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ULTIMATE
WATER SMART INDUSTRIAL SYMBIOSIS

Deliverable D5.1

Short-list of synergies for ULTIMATE Cases

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Executive Summary

Summary of Deliverable

The ULTIMATE project is part of the Horizon 2020 European program and aims to create economic value and increase sustainability by valorising resources within the water cycle. This deliverable presents the findings of Task 5.1 of ULTIMATE that explored the creation of Industrial Synergies in the 9 Case Studies across Europe and Israel. The objective of this task was to explore and comprehend the water and material Symbiotic potential of the project partners individually and as a Consortium.

The exploration was performed by following STRANE's methodology for Industrial Synergy research developed during the EPOS and SCALER projects. STRANE's methodology includes the use of STRANE automatic matchmaking tool and internal databases for the identification of industrial flows, synergies, and industrials sites.

For task 5.1, synergy research started with a thorough analysis of input and output flows of the 9 Case Studies activities. From the total of water and resource flows identified during the CS activity analysis, 11 types if resources were considered for synergy opportunity research. This study resulted in 17 synergy opportunities explored for ULTIMATE partners.

The final result of this deliverable is a short list of 11 synergies that STRANE estimates that are worth pursuing as either Synergy Implementation or a Concept Study. The 11 final synergies where chosen based on a scoring system that qualitatively evaluated parameters such as technical and economic feasibility, replicability around Europe and environmental benefit. By taking replicability around Europe as a parameter to assess in this study, the opportunity for the replication of all the synergies in the shortlist is either medium or high. This potential could be further explored and exploited beyond the project by STRANE and other ULTIMATE partners to maximize the impact of the project.

This preliminary assessment allowed to determine whether the synergies studied have exploitation potential and make recommendations on the actions partners could take to take advantage of that potential impact. If exploited, the results of the deliverable could bring the involved partners new revenues, savings in waste management, pollution taxes and supply management, and improve their environmental performance by advancing in a circular economy logic in its activities.

This task attaches to the logic of finding value in currently wasted resources corresponding to the European Union Circular Economy call CE-SC5-04-2019 to which ULTIMATE responds.

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List of Acronyms

AC	Activated Carbon
AGB	AGROBICS
AnMBR	Anaerobic Membrane Bioreactor
AOP	Advanced Oxidation Processes
BEFB	The Bio Electrochemical Fluidized Bed
CE	Circular Economy
COD	Chemical Oxygen Demand
CS	Case Study
GAC	Granulated Activated Carbon
GSR	The Galilee Society Institute of Applied Research
GtG	Greener than Green Technologies
HT-ATES	High-Temperature Aquifer Thermal Energy Storage
IEX	Ion Exchange
IS	Industrial Symbiosis
nZLD	Near Zero Liquid Discharge
SFE	Supercritical Fluid Extraction
UNIVPM	Università Politecnica delle Marche
UV	Ultraviolet
WRP	Water Reclamation Plant
WSIS	Water Smart Industrial Symbiosis
WW	Wastewater
WWT	Wastewater Treatment
WWTP	Wastewater Treatment Plant

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1. Introduction

1.1. Context

ULTIMATE is a 4-year Horizon2020 project under the EU Water in the scope of the Circular Economy (CE) program. The aim is to create economic value and increase sustainability by valorising resources within the water cycle.

Industrial Symbiosis (IS) as a particular form of CE in industrial contexts that promises synergetic opportunities by systematically reusing waste resources between industries. IS limits the impact of current waste, water and energy management. It reduces import dependency and can provide cost-competitive resources and the diversification of supplies for European industries. Symbiotic synergies across industries create fruitful and sustainable industrial ecosystem networks. ULTIMATE aims to implement "Water Smart Industrial Symbiosis" (WSIS). Water and wastewater play a key role in WSIS both as a reusable resource but also as a vector for energy and materials to be extracted, treated, stored and reused within a dynamic socio-economic and business-oriented strategy. ULTIMATE focuses on three main industrial symbiosis areas:

1. **Reuse water: Recover, refine & symbiotically reuse wastewater from/to industries & local utilities.**
2. **Exploit energy: Extract & exploit energy, combined water-energy management, water-enabled heat transfer, storage & recovery.**
3. **Recover materials: Nutrient mining & reuse, extraction & reuse of high-added value exploitable compounds.**

The main objectives are to assess and demonstrate the performance and the technical feasibility of innovative technologies and symbiosis strategies at large scale. ULTIMATE demonstration activities are built around 9 Water-Smart Industrial Symbiosis Case Studies (CS). These 9 CS will be the experimentation area for 28 technologies systems, governance arrangements and business models oriented to the reuse of water, energy and-materials. CS are located in 7 countries as indicated in Figure 1: Spain, The Netherlands, Italy, Israel, United Kingdom, France and Denmark.

