an advantage over conventional desalination since it does not produce effluents that need to be disposed of.
- *EIA Directive 85/337/EEC* – This is the European Environmental Impact Directive that applies to certain public and private projects. It yet needs to be evaluated if the suggested project would require an environmental impact assessment.
- *Council Directive 98/83/EC* – This directive is about the required quality of water intended for human consumption. It is important to note here that the Commission Directive (EU) 2015/1787 amended parts of the Council Directive 98/83/EC concerning monitoring and specifications for the analysis of parameters. Key informants also mentioned the guidelines for drinking-water quality, as provided by the World Health Organization (WHO), as a relevant policy aspect. These guidelines aim at the safety and acceptability of the products and sufficient quality control and serve together with the EU Commission's Scientific Advisory Committee as a scientific basis for the EU Drinking Water Directive.
- *EC 1907/2006 (REACH)* – This regulation primarily focuses on the Registration, Evaluation, Authorization and Restriction of Chemicals (REACH). It yet needs to be evaluated which chemicals used in the proposed process would be subject to this regulation.
- *Circular Economy Package* – The proposed solution contributes to the objective of the Circular Economy Action Plan to "close the loop" of product lifecycles through greater recycling and re-use and bought benefits for both the environment and the economy."[5] The concrete benefits coming forward from the contribution yet need to be analysed.
- *BAT reference:* The "Best Available Techniques (BAT) Reference Document of Common treatment/Management Systems in the Chemical Sector" may be a relevant policy document to consult when considering the implementation of ZLD desalination in Greece. It yet needs to be evaluated how this policy document is of relevance for the technology implementation.

Next to the number of EU policies, several national laws are either stand-alone or represent the harmonization of national laws with EU law:

- *Law 3199/2003 Government Gazette Issue 280/A/9-12-2003* – This law is about water protection and management and stems from Directive 2000/60/EC.

[5] https://ec.europa.eu/environment/topics/circular-economy/first-circular-economy-action-plan_de

- *Law 1739/1987, Government Gazette Issue 201/A/20-11-1987* – This national law considers water resources management at the national level.
- *Law 3325/2005* – This law concerns the establishment and operation of industrial, craft facilities in the context of sustainable development.
- *Ministerial Decision 221/65*: The ministerial decision considers the disposal of waste and industrial waste.
- *Law 1650, Government Gazette Issue A-160/16-10-1986* is about environmental protection and has been harmonized with EU law via law 3010/2002, Government Gazette Issue 91/A/25-4-2002
- Common Ministerial Decision No 43504/20-12-2005 determines categories of water use permits

In terms of potential **barriers**, key informant stakeholders elaborated on the following:

- *Law 2971/19-12-200* – This law has been mentioned by a stakeholder and is about "establishing the zones of the seashore, beach, old seashore, port, area of the port and the management of them". However, it is yet unclear how this policy document is relevant for the implementation of ZLD technology.
- *P.D. 148/2009 amended by Law 4014/2011 - Government Gazette Issue A 209/2011* "Environmental authorization of projects and activities, regulation of unauthorized constructions about the environmental balance and other provisions falling under the competencies of the Ministry of the Environment" determines environmental licensing. The case study owner notes that this legislation is perceived as a very strict one that is difficult to comply with.
- *Cost-benefit analysis:* According to stakeholders and the case study lead it needs to be checked if the high CAPEX and OPEX of the proposed system can be covered by the revenues for the recovered products.
- *Lack of reference:* According to one stakeholder, there is no technology operating in Greece which would be like the proposed process train. The lack of reference cases could be therefore a barrier for companies to apply the new technology.
- *High energy requirements:* The applied technology requires more energy than conventional seawater plants due to the added ZLD processes. This barrier can be partly overcome by the integration of more RES and/or waste heat, as well as the additional revenues from the recovered products from ZLD.
- *Land use:* Extra land surface area is required for the solar drying process.

Concerning possible **facilitating services**, mostly Greek institutions have been identified that are relevant to this case study:

- *Hellenic Food Authority:* This institution is involved in the permission process for the use of salts in food.
- *Ministry of Maritime Affairs and Insular Policy*: This Ministry is responsible for the desalination plants on the Greek islands and provides also the permissions to operate the plants.

- *The Hellenic Ministry of Environment and Energy* provides funds to municipalities to build the water treatment plants. It may be also of relevance when considering the deployment of ZLD desalination technology.

Since the ZLD technology is new in Greece, it is not clear yet what the role of those national institutions will be. Therefore, it is important to include policymakers in the discussion and the barrier analysis workshop that is yet to be planned.

The Food and Agriculture Organization of the United Nations (FAO) has also been mentioned by stakeholders as potential, however, it is not yet clear how the FAO could address ZLD desalination in Greece. Furthermore, it is recommended to investigate further which other policymakers are relevant (ministries and their departments, regulators of the water system (quality, pricing), etc.) and who could further support the deployment of the technology such as NGOs, business associations to further contribute to a more advanced water sector in Greece.

Next steps

The first step of the market system analysis led to the identification of the market mapping scope, several market actors, and the above-mentioned policy documents. As a next step, it is recommended to first analyse the outcomes of the WP10 deliverable D10.1 which may provide answers to the question of how the identified EU policies are relevant to the particular case of ZLD desalination in Greece.

In parallel, a stakeholder workshop is going to be set up 1) to present the WATERMINING project to a wider stakeholder group in Greece, 2) to explain the ZLD desalination technology as applied in CS1 to the stakeholders, 3) to identify additional relevant market actors, barriers and enablers, and 4) to find solutions to the identified barriers together with the workshop participants.

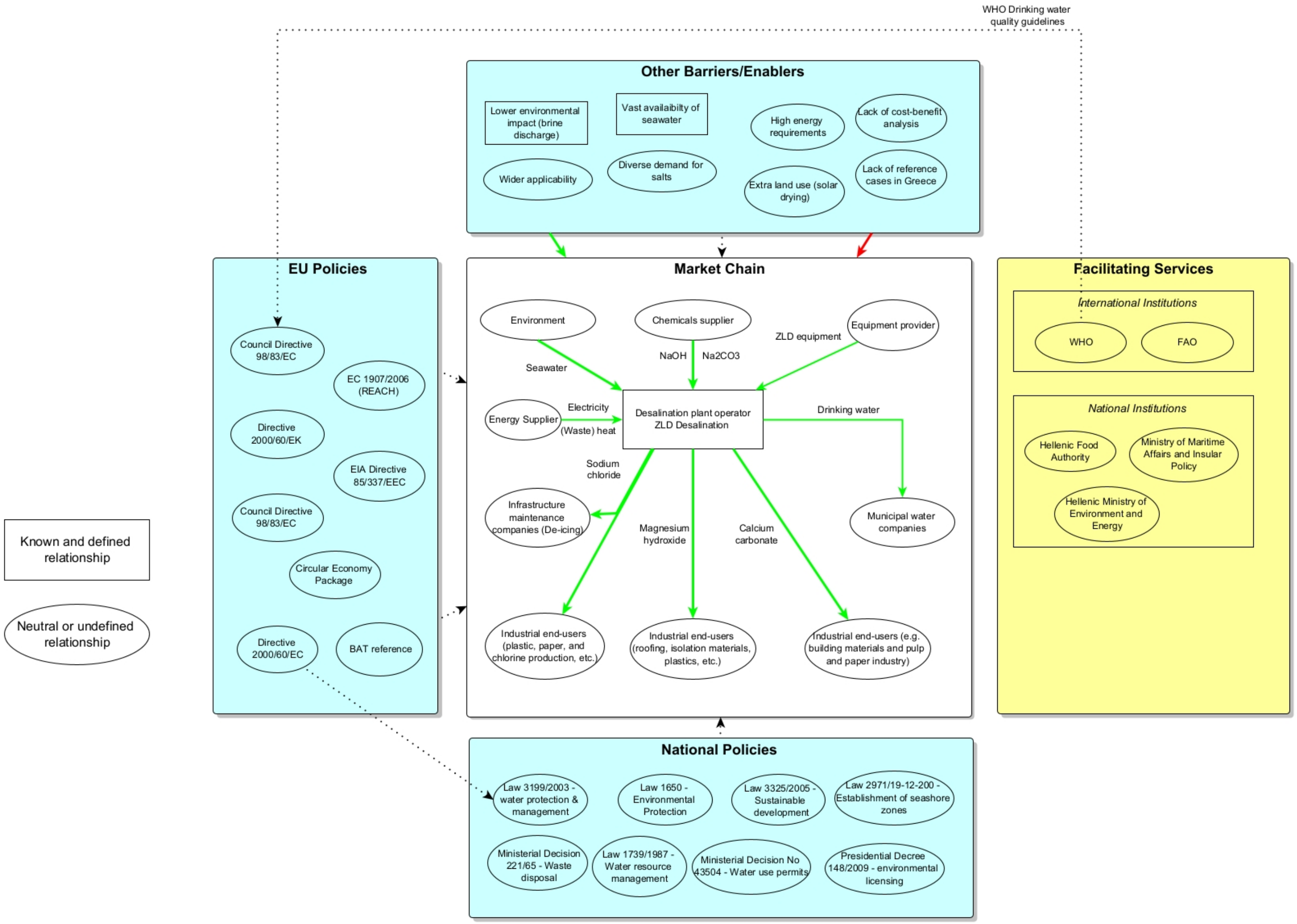

Figure 3-3 - Preliminary Market Map - Greece

3.4. Observations across Sea-Mining case studies

3.4.1. Barriers and enablers

The case studies in Lampedusa and Almeria, with the input from key informant stakeholders, have highlighted the following in terms of barriers and enablers:

Barriers:

- The business model for circular seawater desalination using ZLD and renewable energy sources needs to be proven, as it is surrounded by uncertainties about costs and revenues. As ZLD is a relatively new system, its costs are higher than those of conventional linear desalination techniques. Moreover, the use of renewable energy technologies for ZLD can be relatively expensive due to the high upfront investment costs of renewable energy investments and the insufficient pricing of CO_2 so that environmental costs of conventional energy techniques are not fully internalized in prices.
- A particular aspect mentioned in relation to revenues from supplying desalinated seawater is the illegal catchment of water by users. As such, part of the water supplied to the grid is not paid for. Changing that to the benefit of a better business model for circular seawater treatment requires not only a search for often well-hidden catchment sites, but also a change in the mentality of users in the sense that water is not free, public good, but a product that needs to be paid for.
- From the feedback by key informant stakeholders, it has also been learned that the products (the chemicals) mined through ZLD processes yet need to gain trust or confidence in the market. Not only do potential users know that alternative products, often produced or mined through linear processes, are relatively cheap, but they may also yet need to be convinced of the quality of the circularly mined products.
- Here, government-supported information and awareness campaigns could be helpful, but, particularly, the Lampedusa case highlighted the limited involvement of the national government in supporting sustainable seawater desalination techniques.

Enablers:

- Key informant stakeholders highlighted the growing concern in the case study countries about water scarcity. People increasingly become aware of climate change and its impacts, one of the most important being a lower supply of water. This strengthens the need for producing water for consumption and uses in industry and agriculture from sources such as seawater. As a consequence, momentum is growing in societies in Spain, Italy and Greece in support of sustainable water production from seawater.
- Moreover, communities increasingly realise that desalination of seawater should not take place at the expense of the environment. Especially, in regions that strongly rely on tourism, brine discharge is met with increasing societal resistance. This paves the way for ZLD as a technique to treat water without environmental pollution.

- Key informant stakeholders across the case studies highlighted the rather long list of potential EU policies and policy instruments (see also below) that could potentially incentivize ZLD-type of seawater treatment. Whether these policies and instruments are already sufficiently enabling for WATERMINING's solutions remains to be seen - this is the focus of WP10 – yet it has become increasingly clear for key informant stakeholders that incentives for circular water treatment are growing, e.g. EU Green Deal or other EU funding opportunities, and that policies to preserve the environment are becoming increasingly strict.

3.4.2. Policies: Commonalities concerning EU policies and directives

Based on the three case studies analysed in this chapter, for circular treatment of seawater the following European policies and policy instruments have been identified:

- *Directive 2000/60/EC* – This is the EU Water Framework Directive with the objectives to protect surface water and groundwater from pollution. The suggested technological solution has an advantage over conventional desalination since it does not produce effluents that need to be disposed of.
- *EIA Directive 85/337/EEC* – This is the European Environmental Impact Directive that applies to certain public and private projects. It yet needs to be evaluated if the suggested project would require an environmental impact assessment.
- *Council Directive 98/83/EC* – This directive is about the required quality of water intended for human consumption. If the treated water was used for human consumption, this policy needs to be consulted in further detail. It yet needs to be evaluated what the requirements are and how the suggested solution would meet them. It is important to note here that the Commission Directive (EU) 2015/1787 amended parts of the Council Directive 98/83/EC concerning monitoring and specifications for the analysis of parameters.
- EC 1907/2006 (REACH) – This regulation primarily focuses on the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH). It yet needs to be evaluated which chemicals used in the proposed process would be subject to this regulation.
- Circular Economy Package – The proposed solution contributes to the objective of the Circular Economy Action Plan to "close the loop" of product lifecycles through greater recycling and re-use and bought benefits for both the environment and the economy."[6] The concrete benefits coming forward from the contribution yet need to be analysed.
- *BAT reference:* The "Best Available Techniques (BAT) Reference Document of Common treatment/Management Systems in the Chemical Sector" may be a relevant policy document to consult when considering the implementation of ZLD desalination. It yet needs to be evaluated how this policy document is of relevance for the technology implementation.

These policies, how enabling they are or whether they represent policy gaps towards sustainable seawater desalination, will be further analysed in WP10.

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[6] https://ec.europa.eu/environment/topics/circular-economy/first-circular-economy-action-plan_de

4. Market Systems Analysis: Urban Waste WATERMINING

4.1. CS3 – Portugal

4.1.1. Introduction

Case study 3 belongs to the group of case studies in WATERMINING that focus on the treatment of urban wastewater streams to provide clean water and to recover valuable minerals and products (Urban-Mining). In this case study, the focus is on the production of **Kaumera** which is a new biopolymer with various application possibilities in agriculture, the building sector (flame retardant foam, medium density fibres, etc.), and other high-value applications (e.g., binder in composites). From a sustainability, circular economy perspective, one benefit of mining Kaumera from urban wastewater is that it transforms waste into a valuable product. This renewable and fully degradable biopolymer could substitute oil-based products, thereby reducing among others emissions of greenhouse gases. Moreover, producing Kaumera from waste helps to reduce excess sludge from wastewater, which in its turn reduces sludge disposal costs for wastewater treatment plants.

Kaumera can generally be produced in wastewater treatment plants that operate based on Nereda® technology[7] since the extraction of Kaumera requires Aerobic Granular Sludge – one of the products of Nereda technology. Currently, the Nereda technology is applied in 89 plants all over the world which implies that, in terms of the availability of the technology, Kaumera production can, in principle, take place globally. So far, there are two demo Kaumera extraction installations, one of them is located at the Nereda plant in Utrecht, the Netherlands.

In WATERMINING, the Kaumera demonstration installation in Utrecht is optimized and will be subsequently transported to Faro, Portugal, for further demonstration and operation.

The analysis for this case study focuses on the relevant market system for Kaumera in Portugal. Potentially, the Kaumera extraction process could lead to recovery of phosphorous and nitrogen, but as the testing facility in Faro-Olhão focuses only on Kaumera, only the potential market for Kaumera is considered. The potential recovery of phosphorous and nitrogen as part of the Kaumera extraction process is still in an early development stage.

On the application, demand side, we zoom in on the agricultural sector in Portugal where Kaumera can be used as a material for, e.g., biostimulants, superabsorbents and slow-release fertilizer coatings.[8] A brief overview of the market chain actors in Portugal is shown provided in Table 4-1.

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[7] For more information about Nereda, you can visit https://www.royalhaskoningdhv.com/nereda/

[8] More information about Kaumera can be found online here: https://kaumera.com/

Case study owners and facilitators (AdA, Acciona, both from Portugal) started the market system analysis by drafting a rough market map based on their expert knowledge. The findings were further refined and extended by the outcomes of completed surveys and interviews with academia (University of Algarve), industry (BioSmart, Chaincraft) and the public sector (INIAV). The findings of that process are reflected in the advanced market map (see Figure 4-1).

Table 4-1: Identified market chain actors in CS 3

Market chain actor category	Description	Stakeholders
Chemical supplier	The companies which supply chemicals for the Kaumera production i.e., HCl and KOH for agricultural applications.	N.a.
Energy supplier	Electric power and heat are required to operate the WWTPs.	N.a.
WWTP operator	Maintain and operate the Nereda® and Kaumera technology.	AdA
Licensee and equipment provider	WWTP equipment and equipment provider and Nereda® licensee. Similar to Nereda, Acciona may become as well a Kaumera licensee.	Acciona Agua
Processors	Processing of Kaumera before it is either directly applied or further processed for different end-user applications.	Chaincraft
Post-processor	The product produced by the Kaumera processor may still need a subsequent 'post-processing' step and a respective market actor responsible.	- ADP Fertilizantes - Hubel Verde
Suppliers	The distribution of the final product may need to be taken over by local/national suppliers.	BioSmart
Contractors	Organization of disposal of sludge	N.a.
End-users-Farmers	Application of Kaumera in e.g., fruit orchards.	- Cacial - Frusoal - AlgarOrange - Individual farmers
End users- Golf course & garden maintenance companies	Application of Kaumera to gardens, golf courses and soccer fields.	- Infraquinta - Infralobo
End users- Other users	Flower cultivation and other end uses	- Mil Plantas - Messinagro

4.1.2. The advanced market map for Kaumera in Portugal

The market value chain - market actors

The core of the market map is the value chain, i.e., the actors who together process wastewater towards the product of Kaumera and its use in agriculture. In the rough market map, market chain actors were identified, and their key roles were attributed. The market chain can be divided into roughly three stages:

Suppliers, including:

- energy suppliers: delivery of power and heat for operating the wastewater treatment plant
- chemical suppliers: delivery of chemicals for the production of Kaumera
- equipment providers, such as for wastewater treatment and use of the Nereda technique
- wastewater supply from a municipality

Processors, including:

- Production of Kaumera at the wastewater treatment plant
- Processing of Kaumera after having been 'mined' from wastewater
- Kaumera post-processor, which is a potential, additional step after production of Kaumera, but which necessity requires further research, development, and demonstration. This role could potentially be taken over by the company that operates already in the Netherlands, or a local company which yet would need to be identified.
- Sludge disposal contractor, who is left with less wastewater treatment sludge after 'mining' Kaumera.

Users, thereby considering Kaumera's multitude of possible applications (fire-resistant coating for building materials, biostimulant, coating for fertilisers, etc.), in particular, the currently most promising application of Kaumera to soils, including:

- Farmers, such as fruit orchards, flower cultivators, and citrus growers, have been depicted in the market map via their associations.
- Golf course and garden maintenance companies, who use Kaumera as a sustainable fertiliser.
- Distributors, who can facilitate the transfer of Kaumera from wastewater treatment to end-users

Concerning the users, it is recommended to consult with each potential end-user to specify their product requirements:

- ADP Fertilizantes & Hubel Verde could clarify the requirements Kaumera must meet to be integrated into the current fertilizer and/or biostimulant production process.
- Another possible application could be fertigation via drip irrigation systems on Portuguese farms. In that regard, more stakeholder contact with the farmers and/or farmers' associations is required to clarify the requirements for fertigation of the plants (e.g., required amounts of

nutrients for citrus fruits and avocados) and if Kaumera-based products can technically be distributed via the existing systems.

- To clarify the specific requirements of green maintenance companies, the expertise of companies such as Infraquinta and Infralobo may prove useful.

Barriers and enablers

In terms of the business enabling environment, there are several examples for policy & regulatory, environmental, technological, economic, and social aspects that potentially impact the marketability of Kaumera in the market in Portugal. A recurring aspect during the key informant interviews is the *market price* of Kaumera. At this stage, information about the Kaumera market price is not available but it is expected that more information becomes available throughout the work on the case study, as this will provide better insight on production costs, value-added tax rate, potential subsidies, etc. Eventually, an important factor of success will be the competitiveness of the Kaumera price with alternatives, such as linearly produced fertilizers. In this respect, gathering additional information on the production and market prices of conventional, linearly produced products is required for determining the business plan for Kaumera (this is a key topic of Task 9.4 in work package 9).

The market mapping analysis, based on the expert judgement of case study owners and facilitators and key informant stakeholders, has revealed though that competitiveness of Kaumera does not imply that it must be cheaper than alternative goods in the market. A higher price for Kaumera could be justified and be acceptable for market actors if Kaumera represents and/or lead to higher quality, clear environmental benefits, and positive social perceptions in terms of sustainability, circularity. An evaluation of what could be an acceptable 'circular premium' paid by end-users is not part of the market system analysis but is a topic for consideration by Tasks 9.3 and 9.4 in work package 9.

Taking a *technical* perspective, the market system analysis has considered aspects such as process efficiency (i.e., whether differences in processing can be expected in Portugal as compared to the Netherlands), product characteristics (and impact on the application in different environments), the application procedures (e.g., in soils), quality assurance, heavy metal concentrations, and odour. From these, the strongest uncertainties were pointed out for:

a. The reusability of existing tools for applying Kaumera-based products in agriculture,
b. the overall process efficiency in Faro compared to the Netherlands, and
c. differences of Kaumera characteristics in Portugal (Faro) compared to the Netherlands are likely going to be clarified during the demonstration and testing period.

Particularly, the mentioned product characteristics may change since higher salt concentrations have been observed in the influent of the wastewater treatment plant in Faro. Stakeholders raised related issues that, e.g., local crops (citrus fruits, avocados, etc.) are susceptible to higher salt concentrations. This may require an additional 'washing' process for Kaumera before it is processed (as it is already done for coating applications) or other crops that are less susceptible to salts may be targeted instead. Addressing this uncertainty requires a further analysis of the salt concentrations in Kaumera and the impact on the soil. This could be conducted by accredited institutions such as the University of Algarve.

Concerning *policies*, the application of Kaumera in the agriculture sector could be in line with future, stricter European legislation towards a general reduction of microplastics. This legislation, which may results from the recommendations of the European Chemicals Agency (ECHA) to the European Commission, could imply a ban on, e.g., seed-coatings using microplastics. This could create market opportunities for nature-based, circular alternatives such as Kaumera.

Besides deliberations on potentially stricter future EU legislation, the market system analysis revealed the following EU policies as most important for the successful introduction of Kaumera in agricultural markets:

1) Regulation (EC) 1907/2006 (REACH), and
2) 'Waste Directive' 2008/98/EC.

The first policy document, REACH, defines procedures for collecting and evaluating information about the properties and hazards of substances. Generally, producers must register any new substance to clarify initial human health or environmental concerns. Currently, however, there is a discussion in the Netherlands about whether Kaumera consists of exopolymers. As the latter are considered natural polymers, Kaumera could be exempted from registration under REACH. A dossier on this is currently under validation by Dutch authorities.

The Waste Directive contains criteria for use of end-of-waste products. Based on these criteria many materials made from waste or sludge cannot be used in the production process of, e.g., fertilizers. However, in the Netherlands, authorities have granted Kaumera the status of end-of-waste, so that it can be used in fertilisers in the country.[9] The questions remain what this implies for using Kaumera in Portugal and stakeholders partaking in the market system analysis recommended that the Case Study investigate a) which Portuguese authorities would need to validate claims similar to the ones in the Netherlands, and b) if the dossiers for validation of Kaumera as end-of-waste product as used in the Netherlands are publicly available and can be adapted to the Portuguese circumstances (e.g., translation, different market applications). On this aspect, interlinkages with WATERMINING work package 10 on policy gaps and policy packages for circular water treatment solutions will be utilised.

Finally, consulted stakeholders highlight the facilitating role in the Kaumera product certification process in Portugal of the National Institute of Agrarian and Veterinary Research (INIAV), which accredits external entities to test new bio-fertilizers (such as Kaumera) for product effectiveness and characteristics in agricultural applications. The University of Algarve is among the entities accredited by the INIAV and performs trial tests on products for about three years. The University could, for instance, perform testing of Kaumera's salt concentrations and impacts on soil. In general, it is recommended by case study partners and consulted key informants, for further 'market literacy', to specify the interlinkages between the Portuguese regulating authorities and specific market players/barriers and enablers, thereby paving the way for Kaumera in Portuguese markets.

[9] Dutch authorities prepared and validated a background dossier about how Kaumera meets the requirements stated in the Waste Directive. These documents are with the Case Study partner Royal Haskoning.

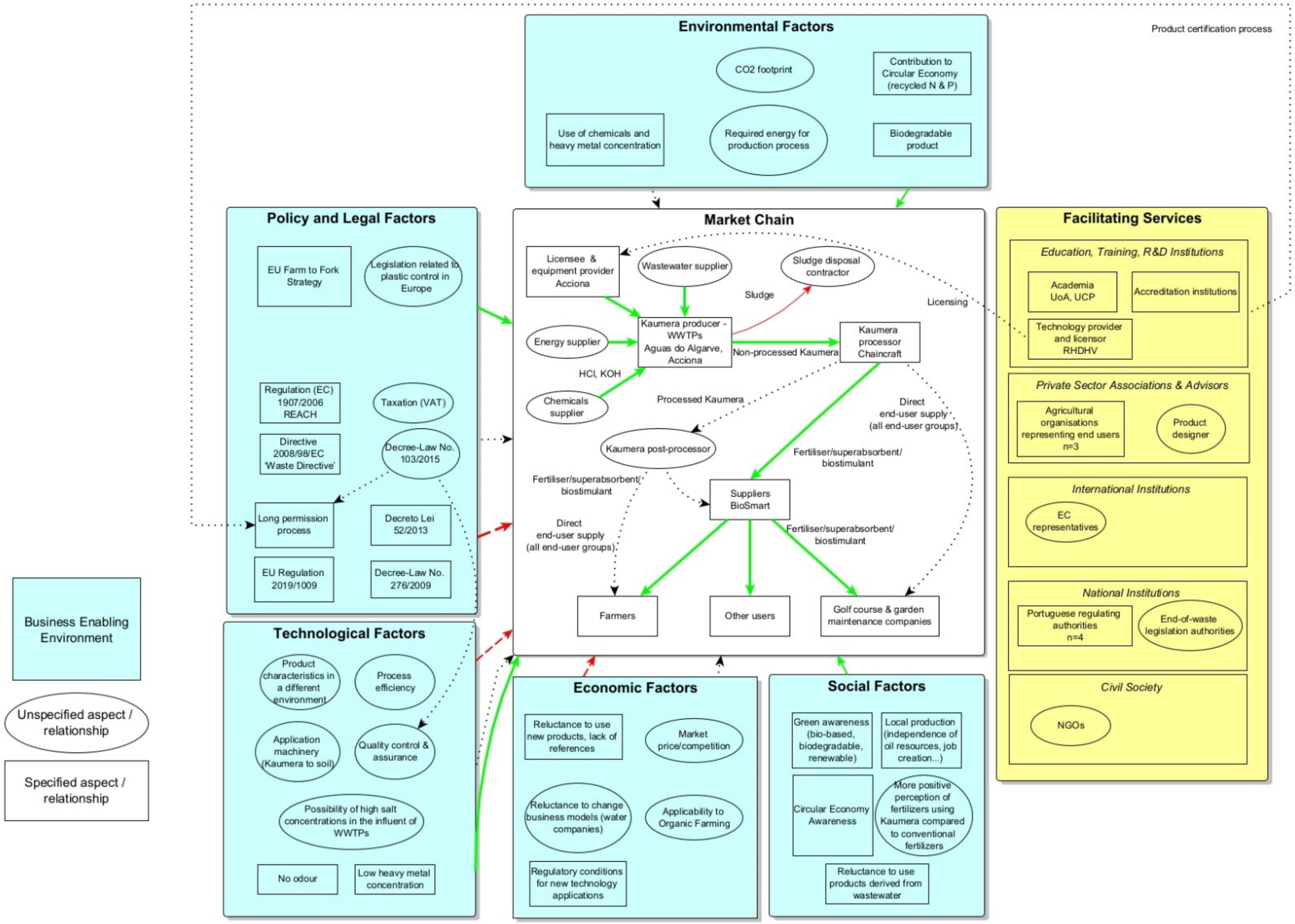

Figure 4-1: Advanced Market Map - Introduction of Kaumera in the Portuguese market system

4.2. CS4 – Cyprus

4.2.1. *Introduction*

Case study 4 focuses on urban wastewater treatment (Urban-Mining) of a wastewater treatment plant in Larnaca, Cyprus. At the plant, different innovative solutions shall be demonstrated, including phosphorus removal to ultra-low levels through adsorption, followed by membrane treatment (powered by renewable energy) and final brine elimination through Zero Liquid Discharge (ZLD). Parts of the treated water is supposed to be used for **irrigation purposes in agriculture.** Next to the treated water, **phosphorus and salts** can be recovered and marketed.

In order to distinguish the relevant market actors and to identify barriers and enablers to the implementation of ZLD desalination in Cyprus, the case study owner and facilitator drafted a first rough market map based on their expert knowledge. The respective project partners NTUA and MADISI further explored the market system by distributing the survey and conducting interviews with six stakeholders:

- Panagrotikos Association of Cyprus, which is an agricultural association representing and supporting a large share of agricultural producers in Cyprus,
- The Mayfair Hotel, which is a congress hotel, located in the south of Cyprus,
- Memira Genesis Ltd., which is a trading company of energy and water equipment systems, as well as systems for the production of renewable energy and exploitation of novel water/wastewater treatment and water reuse,
- Premier Shukuroglou Cyprus Ltd. (PSC) – A Cyprian company active in crop protection, crop nutrition, animal health & public health products in Cyprus. Since 2010, PSC has also been a producer of Green Compost, with a license for Green Waste Management.
- Cyprus Ministry of Rural Development and Environment,
- The Water Development Department of the national Ministry of Agriculture, Rural Development and Environment, is responsible for the protection and sustainable development as well as the rational management of the water resources of Cyprus under national and EU policies.

Subsequently, the market map was updated with the findings from the first stakeholder consultation step and then presented to a broader stakeholder group as part of the Communities of Practice meeting in 2021. Furthermore, the combined findings starting from the rough market map, including interviews and the stakeholder workshop, have provided valuable insight into the context of the reuse of treated water and mined phosphorus in the Cyprian agricultural sector. For instance, the market chain actors that have been identified so far are shown in Table 4-2, and general visualization of the market chain, the policy & enabling environment and facilitation services are presented in Figure 4-2. Furthermore, the findings are described in the next chapter.