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Figure 1 Map of Case Study locations around Europe. (Source: ULTIMATE)

ULTIMATE mobilises a strong partnership of industrial complexes and symbiosis clusters**,** leading water companies and water service providers, specialist SMEs, research institutes and water-industry networks. To maximize its impact, ULTIMATE focuses on high-intensive water consuming sectors: Agro-food, Beverage, Petrochemical, Biotechnology, and service providers: municipal and industry utilities and water service providers.

ULTIMATE's WP5 aims to maximise the project impact by setting-up customised business models and an impactful exploitation strategy beyond and after the project lifetime. WP5 will explore, develop and demonstrate innovative, arrangements and business models, such as Industrial Symbiosis (IS) and water-related synergies, Chemical Leasing models, and other exploitation mechanisms, and applying them to the water related industrial activities and wastewater treatment technologies showcased by ULTIMATE. Activities for WP5 started on M1 and will be carried out until the end of the project on M48.

Task 5.1, started on M1 and ends on M18, has two main objectives:

1. **Identify, explore, and make a screening analysis of potential synergies that could be implemented in the framework of the technology's integration within Ultimate's CS. The direct outcome of this work is a short-list of synergies that were selected according to their implementation potential.**
2. **Collect, gather, analyse, and organize information that will be later used in other tasks of the work package, in particular for the business models exploration in task 5.2 and the Market Place in task 5.**

The conduct of this tasks was massively supported by STRANE's subsidiary Seitiss thorough its knowledge and tools particularly adapted for the efficient and automated research of Industrial Synergies in Europe. They were developed within SCALER and EPOS, IS related projects. STRANE generated key results (knowledge,

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databases, and tools) and exploited them through the creation of a start-up providing an innovative IS toolbox to industrial sites and local authorities. Seitiss was launched by STRANE team in mid-2018. Seitiss tools allow an efficient and automated identification of IS cross-sectorial synergies. The matching algorithm pairs couples of sites using location data and information about waste streams and processes. Seitiss offers IS services to public actors and industrial sites and aims to become a major industrial synergy creator and manager in Europe.

1.2. Objective and scope of the deliverable

Deliverable 5.1 is the result of the work carried out within the task 5.1. The first step of this task was to analyse the input and output flows of material and water of ULTIMATE technologies and water treatment applied in each CS. This initial activity enabled to identify interesting and valuable resources that seemed eligible for IS project creation. When such resource was identified, a preliminary assessment of said potential IS was performed. This process resulted in the identification of more than 18 potential synergies that were assessed on several criteria: technical feasibility, probability to be implemented locally, the replication potential and the monetary value of the resource as well as the environmental benefit. The objective of this analysis is to conclude on the feasibility and applicability in its CS context. The final result will be a recommendation on whether or not each synergy in the shortlist could be pursued in a deeper analysis and implementation process later in the project.

The search for synergy was focused on ULTIMATE CS partners activities related to water treatment and technologies development and demonstration. All material used in the wastewater treatment or recovered from it was eligible to be studied in this task. The scope of the study was limited to the direct industrial and research activities of the ULTIMATE's partners. External stakeholder's activities were not considered in the stream inventory and the synergy research.

From the three key areas of ULTIMATE project, this study focused on recovery of water and materials. The main source of energy was heat recovery and biogas production, but the CS will reuse it internally or already have plans to valorise it. Therefore, it was out of scope for this deliverable. Industrial water recovered is dedicated to CS's internal reuse. Some technologies will produce treated water compliant with irrigation activities. Furthermore, the material outputs of the CS that are already being valorised are also not part of the task 5.1 scope. Finally, the scope covers cross-sectorial resources transfers between ULTIMATE's CS and nearby other activities out of the consortium.

The objective of tasks 5.1 was to analyse at least 18 synergies (2 synergies in average for each CS) and conclude on their potential and relevance in their local context. To maximise the impact of this study and extend it in the next steps, common resources in several CS were targeted.

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1.3. Overall approach

The methodology used to perform this study is presented in **Section 2**. It is used by the start-up Seitiss to find, assess, and implement synergies in a local context. This approach is a key outcome of the EPOS and SCALER projects. This has been applied by Seitiss for industrial private clients, industrial clusters, and local authorities. Sources of information are also mentioned in **Section 2**.

To identify CS material and water flows, a first review of ULTIMATE Living Documents on CS and technology development was done. The initial review worked as an introduction to partners activities and their technologies needs for raw materials and the valuable resources that could be recovered from the wastewater (WW) streams after treatment. This helped to start identifying interesting flows for the partners. Some literature review was needed to have an initial understanding and identify gaps that could be addressed directly with the CS partners during an interview.

Once the context of the CS activities was known, STRANE had interviews with each CS leader based on the information gathered beforehand. These interviews clarified missing information and highlighted problematic resources representing a particular interest to the partners, such as waste with management issues, scarce/expensive materials, or materials being consumed in large quantities. A synthesis introduces the interview key facts, the CS contact point and the data collected in **Section 3**.