Table 4-2: Identified market chain actors in CS 4

Market chain actor category	Description	Stakeholders
Chemicals supplier	Supply of iron and hydrochloric acid to the wastewater treatment plant.	N.a.
Energy supplier	Supply of electricity to the wastewater treatment plant.	N.a.
Wastewater supplier	Convey the wastewater from the Larnaca area to the WWTP by the Sewage Board of Larnaca.	Sewerage Board of Larnaca
WWTP operator	Application of the WATERMINING technology incl. biophree adsorption, nanofiltration (NF), evaporation, crystallisation, and low-temperature evaporation	Larnaca Sewerage and Drainage Board
Water supplier	Receiving treated, cleaned water from the wastewater treatment plant and supplying it to agricultural end-users.	Water Development Department (tertiary treated water)
Phosphorous supplier	Receiving mined phosphorus from the wastewater treatment plant and supplying it to agricultural end-users.	N.a.
Agricultural end-users	Usage of sludge as a fertilizer	
Energy end-user	The sludge could also be used by industries as a fuel (cement factory) or waste treatment plants as an energy source (e.g., biofuel production).	
End-users-Farmers	Application of Kaumera in e.g., fruit orchards.	
End users-Green area maintenance and hotel sector	Usage of sodium chloride for chlorination, irrigation water and fertilizers for garden maintenance.	Mayfair Hotel
End users- Sewerage and water supply boards	Possible markets for sodium chloride are the sewerage and water supply boards to produce chlorine by electrolysis.	N.a.
Other end-users	Usage of water for cleaning photovoltaics, irrigation and usage of phosphorous-based fertilizers.	- Memira Genesis Ltd. - Premier Shukuroglou Cyprus LTD (PSC)

4.2.2. *The advanced market map for Cyprus*

Market actors

The market actors relevant to the proposed WATERMINING technology can be generally broken down into suppliers, operators, and end-users. The suppliers are needed to deliver energy, required chemicals (hydrochloric acid and iron) to the wastewater treatment plant. Furthermore, the Sewage Board of Larnaca which is a Public Utility Organization also supplies urban wastewater to the wastewater treatment plant.

On the operator side, there is mainly the wastewater treatment plant in Larnaca operated by the Larnaca Sewerage and Drainage Board. This Board facilitates the location/space for the WATERMINING technology within the wastewater treatment plant of Larnaca. Furthermore, the sludge by-product from the membrane bioreactor (MBR) after dewatering is distributed to agricultural end-users to be used as a soil conditioner. Also, the wastewater treatment plant supplies electricity for operating the WATERMINING technology.

The operation of the WATERMINING technology itself includes biophree adsorption, nanofiltration (NF), evaporation, crystallisation, and low-temperature evaporation. The produced sodium chloride by this process can be used for the disinfection of water in the tertiary treatment facility and there is also potential surplus production that can be used for other purposes (e.g., the sewerage and water supply board).

The main end-users are farmers who use the sludge as fertilizer and could also make use of the mined phosphorous, although within this market system a dedicated phosphorous supplier has not yet been identified. The water is used by farmers for irrigation.

Interviews with stakeholders have revealed an additional potential and interest for irrigation water in the hotel and green area maintenance sectors. There are also market actors in both sectors that would be interested in the use of the mined phosphorus for the fertilization of gardens and in irrigation water for green area maintenance, hotels and industry (one stakeholder indicated an interest in using the water for cleaning of photovoltaic installations). Furthermore, mined sodium chloride could be of interest to produce chlorine, which again could be used, e.g., for cleaning hotel pools. The last product to be mentioned here is the sludge from the MBR process which could be used by industries as a fuel (cement factory) or waste treatment plants as an energy source (e.g., biofuel production).

Policy environment and facilitators

Case study owner and facilitator, with the stakeholders, identified the following national institutions that could support the overall market chain for sustainable urban wastewater treatment:

- *Ministry of Rural Development and Environment*, a representative of which has been interviewed during the advanced market mapping process. The ministry impacts the WATERMINING solution in different ways, among others: (1) it governs the water price which is currently very low so that farmers prefer the currently available conventional water supply, (2) it has established legislation determining the water source for farmers, and (3) the ministry could help to promote the water provided by the WATERMINING technology.

- *Water Management Advisory Committee (WMAC)*, which comprises key stakeholders in the water management sector and has an active role in the formulation and implementation of water-related policies.
- *Water Development Department:* The Head of Sewage and Recycling Service of this department has been interviewed for the market map. Due to its close affiliation to the Ministry of Rural Development and Environment, the possible impact of this institution is similar to that of the Ministry and the WMAC mentioned above. The Water Development Department could organize workshops to promote the WATERMINING technology and disseminate the results, particularly of water quality and produced salts among potential users.
- *Accredited certification institutions* are required to certify the quality of the product. A certification of the recovered products from the case study at Larnaca by government agencies can help to promote the products to the market. The specific institutions responsible for the certification are yet to be identified within the market map.

Next to the national institutions, there are also associations and advisory boards that have shown interest in the project:

- *Cyprus Agricultural Association* is interested in the development of the Urban-Mining solution as it supports farmers and promotes policies at all levels.
- *Cyprus Employers and Industrialists Federation (OEB)* is the representative body of employers and businesses including all economic sectors in Cyprus. Among others, the OEB organizes capacity building workshops, webinars and online seminars. As part of the market mapping, it has been suggested that OEB promote the exploitation of the WATERMINING technology and recovered products.
- *Scientific Technical Chamber of Cyprus (ETEK)*, which fulfils two functions: It is the statutory Technical Adviser of the State and represents all Cypriot engineers. ETEK could support via its dissemination and communication channels, the Larnaca case study results and plans to the broader public and government authorities.
- For the further process, the *Cyprus Consumers Association (CCA)* could be an interesting organization to be contacted to increase public awareness concerning water issues (e.g., increase of salinity, water scarcity, etc.) in Cyprus and to promote the WATERMINING solutions which address these issues.

Barriers and enablers

In terms of identified barriers and enablers, stakeholders question whether the quality of the products could meet the requirements of several national and EU policies. An important related subject is the certification of products which could help in addressing the former point. From an *environmental point of view*, it has been mentioned that the proposed WATERMINING solution can help in tackling soil salinization due to the use of irrigation water with high salinity, which is currently an important environmental issue in Cyprus. Therefore, should this issue become a policy priority, then it could be an enabling factor for the case study solution.

Another discussion point concerns the position of the agricultural sector which could be ambivalent. On the one hand, the proposed technology helps with providing additional and higher quality water for irrigation (an enabling factor; stronger acceptance). However, it is expected that the removal of phosphorus from the wastewater reduces the fertilizing effect of irrigation water (a potential barrier; lower acceptance).

Consulting stakeholders has led also to the identification of relevant *national and EU policies*. Though, an analysis of said policies is yet required to determine how they could affect the deployment of the technology. The list and description of relevant policies is an interesting output that will be shared with the project partners of WP10 who deal with policies.

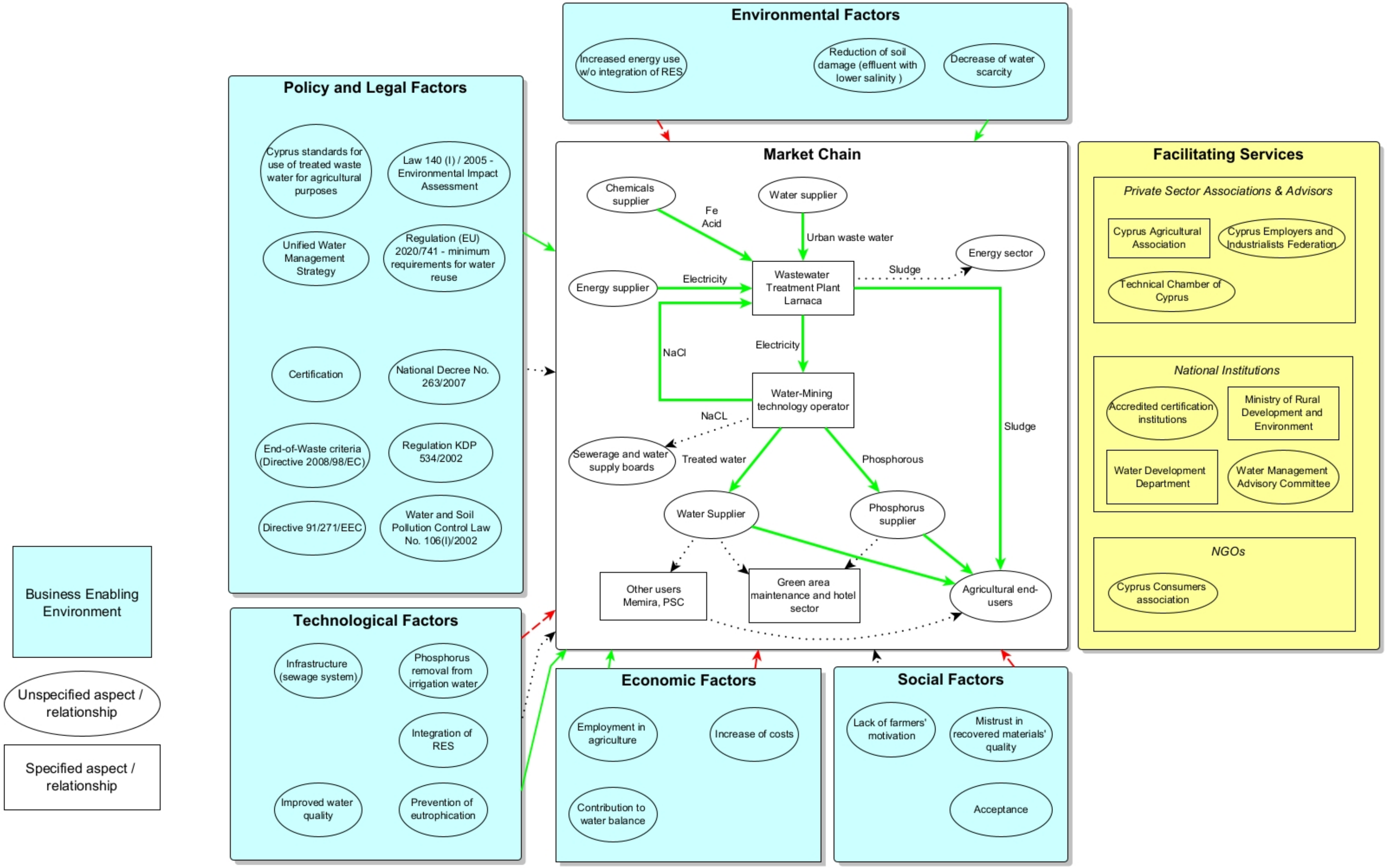

Figure 4-2: Advanced Market Map – Zero Liquid Discharge and recovery of salt, phosphorous and water in Cyprus

4.3. CS5 – La Llagosta, Spain

4.3.1. Introduction

In WATERMINING's case study 5 at La Llagosta, Spain, the focus is on the recovery from urban wastewater of phosphorus (in different ways) and fit-for-purpose water (ranging from street cleaning to agricultural and industrial use). For this circular treatment of wastewater, a demonstration plant will be set up in Catalunya, Spain, using techniques such as a granular anaerobic membrane bioreactor, a fluidized bed vivianite crystallizer and Biophree. Setting up the demonstration plant is done in WATERMINING WP5, as well as the establishment of a pilot-scale next-generation urban wastewater treatment plant for phosphorus and water recovery. Part of the case study analysis is also the demonstration of energy recovery from urban wastewater by converting organic matter into biogas.

This market system analysis is aimed at mapping the market actors in the relevant markets for the outputs of the circular treatment of urban wastewater, as described above, as well as identifying potential barriers and enablers relevant for the marketing of the products. The resulting market map enables case study partners and stakeholders to explore how well the markets are prepared to enable circularly produced goods and services to successfully find a place in the market chain and compete with products that are produced in linear, less sustainable ways. Based on the market system analysis, barriers can be identified that need to be cleared to provide circular urban wastewater plants and their outputs a level playing field in comparison with other, less sustainable products in the market.

In consultation with the case study partners it was decided to focus the market system analysis on three products:

- High-quality water for industrial use,
- Normal quality water for use in the agricultural sector, and
- Phosphorus.

According to the methodology for market system analysis, case study partners have prepared a first draft of the market map based on their practitioner's, expert knowledge. This draft map was subsequently discussed with a small group of key stakeholders within the market to check for completeness and correctness. In this first stakeholder consultation, which took place via interviews between March and May 2021, a first assessment has been done of possible barriers to further deployment of these circular techniques in the market. Subsequently, the draft market map was presented at the first meeting of the Community of Practice for this case study (30 September 2021) and discussed at a meeting with the case study owner on 29 November 2021. In a final step, in the first half of 2022, the updated market map will be presented to WATERMINING partners and a group of wider stakeholders for the case study.

For work on the market map, a list of stakeholders has been put together, of which selection has been made of people and organizations to be interviewed as key informant stakeholders.

Table 4-3 below shows the first results, i.e., the so far identified market chain actors.

Table 4-3: Identified market chain actors in CS 5

Market chain actor category	Description	Stakeholders
Technology Designers/Suppliers	Design and construct the technology.	- EURECAT - Wetsus
Contractor	Design and build WWTP	ACSA-Sorigué
WWTP operator	Maintain and operate the technology.	ACSA-Sorigué
Regulators/controllers	Set the individual revenue cap and efficiency targets and distribute wastewater to the WWTP.	- Catalan Water Agency (ACA) - Besos-Tordera Consortium (CBT) - Catalan Waste Agency (ARC) - Catalan Public Health Agency (ASPCAT)
Equipment & Instrumentation suppliers	Suppliers of (mechanical, electrical) equipment, instrumentation, and materials.	N.a.
End-users – Electricity & gas companies	Potential users of biomethane.	N.a.
End-users – Phosphorous	Usage of phosphorous-based products	Waste managing companies and fertilizer producers
End-users – Water	Usage of water for irrigation and environmental purposes (maintaining river flow rate and aquifers).	- Farmers & industry associations - Environment

4.3.2. The advanced market map for Catalonia

The draft market system map has been discussed and eventually agreed upon with five key informant stakeholders. As such, it has formed a basis for further discussion with wider stakeholder groups in the next stages of WATERMINING, such as via the Community of Practice gatherings (under WP2).

The components of the market map are explained in further detail below.

Market Chain Actors

Next to the regulatory organizations, the following market actors will have a key role in the successful deployment of the case study's circular water treatment approach:

- **Technology designers building the circular solutions:** actors in this category are involved in the case study as WATERMINING partners (EURECAT and Wetsus). Through the demonstration and pilot applications in the case study at LaLlagosta, they work on increasing the technology readiness level of the solution.
- **Water utility:** For the case study, ACSA-Sorigue is the water utility that partakes in the project. The responsibility of the water utility can be divided into two main roles in this case: One is to design and build the wastewater treatment as requested by the regulating and controlling authorities, and second, to operate and maintain the wastewater treatment. This would also include the operation of the new urban-mining technology.

Both types of market actors hold a key stake in the application of circular water treatment approaches as they provide the technology needed for the water purification and the mining of phosphorous from wastewater, and operate the water generation, treatment, and supply chain. Their role in the market chain for circular wastewater treatment is therefore indispensable and their engagement in the project WATERMINING can be considered an enabling factor for successful market deployment.

Not directly included in WATERMINING as a project partner, but nevertheless of key importance for the circular solution at stake, are the suppliers of equipment and instrumentation (mechanical, electrical) and materials. Their role will become particularly important during the implementation stages of the WATERMINING solutions when deploying the technique and its products in the market.

Finally, the market value chain contains the potential users of the treated water and the 'mined' phosphate products. The generated biogas will be used internally by the plant as a fuel for boilers and electric generators to produce power and heat. Presently, it is difficult to upgrade the biogas (i.e. further purified) to biomethane, but should the biogas in the future be upgraded to meet the quality standards of natural gas, it could be injected into the gas grid for consumption directly by gas companies or be used as a car fuel (for instance, this is done with upgraded biogas from the wastewater treatment Chiclana in Seville). There are various stakeholders identified in the draft market map, as follows:

- The reclaimed water and phosphate products could be used by many different actors such as farmers (normal-quality water), industrial entities (high-quality water). In the draft market map, these actors have been covered by including their associations, i.e., farmer associations and industrial associations.

- Another main end-user is the **environment** in the sense that WWTPs also dispose of the clean, treated water in rivers to maintain their water level, and in aquifers (percolation/direct injection). For the WWTP owner CBT, about 70% of the regenerated water is directed to maintain the minimum flow of nearby rivers. However, it is important to note that the applied WATERMINING technology is an advanced technology that is not designed mainly to keep the minimum flow of the river, as simpler technologies would also be sufficient for that purpose. The technology is rather designed for meeting the quality requirements of agricultural and industrial water applications.
- As phosphate products are considered a waste in this case study context, even when produced through a circular approach such as developed in Case study 5, it is important to include waste management companies in the market chain description. In this respect the market mapping has revealed a potential barrier to further market deployment of the technology: should phosphate products as mined from urban wastewater be considered a product, it could be used by a fertiliser company. However, for that to happen current legislation needs to be changed. From the stakeholder consultation, it has been learned that some fertiliser companies in the region fall into the category of 'waste managers' and thus can legally accept a waste (depending on the waste category) containing phosphorous and use it in their fertiliser formulas. This will be a topic of discussion with the wider stakeholder groups within the Community of Practice established for WATERMINING.

Facilitating service providers

To support the upgrading of the market value chain for scaled-up application of the circular wastewater treatment solution in La Llagosta the market map contains the following supporting actors, focusing on knowledge building and business model development:

- **Catalan Water Partnership (CWP)** is a non-profit and strategic association formed by companies and research centres that work in the sector of the sustainable use of water. Its mission is to improve the competitiveness of its members through the development of business models for identified water management solutions. CWP involves consultancies, knowledge centres, equipment manufacturers and other entities involved in the water management chain of action and the solutions for sustainable use of water, including circular ones. CWP promotes projects and multilevel collaborations, for developing innovative & sustainable solutions to the global water needs, in any part of the world.
- **Polytechnic Catalan University (UPC)**, which is a public institution of research and higher education in the fields of engineering, architecture, sciences, and technology, and one of the leading technical universities in Europe.

Also relevant for the scope of the case study are the **regulators and controllers** as they determine the relevant policies, regulations, and rules for (waste) water treatment in the region and to which the proposed WATERMINING solution must comply. Among these regulatory actors are also entities responsible for monitoring health and environmental aspects, to ensure that the circular wastewater treatment procedure and its product do not negatively impact people's health and the environment:

- **Catalan Water Agency (ACA)** is the Catalan government-owned public company in charge of water planning and management following the basic principles of the EU Water Framework Directive. Through its action plan, ACA must guarantee water supply and water quality at source (groundwater and surface water) for now and into the future. The action plan also calls for wastewater treatment at the more than 500 operational water treatment plants, as well as the protection and conservation of water bodies and associated ecosystems. In line with that, ACA promotes the use of reclaimed water, which at some water-treatment plants has resulted in obtaining clean water to be used for industrial, agricultural, leisure and municipal purposes. As such, ACA enhances the security of the water supply. ACA is financed basically through the water rate, which is an environmental tax levied via the water bill (30% of the bill). The water bill is determined by the town councils, the actual owners of the water supply.
- **Consorci Besos Tordera (CBT)** is a local water administration composed of 64 municipalities in four different regions of Catalonia with a population of about 470,000 inhabitants. CBT is responsible for the sanitation facilities from the very beginning in design and building stages to the final operation and maintenance of facilities — including 300 km of sewers and 22 wastewater treatment plants (one of them being La Llagosta wastewater treatment plant) — with the main objective of preserving and improving the good health of the rivers in its area: Ripoll River, Besos River, Riera de Caldes, Tenes River, Congost River, and Mogent River.
- **Catalan Waste Agency (ARC)** is responsible for dealing with the waste generated in Catalonia and for waste management in its territorial area, including industrial, municipal, health care and agricultural waste. Its scope is planning, promotion of legislation, inspection, awareness building, technical and economic support to local authorities for different waste streams (municipal, industrial, construction waste and debris, waste from agriculture and livestock, sanitary waste), and recovery of contaminated soils.
- **Catalan Health Agency (ASPCAT**) ensures the improvement of individual and collective health through the implementation of health policies through health promotion, protection, and surveillance of health.

As these regulatory bodies monitor whether the proposed solution for treating wastewater meets the water quality as well as health and environmental standards, their support and eventual approval of the circular wastewater treatment approach will be indispensable for its deployment of the market.

Barriers and enablers for further discussion

From the advanced market map, the following barriers can be identified as well as enabling, supporting factors:

Barriers:

- Phosphate products 'mined' from wastewater streams are currently considered by EU **legislation** (such as the Waste Directive and REACH) as waste and are therefore not eligible as fertilizers for use in agriculture. Clearing this barrier requires that phosphates be considered fertilizers. This is an example of required changes in licensing and regulations, including those related to waste authorities.

- Stakeholders interviewed for the market map highlighted the existence of alternatives to the circular solutions as developed by the case study, such as alternative fertilizers, biogas, and water treatment technologies. The effect of that could be **a lower demand for goods 'mined'** from urban wastewater treatment.
- Generally, it can be said that consumers in the case study context are mainly driven by the costs of the products and thus prefer low-cost options. Next to making the case study's solutions more cost-effective, efforts could also be directed to increasing consumers' **awareness of the benefits of using more sustainably produced goods**. For instance, as the case study solution leads to a higher production of water and phosphorus, this could lead to lower prices and thus result in an overall increase in water and phosphorus consumption (of both circularly and linearly produced goods). As the latter could outweigh the sustainability benefits of the WATERMINING solution, consulted stakeholders suggested three measures: (1) to offer a discount bonus for sustainable consumption, so that circularly produced goods can compete better with linearly produced equivalents, (2) increase consumers' awareness of this effect, and (3) improve and/or create regulation and controls that, e.g., allow for substitution of existing, non-circular water allocations.
- In line with the above barriers, at the first CoP session, stakeholders highlighted the need for **a circularity assessment** to clarify how the proposed WATERMINING solution contributes to the circular economy. In that regard, doubt was expressed about the real circularity of water produced by the wastewater treatment plant if this is subsequently used to produce goods that are exported abroad.
- Another outcome from the first CoP session were questions about the **economic feasibility of the WATERMINING solution**. Questions asked dealt with the aspects of who determines the cost of the technologies, subsidy requirements who would benefit from those subsidies, and what is the role of patents. Stakeholders pointed out specifically that costs must be translated into product prices. As end-users are not the only beneficiaries of using circular technologies, the production costs related to WATERMINING solutions could be distributed also to other market actors and/or society.
- According to the wastewater treatment plant operators, the process of **upgrading biogas to biomethane is currently too difficult and costly** to be seriously considered. This is the main reason for many wastewater treatment plant operators to simply use the produced biogas for their power and heat generation, which is also reflected in this case study's market map.

Factors that have not yet been assigned to barriers/enablers:

- *Royal Decree 1620/2007 of 7 December*: This decree is about the Spanish regulations for water reuse. Important aspects in this decree are among others a) the **provision of definitions** for among others, water reuse, treated wastewater, reclaimed water, Water reclamation plant, etc., b) the **prohibition** to use reclaimed water for **human consumption and the food industry**, c) the provision of **opportunities for local administrations to develop water reuse plans** (including specifics about the required infrastructure, economic and financial analysis and the pricing scheme), however, those are subject to environmental assessment, and d) the **provision of quality criteria** for the reuse of water specific to its intended use:

- Urban uses (e.g., irrigation of residential gardens)
- Agricultural uses (e.g., crop irrigation, aquaculture)
- Industrial use (e.g., process and cleaning water)
- Recreational use (e.g. golf course irrigation)
- Environmental use (e.g., aquifer recharge, irrigation of woodland)

Concerning the latter, it is good to notice that the criteria for **minimum stream flows** are set on a case-by-case basis.

Enabling factors:

- ACA has an **action plan for water reuse** to secure water supply to customers. The La Llagosta case study approach is in line with the action plan as it increases water supply for industry (high-quality water) and agriculture (normal-quality water).
- Sorigue as a water utility is **a partner in WATERMINING** and co-owns the case study. As the involvement of the water utility is indispensable for the success of the solution, Sorigue partaking in the project enhances the likelihood of eventual success. Similarly, Wetsus as a technology (co-)developer is a case study partner (and WATERMINING partner), supporting the further development and demonstration of the solution.
- The self-supply with heat and power generated from biogas **reduces the energy demand** from energy suppliers, which reduces energy costs for the wastewater treatment plant. Moreover, increasing energy prices in Spain favour the self-supply options.
- The **general scarcity of phosphorus** could be an enabler of mining phosphorus from wastewater streams.

Next steps

The joint findings of the rough market map, the interviews, and conclusions, have been integrated into an advanced market map (Figure 4-3). This market map is the basis of discussion for the Market System Analysis during the second Communities of Practice meeting. Therefore, the focus of the case study activities during the first half of 2022 is going to be on setting up the next CoP meeting to a) validate the advanced market map including market actors, enablers and barriers, b) identify missing market actors, barriers, enablers and facilitating services, and c) analyze the identified barriers including barrier prioritization, analysis of causes to the barriers and the identification of possible measures to overcome the barriers. A particular discussion item for further investigation in conjunction with WP 10 (policies) evolves around the questions of whether existing laws and regulations need to be changed to allow the usage of recovered phosphorous in e.g., fertilizer production. On the one hand, there may already be users i.e., specific waste managers who can use the recovered product in their fertilizer production process. In contrast, phosphate products ‘mined’ from wastewater streams could currently be considered by the EU Waste Directive as waste and may therefore not be eligible as fertilizers for use in agriculture.

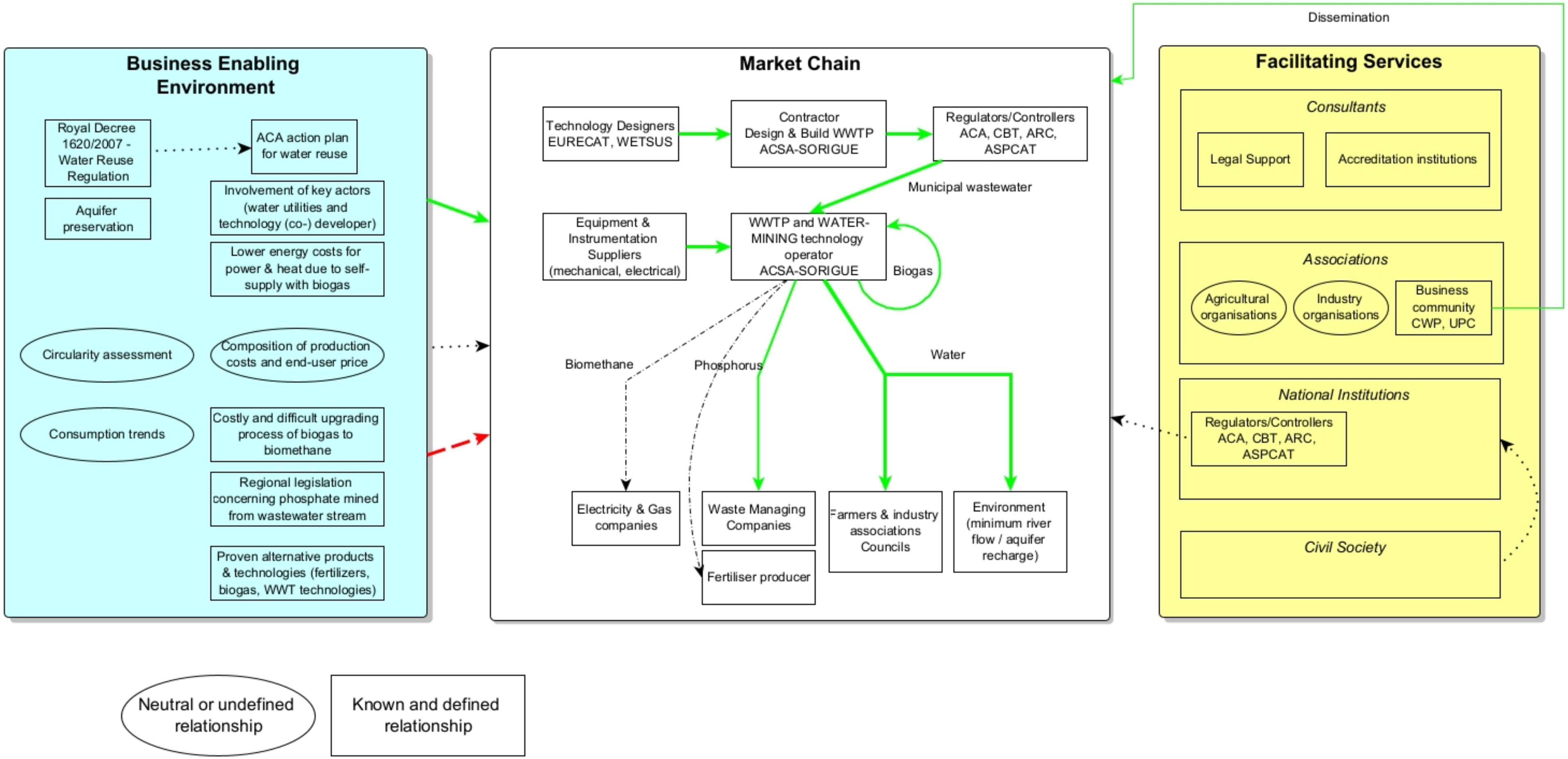

Figure 4-3: Advanced market map for CS5 La Llagosta

4.4. CS7 – Israel

4.4.1. *Introduction*

Case study 7 belongs to the group of replication case studies with the purpose to evaluate one of the established WATERMINING technologies in the first six case studies in a different country context. Generally, this case study focuses on urban water mining, i.e., the treatment of urban wastewaters and recovery of usable products by urban wastewater treatment facilities. This report describes the market system mapping for the Israeli case study and documents the results that have been obtained thus far.

The case study owner *Jerusalem Institute of Policy Research (JIPR)* conducts the market system analysis for the water system in Israel. The analysis focuses on the recovery of the following products from urban waste-water streams:

- Higher quality effluents (water used for irrigation),
- Direct and indirect application of sludge in agriculture, and biogas production of sludge (direct use/use for electricity generation), and
- Phosphates.

So far, the market system analysis is comprised of developing market literacy about the Israeli water sector in general. In the next phase of the analysis, the scope with a WATERMINING technology will be specified that is already applied in CS1-6.

An overview of market chain actors that have been identified so far in case study 1 is provided in Table 4-4.

Table 4-4: Identified market chain actors in CS 7

Market chain actor category	Description	Stakeholders
Domestic and industrial wastewater producers	Discharge of wastewater that needs to be treated by WWTPs.	N.a.
WWTP operator	Maintain and operate the technology.	- HaGihon - JWPI - Shafdan
Water distributor	Distribution and allocation of water to end-users.	National Water Authority
Electricity end-users	Users of electricity produced from biogas at the WWTP.	- WWTP operator - Israeli Electricity Corporation (IEC)
Phosphorous processor	The processor of recovered phosphorous products.	N.a.
Contractor	Disposal and/or treatment of sludge.	N.a.
Digitalization technology providers	The water management process is accompanied and administered by advanced computing and technologies, real-time data technologies, field laboratories and various technologies that regularly measure abnormalities of the effluents.	- Takadu - Arad - RHDHV - Igreen
Phosphorous recovery technology providers	Removal of phosphorous from wastewater.	OSTARA
End-users – Phosphorous	Usage of phosphorous-based products	N.a.
End-users – Water	Usage of water for irrigation and environmental purposes (e.g., reviving streams).	N.a.

4.4.2. The advanced market map for Israel

As in the other case studies, the case study owner started the process with developing a rough market map, using JIPR's best professional judgement, and a subsequent series of interviews with three key informants from *Igudan* which is a regional association for environmental infrastructure supervising the Dan Region wastewater treatment plant, the Israeli Ministry of Health, and the Jerusalem Water Purification Institute (JWPI).

The information provided by key informants as well as findings from the previous project R2Pi about the development of circular economy business models[10] has been used to update the rough market map to an 'advanced market map'. Both outcomes contributed substantially to the description of the current water system in Israel.

Market actors

The key informant stakeholders interviewed provided useful information to improve the first rough market map based on their expert knowledge. With this information, the market value part of the market map is ready and elaborate (see Figure 4-4).

Generally, the market chain shows that the Israeli urban wastewater treatment sector is oriented to high resource efficiency due to the very high scarcity of water. One important impact is that wastewater treatment plants recycle a high percentage of wastewater, which is then mostly used for agricultural purposes. At the Shafdan treatment plant, for example, about 80-90% per cent of the wastewater is recycled and deployed to agriculture and municipal gardens. Next to the efficient (re)use of water, the treatment of sludge is commonly applied. The treatment allows for (1) the production of biogas from sludge for electricity generation, which then is mostly self-consumed but can also be fed partly into the electricity grid, and (2) sludge-based fertilizers for application in agriculture.

The core of the Israeli market value chain is formed by the WWTP operators. According to regulations in the State of Israel, every sewage institute must produce effluents at least to the tertiary level. This treatment can be in several methods, the most common method is sand filtration. No private WWTPs are operating in Israel as all WWTPs are owned by the respective municipality. Though, municipalities can hire an independent contractor to operate the treatment plant for them. One stakeholder interview has shown that WWTPs deal differently with the treated water. Some plants discharge the water to the river (e.g., in Jerusalem), use it for irrigation, which is the case in Raanana, and some others like the Shafdan and Ashdod plant provide the water to Mekorot for further distribution. Some plants do both, discharge in a river and provide water to Mekorot. The following WWTP operators have been specified:

- **HaGihon** - a municipal company and the main Water and Sewage Corporation in Israel (centred in Jerusalem). HaGihon's main activity is the supply of drinking water to Jerusalem and its surroundings while transporting wastewater from out of the city.
- **JWPI** – which is the Jerusalem Water Purification Institute, a subsidiary of HaGihon

[10] https://www.r2piproject.eu/

- **Shafdan**: Shafdan also produces quaternary effluent treatment that is designated for unlimited irrigation. The type of effluent treatment determines their purpose - whether it is for unlimited irrigation or a limited purpose: in case the effluents have only undergone tertiary treatment. The water regulations and sludge regulations determine which purpose is most fitting. The effluents are not sold by the Shafdan directly to consumers but are allocated and sold to consumers (farmers) according to the decision of the Water Authority.

Next to the WWTP operators, there are *Suppliers of technologies and wastewater* including:

- *Wastewater suppliers* from industry and domestic water users
- *Suppliers of phosphorus removal technologies* such as OSTARA that produce agricultural fertilizer or similar facilities that mix the phosphorus with pure institute sludge
- *Providers* of *digitalization technology* that allows to collect data and perform various measurements. Digitalization is more dominant in the process management of water. The water management process is accompanied and administered by advanced computing and technologies, real-time data technologies, field laboratories and various technologies that regularly measure abnormalities of the effluents. Many of the existing technologies are European. Examples are:
    - **Takadu** (An Israeli company for water management solutions, most notably leak detection);
    - **Arad** (An Israeli company for water metering);
    - **RHDHV** (a Dutch software package "AquaSuite" which studies the normal behaviour of waste and reacts to abnormal events. The software has various modules which operate to manage and optimize processes in the wastewater treatment plants).
    - **Igreen** ("Iosight" - an Israeli software supporting the data collection, producing of reports and dashboards for decision-making processes)

Furthermore, the national water company Mekorot has a versatile role that ranges from **water distribution** over EPC and the operation of some water treatment plants. It is also responsible for the allocation (together with the National Water Authority) and selling of effluents to users/consumers. However, there is a limited allocation to farmers for effluents. Large-scale public (water) companies such as Mekorot also provide beta-testing sites providing “proof of concept” for new technology.

The currently existing *end-users* of WWTP-related products are listed below:

- *Agriculture:* Most of the effluent water goes to agriculture. In general, irrigation with effluent water is only allowed for places that do not come into direct contact with humans - for example, the vegetation of roads and forests. There are guidelines from the Ministry of Health for this. For example, the Ministry of Health does not allow the irrigation of parks with effluent water because of insufficient quality and exposure to people, particularly children.
- *The environment:* About 5-7% of the water is used to revive streams (dry streams) for the benefit of their ecosystem, for example in the Nahal Sorek river in the case of the Jerusalem area.
- Electricity end-users: From biogas, electricity is produced for being used by the plant itself (for internal use - but less economically worthwhile) and/or for being sold to and distributed to the Israeli Electricity Corporation (IEC).

What could be improved in the market chain is the recovery of phosphorus to e.g., produce fertilizers. So far, it is not yet clear if this could be done internally at the wastewater treatment plant or if the process needs to be taken over by an external party. Furthermore, there are still market actors, mostly end-users, that need to be specified. It would be valuable to obtain more information about end-users of effluents, sludge, and fertilizers to identify the linkages between them, any connected third parties (e.g., branch organizations) and the wastewater treatment plant operator.

In the **business and policy enabling environment**, it is noted that there are strict policies and regulations for water management in place in Israel, among others due to a generally water-stressed region where natural water is scarce. Derived from the high national importance of the Israeli water sector, national institutions strictly enforce on the one hand wastewater recycling such as requirements to integrate water reuse in water planning and management, but also the usage of recycled water (effluents), e.g., in the agricultural sector. On the one hand, this is partly perceived as a barrier to wastewater treatment plant operators. However, the tight regulations and policies keep a high pressure on water treatment plants and end-users to apply state-of-the-art technology to ensure that the least water is 'spilt'. These and other factors, such as available funding and facilitating services, are good conditions for deploying innovative wastewater treatment technologies.

The **facilitating services** are characterized by an innovative ecosystem that is driven by collaboration between research, business, and the public sector. In that respect, it is remarkable that national institutions such as the New-Tech Department of the Ministry of Economic Affairs, support the development of innovation in the clean-tech domain. Also, the opportunity to get access to beta-testing sites of public water companies is an important support to test new technology.

One **barrier** which has been highlighted by a key informant though is the missing collaboration between research organizations and the water companies. Stronger linkages between universities and public wastewater treatment plans are desired and can help the Israeli water sector to stay on top of the latest technology developments.

Overall, we can conclude that being a water-stressed country, Israel has built up a water sector that is already highly innovative to cope with the challenges of treating urban wastewater and related waste handling. The analysis at this stage shows that the current market system is in that sense clear. However, the results also show that it would be highly interesting to analyse barriers and enablers to the deployment of specific WATERMINING technology in Israel. This could provide additional information and value for external stakeholders and in turn for the WATERMINING case study partners by the information provided by stakeholders. This extension of the barrier analysis is foreseen during the next stage of the market system mapping in Task 9.2, after selecting a focal technology in this case study.

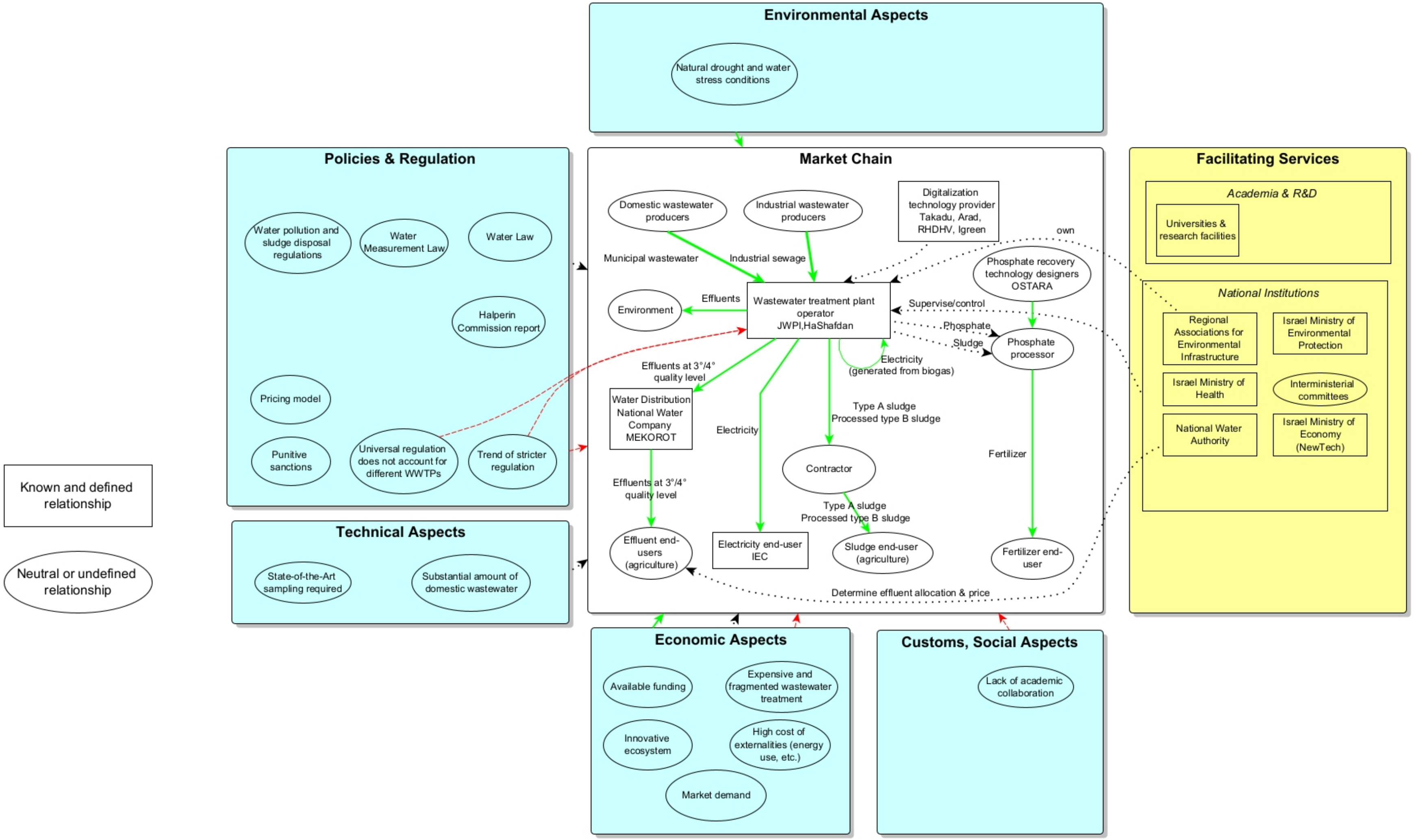

Figure 4-4: Advanced market map - Israel

4.5. Observations across urban wastewater treatment case studies

4.5.1. Barriers and enablers

Case study partners and stakeholders identified several potential **barriers** to the market entry of products from the circular treatment of urban wastewater, which apply to multiple cases:

- Uncertainty exists about the market prices of mined products as this depends, next to production costs, on, i.a., eligibility of subsidies and the VAT regime. Hence, it remains uncertain for stakeholders how competitive circularly produced products can compete in the markets against conventional products. This barrier is called upon to be addressed with priority as stakeholders consider potential customers in the relevant markets for the case study products as being mainly driven by the costs and a preference for low-cost options.
- While specifically mentioned for the case study on Kaumera in Portugal, the issue of dealing with higher salt concentrations of a water-mined product when applied in agriculture can be applicable for other cases. This is especially the case when a product is used for crops that are susceptible to higher salt concentrations.
- The quality of the products has been raised by stakeholders as an important factor for market success. Quality improvements are the subject of WATERMINING case study analysis, but of key importance is whether potential customers share the faith of case study partners in the quality levels of their products. The main instrument for coping with this uncertainty is the certification of products at quality levels that are needed for market deployment. At the same time, the case study analysis demonstrates how irrigation is improved due to the larger availability of higher quality water.
- Current legislation within the EU, such as the Waste Directive and REACH, consider phosphate produced from wastewater as waste, which prohibits its use as a fertilizer in agriculture.
- Finally, while not visible in all case studies analysed, there has been mentioning in some of the urban wastewater treatment case studies of a need for improved collaboration between research institutes and water treatment companies, as this generally enables improvement of products, procedures, and cost-effectiveness of WATERMINING solutions.

In terms of enabling factors, the case studies revealed insights from stakeholder dialogues on how the market entry of WATERMINING solutions can be enabled:

- While in the discussion on costs and competitiveness of, e.g., Kaumera and phosphates the importance of costs has been underscored, stakeholders also elaborated on how increased awareness among potential customers of ancillary benefits of circularly mined products could outweigh higher prices. High quality, clear environmental benefits, and positive social perceptions in terms of sustainability, as well as contributions to the circular economy, may be reasons for customers to pay a higher price.
- Stricter legislation on the use of conventional products can leverage the market potential of products such as Kaumera and phosphates. For instance, a ban on seed-coatings using microplastics could create market opportunities for nature-based, circular alternatives such as Kaumera. Moreover, the decision by Dutch authorities to grant Kaumera the status of an

end-of-waste product enables the product to be used as a fertilizer in the Netherlands, thereby enabling access to a new market.

- In line with the above enablers, the case study solutions increasingly fit in regional action plans for increased water supply for industry and agriculture.

4.5.2. Policies: Commonalities concerning EU policies and directives

Similar to the case study analysis in Chapter 3 (circular seawater desalination techniques), for circular treatment of urban wastewater the following European policies and policy instruments, have been identified in the case study analysis:

- *Directive 2000/60/EC* – This is the EU Water Framework Directive with the objectives to protect surface water and groundwater from pollution.
- *Directive 2008/98/EC* – the Waste Framework Directive.
- *EC 1907/2006* – the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH).
- *Directive 86/278/EEC* – the Sewage sludge Directive.
- *Directive 91/271/EEC* – Urban Waste Water Treatment Directive
- *Circular Economy Package* – The proposed solution contributes to the objective of the Circular Economy Action Plan to “close the loop" of product lifecycles through greater recycling and re-use, and bought benefits for both the environment and the economy.”[11] The concrete benefits coming forward from the contribution yet need to be analysed.
- *BAT reference:* The “Best Available Techniques (BAT) Reference Document of Common treatment/Management Systems in the Chemical Sector” may be a relevant policy document to consult when considering the implementation of circular urban wastewater treatment technologies. It yet needs to be evaluated how this policy document is of relevance for the technology implementation.

These policies, how enabling they are or whether they actually represent policy gaps towards sustainable seawater desalination, will be further analysed in WP10.

[11] https://ec.europa.eu/environment/topics/circular-economy/first-circular-economy-action-plan_de

5. Market Systems Analysis: Industrial Mining

5.1. CS6 – The Netherlands

5.1.1. *Introduction*

In this chapter, the focus is on industrial wastewater treatment (Industrial Mining), based on three case studies. First, an advanced market map is produced for the chlorine cluster of the Rotterdam Port, in the Netherlands, followed by two replicability case studies focussing on digitalisation in support of the circular treatment of industrial wastewater in Germany, and on wastewater treatment in a sugar factory in India. As part of the pilot plant in the Netherlands (WATERMINING Case Study 6), removal of organics using the technique of High-Pressure Oxidation, the integration of waste heat and innovative Zero Liquid Discharge (ZLD) desalination will be tested. The products of the innovative WATERMINING technology, i.e., purified brine and recovered salts (e.g., sodium chloride) supplied to industrial applications, are included in the scope of this market system analysis.

The case study owners and facilitators have executed the following actions:

1) Determination of market system analysis scope:
   - **Products:** Purified industrial brine, salts, and possibly hydrochloric acid (HCl) and sodium hydroxide (NaOH)
   - **Application:** Water is mostly reused in the industrial process, and sodium chloride can be recycled for chlorine production.
   - **Combined** market map for all products.
   - **Geographic scope:** The Netherlands.
2) Preparation of a rough version of a market map based on the expert knowledge of case study owners and facilitators.
3) Discussion of this rough market map through interviews with key informants, i.e., external stakeholders that have knowledge on the subject and can provide additional insights to further develop market literacy. The interviewees were:
   - The site manager of the Hexion plant in Pernis – Hexion is the case study owner of CS6 and will operate the demonstration plant at the production site in Pernis.
   - Nobian- This company is a base chemical company producing high-purity salt, chlorine, caustic lye, hydrochloric acid and chloromethanes.
   - The third interview was conducted with Huntsman which is a global chemicals company active in the chlorine cluster at the Rotterdam Harbour.

Also, information from the first Community of Practice (CoP) meeting was incorporated in the market system analysis. Table 5-1 shows the market chain actors that have been identified so far.

Table 5-1: Identified market chain actors in CS 6

Market chain actor category	Description	Stakeholders
Water supplier	Supply of surface water to industrial plant unit.	N.a.
Energy supplier	Supply of energy and heat to the WATERMINING technology operator.	Shell
Technology provider	Provide technology for brine/wastewater treatment.	KVT
WATERMINING Technology Operator	Operation of ZLD with integrated waste heat recovery.	Hexion
Conventional wastewater treatment operator	Existing treatment plant operator for industrial sludge.	Shell
Secondary raw materials trader	Potential trader of recovered salts e.g., sodium chloride.	Aqua Minerals B.V.
End-users	Potential industrial consumers of produced sodium chloride and generated purified industrial brine.	- Nobian - Huntsman - Shin-Etsu PVC B.V.

5.1.2. The advanced market map for the Netherlands

In this section, the findings from the interaction with stakeholders and case study partners are presented and visualized in an advanced market map (see Figure 5-1).

Market actors

The main identified market chain actors of CS 6 have been identified as follows:

- Technology operator for the WATERMINING case study:
  - **Hexion** operates the demonstration plant of Zero-Liquid-Desalination with integrated waste heat recovery at its production facility at Pernis, Rotterdam. The industrial brine provided by other companies is treated at the demo site under the case study and the recycled sodium chloride can be provided to nearby chlorine production companies. During the first CoP, Hexion explained, regarding the suggested WATERMINING solution, that by 2030 all its new products will incorporate sustainable attributes. Next to energy and CO_2 emission reduction projects and product innovation, reducing and repurposing waste streams is high on the

agenda of the company. Hexion expressed its appreciation that the topics of raw material reduction and circularity are also high on the agenda of authorities.

- **Nobian** currently uses fresh brine for its electrolysis process, and it is yet to be determined if Nobian could also use the WATERMINING technology for industrial brine. Similar to Hexion, Nobian indicated that, in line with its commitment to reduce its carbon footprint and energy use, it has the ambition to collaborate with its customers on realizing more sustainable production processes that also can create a win-win for all parties. Nobian emphasized that an important condition for the solution will be whether a positive business case can be realized and whether quality requirements for recycled brine on the delicate chlor-alkali process equipment and resulting products.
- **Kanzler Verfahrenstechnik GmbH** (KVT) is an internationally operating engineering company that provides among others technology for brine/wastewater treatment. Their technology is used in the WATERMINING process in this case study.

- **Suppliers of resources** to the process as identified in the market mapping are:
  - **Secondary raw materials trader:** Aqua Minerals B.V. has been included in the market map as a company specialized in the trade of secondary raw materials (e.g., lime granules & sludge, iron pellets) and a potential supplier to the WATERMINING case study.
  - **Electricity and heat** are supplied to the case study plant by Shell. During the CoP, stakeholders noted that there is also an existing heating network (pipeline) that could be used as a heat source at a temperature of about 70 degrees Celsius.

In general, wastewater treatment plants that are connected to the industry may be impacted when that industry implements ZLD technology. The rerouting and/or decrease of the industrial wastewater streams due to ZLD could lead to cases in which wastewater treatment plant operators need to adapt their processes accordingly. For this case study, Shell operates the **bio-wastewater treatment plant** connected to the industrial cluster in Rotterdam. According to information provided by the case study leader, Shell initially did not share concerns about potential issues but showed interest in the project overall.

Finally, the group of **industrial salts consumers** can be identified as the ‘chlorine cluster’ with companies located close to the demonstration plant. Potential customers for the produced sodium chloride are foremost the case study owners **Hexion** and **Nouryon** (which is the largest chlorine producer in the Netherlands) which have already expressed their interest in the product from the case study. Other potential users belonging to the chlorine cluster are the global chemicals company Huntsman, and Shin-Etsu PVC B.V., a global PVC production company.

In the next project stages, some of the key market actors need to be further specified, including the commodity suppliers (heat, electricity, water) and infrastructure providers (water and/or industrial brine pipelines).

In terms of **facilitating services,** stakeholders mainly highlighted the role of business associations of chlorine and salt producers, associations representing the chemical industry in general, and a local association for the industrial companies located close to the Rotterdam harbour. In the next steps of the market mapping in Task 9.2, when reaching out to wider stakeholder groups for this case study, their role in the market system will be further elaborated on.

As for **identified barriers and enablers** in this market chain, mostly *technological and economic barriers* have been identified, especially concerning brine quality and price. The brine or solid salt produced by the WATERMINING case study technology competes with fresh brine which currently may be cheaper and meets the specific quality requirements of several potential industrial customers. For further progress within the case study work, it is of key importance to explore, i.e., within WATERMINING Tasks 9.3 and 9.4, whether and how the benefits of the case study solutions, such as lower heat demand and higher sustainability standards of the end products can be monetized for a competitive business model.

It is important to note that during the stakeholder consultation, also potential *legal barriers* have been identified. It has been pointed out that there is a need to i) identify operation permits/licenses which may be necessary for the WATERMINING technology, ii) analyse to what extent existing contracts with wastewater treatment operators may be affected by a reduction in wastewater production (as wastewater will be mined for circular products), and iii) develop options to determine the ownership of required brine transport infrastructure.

Issues for further consideration in the next steps of the market system mapping in Task 9.2 and linked to working in work package 10 are potential policies, laws, and regulations which may foster or block the suggested implementation in the case study context of ZLD, waste heat recovery and the reuse of purified brine and salts. These issues will be addressed in follow up stakeholder consultations, including at subsequent CoP meetings for the case study.

Furthermore, it can be beneficial for the eventual success of the case study solution to include the public perception towards the integration and deployment of ZLD in further deployment steps in the markets. Such highlighting of environmental benefits can be combined with promoting other environmental benefits of the technology (less surface water salination, improved energy efficiency, etc.). A potential partner to support this aspect could be the Nature and Environment Federation South Holland (NMZH), as suggested by the current set of stakeholders in the overall market mapping process.

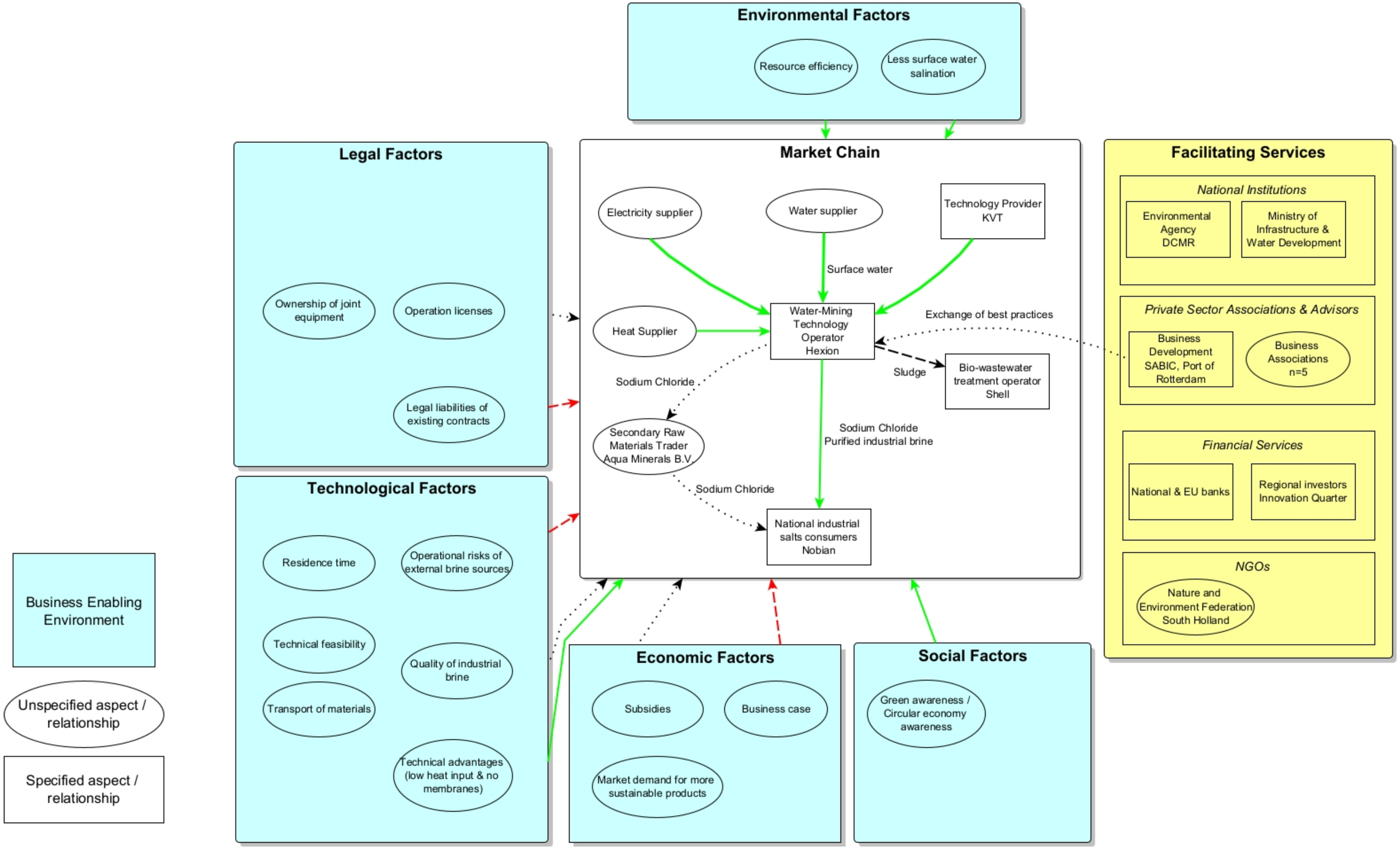

Figure 5-1: Advanced Market Map - Zero Liquid Discharge Desalination and waste heat integration

5.2. CS9 – Digitalization as a tool for circular processes in industrial water management in Germany, DECHEMA

5.2.1. *Introduction*

In WATERMINING, most of the case studies primarily concentrate on technologies that directly recover or 'mine' resources from either municipal or industrial wastewater streams (urban mining and industrial mining), or seawater (sea mining). Next to those technologies that directly produce a (circular) good (e.g., water, sodium chloride, etc.), there is also a need for auxiliary tools and technologies such as the **integration of digitalization technology into (waste) water management processes**. Within this perspective, Case study 9 led by DECHEMA e.V. focuses on the use of digitalization as a tool for circular processes in industrial water management in Germany.

The case of digitalization tools is particularly interesting from a sustainability point of view since such tools provide the opportunity to: 1) enable circular solutions and products in the first place, 2) improve the overall resource efficiency (energy/materials) of industrial water management processes, and 3) thereby measurably enhance sustainability (e.g., via improved Environmental Social Governance (ESG) criteria) across the whole market chain.

Germany represents an interesting case study to analyse the market conditions about digitalization and the circular economy. Characterized by a large industrial and manufacturing base, Germany is poised to take advantage of the digital revolution in the industry, Industry4.0, or the digital transformation in production and the associated value creation processes (Becker et al., 2021; Blanchet et al., 2014). This transformation also includes the water management sector, where there are many opportunities to introduce digital tools to optimize processes and result in cost savings. The German Water Partnership defined the term 'Water 4.0': the incorporation of sensors, computer models, intelligent networks and the internet for water resource management, including both urban and industrial water management (German Water Partnership e.V., 2019). This digitalization of the industrial water management sector has not advanced at the same pace as digitalization in other sectors, creating the opportunity for Germany to further develop in this area (Becker et al., 2021).

Further, Germany is well-known for its progressive recycling separation strategies but has made little progress in developing a Circular Economy, closed-loop management processes (Kadner et al., 2021). The country's large industrial base requires a large consumption of resources and raw materials, but the current recycling processes and legislations do not promote the recovery and reuse of materials and resources. EU and national policies need to better address the quality of recovered materials and the circular business models needed to successfully bring recovered products to the market (Kadner et al., 2021). An additional area that needs to be addressed is the innovation of digital tools and strategies that would enable this transition to a circular economy. Digital tools can be used to increase the resource use efficiency of industries, monitor and communicate the quality of recovered materials, and assist with circular production; these tools also pertain to improvements in sustainability and the development of circular business models (Antikainen et al., 2018). Further, the financial benefits and incentives of a digital and circular transformation need to be made clear and enhanced.

This market system analysis aims to better characterize the current situation in Germany, highlight and prioritize the challenges associated with digitalization and Circular Economy, and identify potential solutions needed at the EU, national and/or industry level.

This report describes the methodology applied in the German case study and documents the results that have been obtained thus far.

During bilateral discussions with the case study partners, the following scope has been determined:

- **Geographic scope**: Germany
- **Application scope:** Data-Mining – Digitalization as a tool to promote circular economy systems and technology in industrial wastewater management
- **Product scope:** In this context, digitalization encompasses the digital linking (e.g., via Internet of Things) of sensors that are located at several places across the water management and treatment value chain for an integrated approach of water system planning, operation and maintenance. This enables real-time data collection as input into computer (forecasting) models and real-time control systems, in support of process simulation, stronger decision making and risk and cost reduction in the industrial water management sector. The market system analysis explores the implementation of 'Water 4.0' to assist the development/implementation of circular economy processes (i.e., resource recovery) within this sector, focusing primarily on the process industry.

The first 'rough' market map of this case study was drafted based on the expert knowledge of the case study owners, including internal experts from DECHEMA. Based on the rough market map, interviews with four key informants from a non-profit research institute (BFI), the association of the chemical industry (VCI), a company focusing on process engineering including big data applications (aixprocess GmbH) and a representative from the water & wastewater department of Siemens AG.

The information provided by key informants was used to update the rough market map to an 'advanced market map' concerning market actors, barriers, and enablers, as well as required facilitating services (see Figure 5-2). A brief overview of market chain actors in CS9 is presented below in Table 5-2.

Table 5-2: Identified market chain actors in CS 9

Market chain actor category	Description
Utilities	Supply of water, electric power and heat required to operate industrial processes.
Raw/input supplier	Industrial processes require various raw materials, such as chemicals and metals, which need to be supplied from either external or internal suppliers.
Industry	An activity about the processing of raw materials and production of finished goods.
Service provider	Develop and implement data architecture, programming, code modifications as part of digital systems, based on customer needs. The developed solutions are applied in various applications, such as the process industry, chemical industry and water management, and can also be individually tailored or connected to existing digital infrastructures.
Industry customers	Any customer who purchases or receives finished products from a specific industry.
Potential customers of recycled/recovered materials	Any customer who purchases or receives products recovered through circular economy processes (i.e. recovered water used as industrial cooling water either within the same industry or by an external industry).

5.2.2. The advanced market map for Germany

The advanced market system analysis conducted by the case study lead DECHEMA has helped to generate valuable information, contributing to a better understanding of the market system, business and policy enabling environment, and potential facilitating services. This information outlines how digitalization can support circular economy efforts undertaken by the industrial wastewater management sector in Germany.

Market actors

This case study is characterized by a market chain that emphasizes the role of industry market actors and digital tool providers. Considering the role of the latter, this case study could benefit from the expert knowledge of the WATERMINING partner KWR Water Research Institute. KWR has supported the development of this market system analysis by providing valuable examples of the role of digital technology in water management.

Since digitalization technology does not itself produce a (circular) good (water, sodium chloride, etc.), but can rather be seen as an auxiliary tool to allow for a more resource and/or cost-efficient industrial water management process, end-users of the circular economy market chain have not been specified in detail. Nevertheless, benefits generated by digitalized water management systems in the industry also represent an opportunity to positively affect end-users. For example, digital tools help to enable circular solutions and products in the first place and/or could improve the overall resource efficiency (of energy or materials) and thereby the Environmental Social Governance (ESG) criteria across the market chain.

Facilitating services

A multitude of different associations and initiatives could already be identified during the first step of market system analysis. Some of these are already known from recent/ongoing research cooperation (DECHEMA and NFDI, EOSC) and actively support the harmonization of data quality as well as data sharing among different stakeholders. Other associations clarified the industry perspective on digitalization (VCI, BDI), and more services have been mapped which could support the implementation of digital tools for Circular Economy purposes. What could be helpful here is to add an association that represents the (industrial) water treatment sector. Such an association could be consulted to assist in finding additional enablers and barriers, as well as developing solutions to those.

Barriers & enablers

During the process of market system analysis, barriers and enablers focused mostly on three subjects: (1) the technical aspects of digitalization, (2) the interaction between the business and policy enabling environments, and economic considerations concerning digitalization tools, and (3) social aspects of implementing digital tools.

First, concerning technical aspects of digitalization, key barriers were raised about **data quality**. Particularly, this means that data may not be available to feed digital tools with information, and/or that interfaces between new digital tools and existing industrial processes can be difficult to establish due to **data format incompatibilities**. However, stakeholders also indicated that if the purpose of data is clear, it is likely that technical solutions can be found to establish those interfaces.

As an enabler, it can be observed that digital tools have the potential to improve existing processes, increase their efficiency, and reduce waste of materials and/or energy. Though these factors have been named in general, underpinning technical advantages with possible examples from industry could support and substantiate this claim, making those benefits more tangible to the stakeholder community. In that regard, the continued cooperation with KWR can be a great opportunity by using the digital tools they develop as practical examples.

Second, the perceptions of stakeholders about the business and policy enabling environments revolved around the main question of why digitalization and digital tools for industrial processes are **insufficiently addressed by companies** in industrial wastewater treatment. Reasons discussed with stakeholders were versatile but focused mostly on missing incentives from multiple sides. Those include in principle three interrelated elements:

a. **A lack of EU and/or national policies and strategies to encourage digitalization** and provide clear objectives and incentives to industry. As a comparison, stakeholders mentioned for example the carbon tax on process emissions as an incentive to decarbonize industrial processes. For this aspect, it may be helpful to analyse the individual policies that have already been identified in the market system and note where the root causes of the problem may lie.

b. **Missing company policies and strategies supporting the digital shift** of their organization is linked to the perception that the company's intellectual and financial resources must compete between themes such as decarbonization and digitalization. Yet, key informants have brought up already potential solutions to clear this barrier, e.g., by creating awareness of synergy effects between high-priority subjects and digitalization (digitalization and circular economy can positively impact decarbonization, ESG criteria, etc.) and a deeper understanding of the economic benefits (see next point).
c. **The economic benefits of implementing digital tools may be insufficiently understood** at the company level. Key informants also identified a possible root cause to this issue, namely missing information about the actual costs and benefits of implementing the tools. Digitalization has a higher probability of being implemented when a business case exists, either via direct cost savings or to avoid process or system disruptions. Suggestions to resolve this barrier include the provision of resources by the company management to conduct cost-benefit analyses for the suggested digital tools.

Finally, social aspects that were brought up mostly referred to the employees of organizations where digitalization is implemented. Barriers could arise when employees are not informed about the impact of digital tools on their work (fear of job loss, etc.), consecutively leading to the reluctance with implementing solutions. Stakeholders pointed out that it is highly important to involve employees in the decision-making process and inform them about the potential impacts on their work.

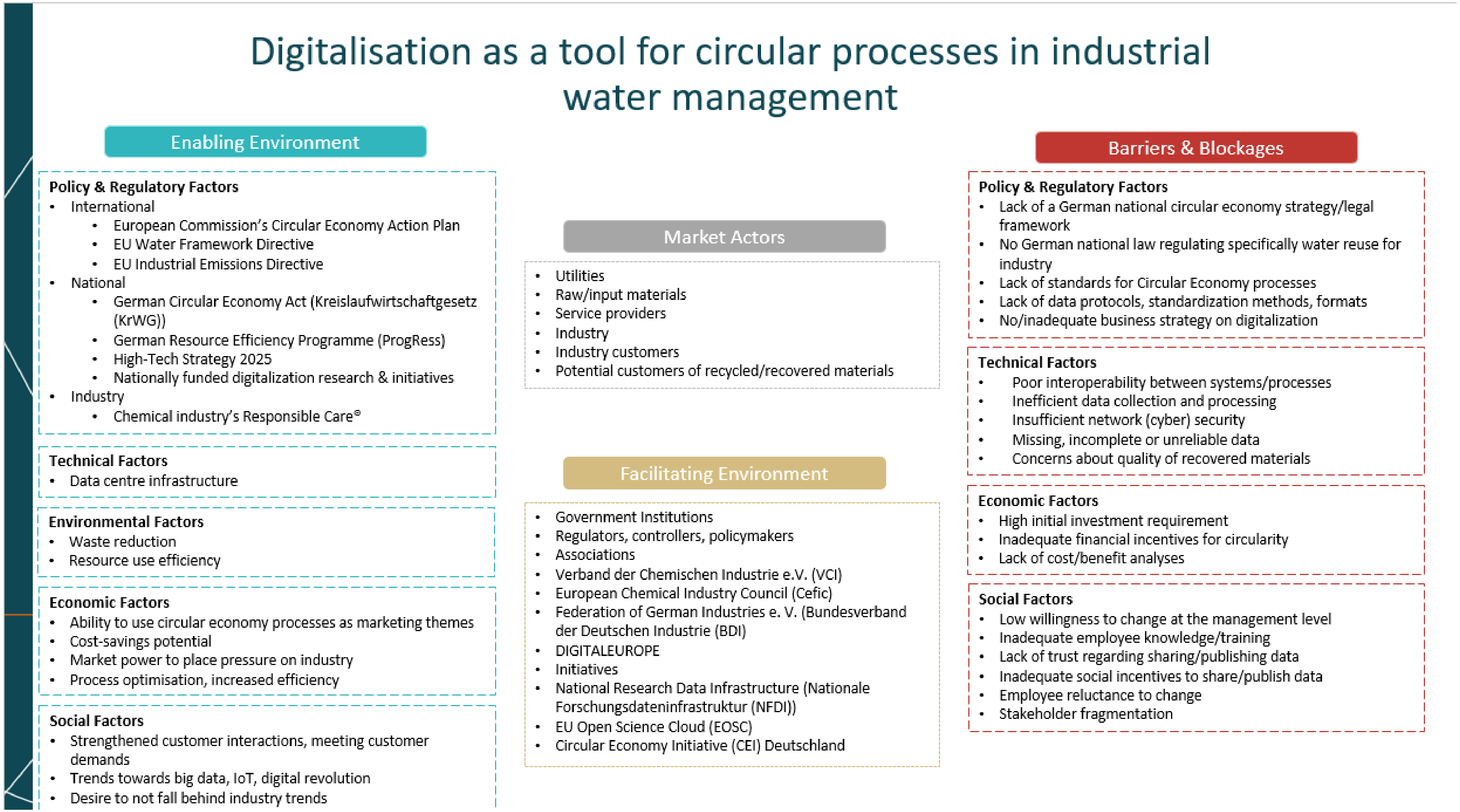

Figure 5-2: Advanced market map of the case study in Germany

5.3. CS10 – India

5.3.1. *Introduction*

The case study in India (case study 10) belongs to the group of replication case studies and focuses on industrial mining, i.e. the treatment of industrial wastewaters and recovery of usable products by industrial wastewater treatment facilities. This report provides an overview of the market system analysis carried out within WATERMINING for the Indian sugar sector. India is the second-largest sugar producer globally with more than 550 sugar mills in operation. About 290 million tons of sugarcane crops and 33 million tons of sugar are produced nationally, whilst about 26 million tons of sugar are consumed in the country.

The large resulting surplus could be used for multiple purposes, e.g., export for dietary consumption in other countries but also aiding the (national) production of biofuels. The latter option becomes increasingly interesting for Indian sugar mills due to the development of stricter nationally mandatory blending rates for ethanol in gasoline/petrol (i.e., 20% blending by 2025). The resulting demand for ethanol is a key driver for sugar mills to set up distilleries processing the excess sugar to ethanol.

However, what comes together with the development of distilleries are huge demand for freshwater (8-10 litre fresh water required per litre of produced ethanol) and the need to treat the effluents generated as a result of the distillery process. To address those issues, two main options are currently considered in WATERMINING, either in combination or in isolation:

1) The treatment of distillery effluents with Nereda Technology and subsequent Kaumera extraction (technology applied in case study 3)
2) High-Pressure Oxidization to remove organics from the effluent (technology applied in case study 6)

For the market system analysis in this case study, the scope is the treatment of distillery effluents in India, although the specific technology scope is yet to be determined. This is essential information for formulating the basic research questions of market system analysis: How does the market system for deploying the technology look like, who are the market actors, what are the barriers and enablers to the deployment of that technology, and which facilitating services could improve the efficiency of the functioning of the overall market chain? The determination of the technology scope in that regard depends on the results of bench-scale tests for both technologies under consideration which are supposedly available in the third quarter of 2022 and will be input for D9.6.

5.3.2. The rough market map for India

The first component of market system analysis is the setup of a ‘preliminary’ market map. This market map has been drafted by JIN based on the expert knowledge of the case study owners and facilitators, which has been exchanged via interviews and other online meetings, as well as email correspondence. The preliminary market map is shown in Figure 5-3.

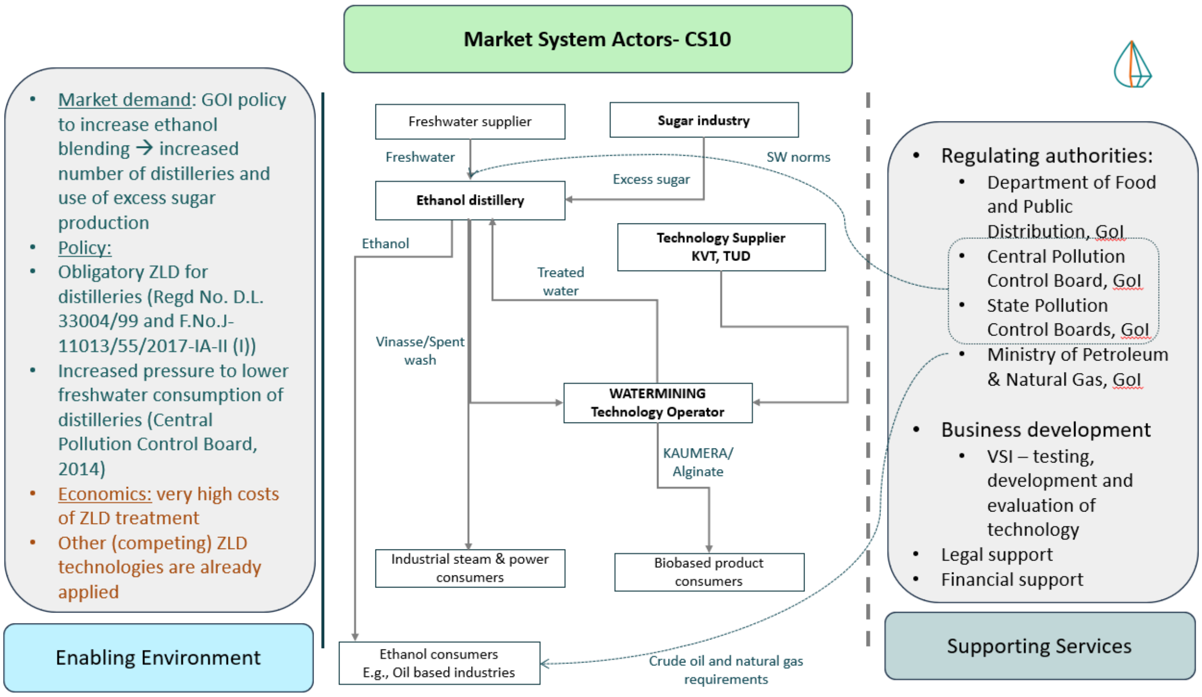

Figure 5-3: Rough market map of CS 10

Market chain actors

At the core of the market map are the actors that together form the market value chain for any WATERMINING technology applied to the treatment of effluents from distilleries. Those are presented in Table 5-3.

Table 5-3: *Identified market chain actors in CS 10*

Market chain actor category	Description
Technology suppliers	Those are the market actors who eventually could provide water treatment technology for treating the distillery effluents. Depending on the final technology selection, this could be either KVT (High-Pressure Oxidization) or TUDelft (Nereda and Kaumera technology) separately, or a combination of both.
WATERMINING Technology Operator	The operation and ownership of the technology are yet to be determined in the project (as explained above). Possible options are to include the distillery operator, the sugar mill operator, or a third independent party.
Sugar industry	This market actor is represented by the vast amount of sugar mills in India that process sugar cane to various sugar-based products. The excess of those products is used by the ethanol distilleries.
Ethanol distillery	There are about 450 distilleries in India, either attached to sugar mills or stand-alone producing ethanol from sugar.
Freshwater supplier	Currently, distilleries consume large quantities of freshwater 8-10 litre fresh water required per litre of produced ethanol). The actual market actors who are responsible for the supply of that required freshwater (municipal organizations, extraction from rivers, lakes, etc.) still needs to be determined.
End-users – Ethanol	The consumers of the main product ethanol are mostly oil-based industries that blend the bio-based ethanol with fossil-based fuels to petrol/gasoline.
End-users – Industrial steam & power	Sugar Mill by-products, distillery waste or effluents can be incinerated. The generated energy and heat (steam) can be reused by the plant for self-consumption and/or distributed to other industrial power and steam end-users.
End-users – Bio-based products	Depending on the applied WATERMINING technology, products such as alginate and Kaumera could be used for different consumption purposes. The end-users for these products can be specified once the WATERMINING technology is selected.

Facilitating services

The actors that can support the market value chain, e.g., with help of policy instruments, are:

- *The department of Food and Public Distribution of the Government of India (GoI)*: The Department of Food and Public Distribution, GOI, in principle determines the remunerative prices of farmers' crops (among others sugar beet), thereby indirectly impacting the sugar industry.

- *Central Pollution Control Board (CPCB), GoI and State Pollution Control Boards (SBCB), GoI:* The central and state pollution control boards set norms for the quality of distillery effluents and for decreasing the freshwater consumption by distilleries. The boards insist enforce the reduction of water consumption and also cause the industry to take measures to eliminate the discharge of effluents.
- *VSI*: VSI is a national R & D consultancy organization that supports sugar mills and distilleries e.g., via technology testing, development, and evaluation.

Next to the specified actors in the facilitating environment, there could be needs for legal and financial support. These needs could be specified once the market mapping progresses.

Barriers and enablers

Throughout the first preliminary market mapping process, the barriers and enablers to the deployment of wastewater treatment technologies in general, and ZLD technologies in particular, could be identified. In terms of barriers to the deployment of ZLD technology mainly the aspect of *very high costs of ZLD treatment* has been singled out as a key obstacle, specifically for the technologies applied in WATERMINING case studies; it has also been concluded *other, more competitive ZLD technologies* could be applied in the market instead. The high costs could be an important obstacle for distilleries to switch to yet another ZLD technology.

As for enablers, the market system analysis has revealed that the Government of India has created a significant demand for ethanol production (Sarwal et al., 2021), through the introduction of policies concerning **mandatory ethanol blending** percentages. As a result, the number of distilleries producing ethanol from excess sugar or molasses (Sugar Industry byproducts) has increased. Furthermore, the Government of India creates an improved enabling environment for circular industrial wastewater treatment by setting standards for:

- The application of ZLD technology in all distilleries (Ministry of Environment, Forest and Climate Change, 2018; Pallerla, 2018)
- The reduction of freshwater consumption by distilleries to a range of 3 to 5 litre freshwater per litre of produced ethanol (Central Pollution Control Board, 2014)

Next steps

The market system mapping for the application of industrial wastewater technologies in the Indian sugar industry sector has resulted in a preliminary market map for the Indian sugar sector with key market actors, how they collaborate/compete, as well as barriers to further market entry and possible policy measures to clear these barriers. For the further procedure of developing an advanced market literacy, the technology which is going to be analysed in more detail throughout the market system analysis must be specified. This depends on the results of the bench-scale test that are currently performed by WP4 (TUDelft) and WP6 (Hexion).

Following up on the results of the bench-scale tests, the technical scope of this case study including products and technology is going to be determined (approximately by Q3 2022). Subsequently, a discussion with the T9.2 lead (JIN) and the case study leads (VSI and Hexion) will be set up to structure the market system analysis process for the remaining period of 2022 and 2023. The obtained information will allow VSI to proceed with the advanced and participatory market mapping process, i.e.:

1) Performing 3-5 key informant interviews to identify missing market actors in the market chain, barriers & enablers to the deployment of the selected technology and facilitating services that could improve the efficiency across the market value chain.
2) Discussing the market map in a separate stakeholder workshop or as part of an industry conference contribution (approximately in March/April and October 2022) to validate the identified market map components and co-develop measures to overcome identified barriers (barrier analysis).

5.4. Observations across industrial wastewater treatment case studies

5.4.1. Barriers and enablers

The case studies for industrial wastewater treatment have highlighted that potential market deployment of the case study technologies may be hampered by technical and economic **barriers**:

- Similar to case studies in chapters 3 and 4, the brine or solid salt produced by the WATERMINING technology competes with fresh brine which currently may be cheaper, and which meets the specific quality requirements the different industries may have. In the case of the sugar sector in India, applying ZLD technology is considered by stakeholders as very costly, especially when realising that lower ZLD technologies are available.
- Concerning legal barriers, it has been pointed out that it must be clear what permits and licences are required for the operation of the cases studies' technologies in the Netherlands and India. Moreover, as mentioned for the case study in the Netherlands, contracts between industrial plants and wastewater treatment plants may need to be revised if industrial wastewater streams become smaller when applying circular treatment techniques.

In terms of **enablers**, the case study in India has pointed out the role of the central government by:

- Mandating ethanol blending in transportation has resulted in a strong increase in ethanol production, including ethanol generated from excess sugar or sugar by-products.
- Setting standards for application of ZLD technologies in all distilleries as well as for (reduced) freshwater consumption by distilleries.

Concerning barriers to deploying **digitalization** techniques for circular industrial wastewater treatment, the market system analysis has highlighted data quality and data format compatibility issues. Largely, these issues relate to the uncertainties in the market about the purpose of data in circular wastewater treatment. Once that is clarified, data quality and format compatibilities are likely to be improved. The case study has highlighted the required interplay between the EU, national level and company level decision-makers to further stimulation digitalization for the circular economy: EU-level strategies and national policy actions create objectives and incentives for companies and leads to an improved understanding of the economic benefits of implementing digital tools, including among employees.

5.4.2. Policies: Commonalities concerning EU policies and directives

For industrial wastewater treatment, the following policy documents in the EU have been considered. These are particularly relevant for shaping the policy environment for the Netherlands case study at Hexion (CS6):

- *Directive 2000/60/EC* – This is the EU Water Framework Directive with the objectives to protect surface water and groundwater from pollution.
- *Directive 2008/98/EC* – the Waste Framework Directive.

- *EC 1907/2006* – the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH).
- *Directive 2010/75/EC* – the Industrial Emissions Directive – BREF documents
- *Decision C(2013) 8589* regarding the BREF on Chlor-alkali production
- *Circular Economy Package* – The proposed solution contributes to the objective of the Circular Economy Action Plan to “close the loop" of product lifecycles through greater recycling and re-use and bought benefits for both the environment and the economy.”[12] The concrete benefits coming forward from the contribution yet need to be analysed.
- *BAT reference:* The “Best Available Techniques (BAT) Reference Document of Common treatment/Management Systems in the Chemical Sector” may be a relevant policy document to consult when considering the implementation of circular urban wastewater treatment technologies. It yet needs to be evaluated how this policy document is of relevance for the technology implementation.

These policies, how enabling they are or whether they represent policy gaps towards sustainable seawater desalination, will be further analysed in WP10.

[12] https://ec.europa.eu/environment/topics/circular-economy/first-circular-economy-action-plan_de

6. Key findings

This Deliverable contains the advanced market maps for the six case studies working on the circular treatment of seawater, urban, and industrial wastewater under the project WATERMINING. Furthermore, four case studies have been selected in other WATERMINING partner countries to replicate the market mapping. The case studies explore new technology systems for circular treatment of sea- and wastewater so that products can be 'mined' for useful utilization elsewhere in the economy. Case study partners, with input from key informant stakeholders, developed a draft market map showing what the relevant market conditions for their 'water-mined' products look like, in terms of market actors, existing policies and other aspects that support or block market deployment of the case study's circular solution.

6.1. Key barriers to marketing of water-mined products

Across the case studies, **market-related barriers** can be categorized as follows:

1. An important concern of case study partners and stakeholders is related to the **business model** for technologies and systems for the circular treatment of sea and wastewater. In the market, products 'mined' from sea or wastewater must compete with conventional, linearly produced alternatives. Stakeholders point at uncertainties about costs and market price of the products and related to that, whether subsidies will be available for 'water-mined' products or what will be the VAT rate for them.

   Key aspects that potentially stand in the way of a 'deployment-ready' business model, as identified by stakeholders, are:

   a. The relatively high costs of a new technology that is being developed from research and development towards market deployment. These costs may decrease over time though, due to learning effects and reaping of economies of scale.
   b. While the circular solutions pursued by WATERMINING case studies have a range of environmental benefits, the environmental damage from conventional systems has not yet been fully addressed by environmental costs, such as the cost of CO_2 emissions.
   c. Internalizing these environmental costs into market prices would make conventional technologies more expensive, hence supporting the business models for circular systems.

2. As markets are used to conventional, linearly produced products, in terms of **product characteristics and quality**, new products mined from the sea- or wastewater needs to gain trust among market actors. The quality of the products, or for instance higher salt concentrations of some water-mined products, has been raised by stakeholders as an important factor for market success. While quality improvement is a performance indicator

for WATERMINING case studies, it is of key importance that potential customers share the faith of case study partners in the quality levels of their products.

3. Stakeholders have, concerning the enabling policy and business environment, pointed at current **EU legislation**, e.g., the Waste Directive and REACH, which often considers products such as phosphate produced from wastewater as waste. As this prohibits the use of these products as, for instance, fertilizer for agriculture, a potential market for them cannot yet be deployed. In general, unclarity about **permits and licences** are considered an important barrier for the operationalisation of the cases studies' technology systems.
4. Finally, stakeholders pointed at the, sometimes, limited collaboration between research institutes and water treatment companies, as well as the **lack of engagement by the national government,** which slows down the improvement of products, procedures, and cost-effectiveness of WATERMINING solutions.

6.2. Key enablers for marketing of water-mined products

As part of the advanced market system mapping, stakeholders have been asked to identify enabling factors in support of the market deployment of WATERMINING technology systems. The thus identified enablers can be categorised as follows:

1. Within societies, especially in the case study countries in Southern Europe, there is a growing concern about **water scarcity**. This strengthens the need for producing water for consumption and uses in industry and agriculture from sources such as sea or wastewater.
2. Communities also increasingly realise the potential **environmental impacts** of conventional treatment of sea- and wastewater, such as in the case of desalination of seawater or disposal of wastewater in the environment. These concerns pave the way for, e.g., circular systems such as ZLD as a technique to treat water without environmental pollution. Utilizing environmental awareness can be further strengthened by specifying ancillary benefits of water-mined products for the environment and society, which could justify paying higher prices for these and generally give rise to positive social perceptions in terms of sustainability, as well as contributions to the circular economy.
3. The market value of environmental benefits can be further strengthened by formulating **stricter legislation** on the use of conventional products. As the example of Kaumera shows, a ban on seed-coatings using microplastics could create market opportunities for nature-based, circular alternatives such as Kaumera. Concerning this, a product 'mined' from wastewater can be strongly stimulated in the market if it is no longer considered by law as waste, but instead listed as an end-of-waste product.
4. Currently, there is already a **rather long list of potential EU policies and policy instruments** that could potentially incentivize circular sea and water treatment, and the policy momentum seems to be growing with the introduction of the EU Green Deal and other EU funding opportunities. Stakeholders are not yet fully clear of the efficacy of these policies and instruments for their case study systems. National governments can further enable market entry of water-mined products by, e.g., mandating ethanol blending in transportation (supporting circular treatment of wastewater from sugar production) and setting standards for application of ZLD technologies in all distilleries as well as for (reduced) freshwater consumption by distilleries.

In the advanced market system maps discussed in this Deliverable these barriers and enablers are not yet attributed and analysed in terms of, e.g., who has responsibility for addressing these, within what time frame and at what costs, and ranked, such as which barriers to tackle first. Such characterisation of barriers and enablers will be the main topic of the upcoming stakeholder consultations within the WATERMINING Community of Practice for each case study and reported on in Deliverable D9.6.

6.3. Policy recommendations based on Advanced Market Maps

In the above discussion on barriers and enablers for circular sea and wastewater treatment, several aspects have been mentioned that are relevant for policy making. In the next stage of this work, these aspects will be worked out in further detail, when stakeholders, in their Communities of Practice, will prioritise barriers (to be tackled first) and elaborate further on solutions to clear these with concrete action plans. The outcome of this work will be reported on Deliverable 9.6. Nevertheless, from the advanced market maps described in this report the following initial policy recommendations can be formulated with relevance at both at the national and EU level.

At the **national level**, for instance, case studies have revealed that applying WATERMINING's case study technologies has relevance for multiple policy areas, such as regulating origin and quality of (irrigation) water, use of desalinated water in sectors other than agriculture and stimulating use of renewable energy sources in water treatment. This calls for integrated policy packages for optimised interlinkages between policy instruments in support of circular water treatment.

Also at the national level, or even the regional level, stakeholders have called for policies to level the playing field for circular water treatment solutions, such as in WATERMINING's case studies. Suggestion made are, i.a., renewable energy investment support, pricing negative environmental externalities (such as CO_2-eq. emissions by conventional water treatment), stricter monitoring of illegal water catchment, stricter legislation on the use of conventional, linearly produced substances, and efforts for increased public awareness of the need for sustainable, circular water treatment. These policy measures will eventually contribute to enhanced business models for circular water treatment.

With respect to potential policy implications to be considered at the **EU-level**, the case studies have demonstrated how, based on criteria of the Waste Directive and REACH, 'watermined' substances as Kaumera and phosphates are often considered waste products. This reduces or even prohibits their eligibility as fertilisers in agriculture. Dutch authorities have granted Kaumera the status of an end-of-waste product, but it remains to be seen whether a similar decision will be taken by Portuguese authorities. This increases uncertainty about the business model of mining Kaumera and phosphates from wastewater. For a more harmonised policy treatment of Kaumera and phosphates it is recommended that criteria derived from the Waste Directive or REACH are reconsidered so that circularly produced, nature-based substances obtain the status of end-of-waste and can be applied as sustainable alternatives to conventional, linearly produced substances. Moreover, at the EU level stricter legislation could be considered on the use on conventional products, e.g., a ban on seed-coatings made of microplastics in fertilisers.

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