Once the main information was gathered, research and analysis about the flows and potential synergies was carried out respectively in **Section 4** and **5.**

This deliverable is organized as follow:

- **Section 2 presents the methodology and its application for ULTIMATE.**
- **Section 3 presents relevant information gathered from the CS and first flow screening.**
- **Section 4 provides an analysis and a prioritisation of the industrial flows targeted.**
- **Section 5 focus on the assessment of the potential synergies that could be implemented in each concerned CS.**
- **Section 6 concludes and provide an action plan for next steps.**

2. Methodology for researching and analysing synergies.

2.1. General process of a synergy creation

The creation of an industrial synergy can be a complex process that usually starts with the identification of value and opportunities in a sector, process or resource and

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ends with a long-term successful synergy implementation and operation. Synergy creation process is dependent on the project being developed, its characteristics (scope, stakeholders involved, resources being assessed and the information available). Therefore, the synergy creation methodology must be general enough to be applicable to most cases but also should allow customization when needed.

The general methodology proposed is schematically represented in **Figure 2.**

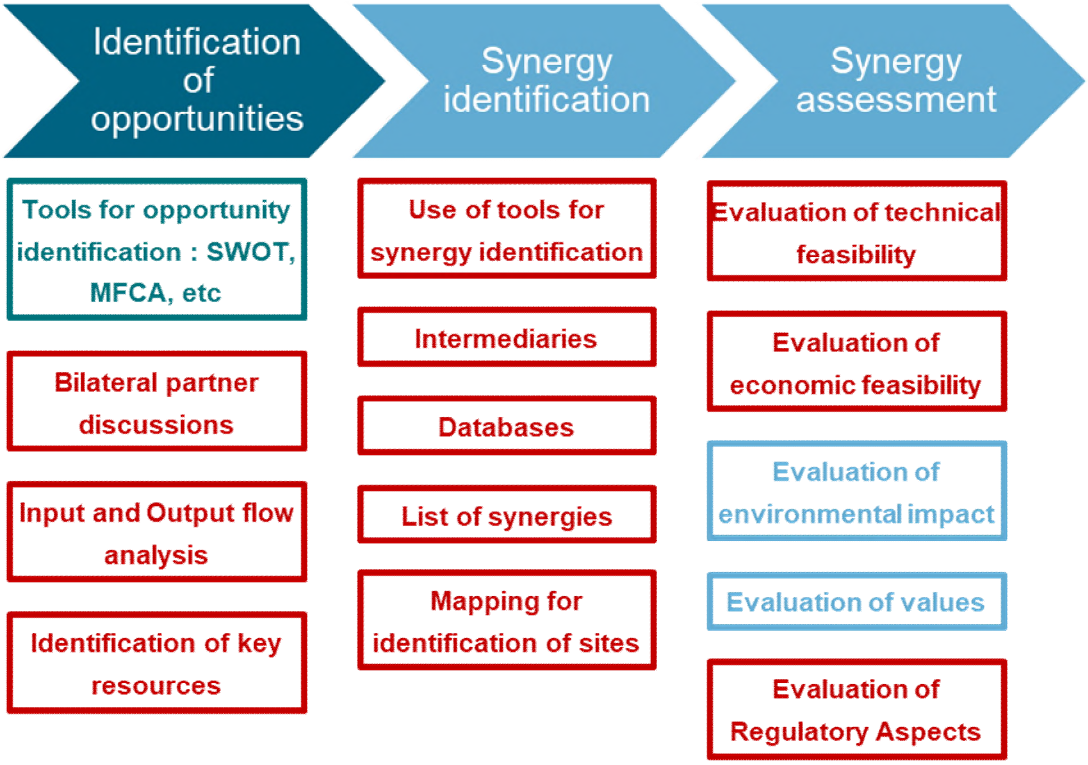

Figure 2 Presentation of the general methodology for IS creation. Activities highlighted in red are the ones corresponding to Task 5.1. Activities corresponding to the synergy assessment were preliminary for ULTIMATE's Task 5.1. (Source: Strane)

For ULTIMATE, the application of the synergy creation was adapted as an opportunity identification. It is also adapted to the scope and objectives of the project and it's in those which respects to information availability, technical development and resources that can be allocated.

2.1.1. Step 1 Identification of opportunities

The first main step is to identify potential waste/missing value at a regional, local, installation, process, or resource level. This opportunity could either be an identifiable resource in the waste stream or a gap in the supply management process. Value found could be economic, environmental, social, or other.

To look for uncaptured values, several methodologies can be used. They range from a simple but thorough observational analysis of a process or flows with the support of methodologies and tools like LESTS, SWOT, MFCA, etc.

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The identification of opportunities of IS in ULTIMATE involved the following tasks:

- **Analysis of information shared by CS partners in the grant agreement and in the living documents from WP1.**
- **Creation of a CS technology and of flow matrix (3.1. Preliminary matrix: Technologies and Resources and 3.11. Final Matrix)**
- **Interview with CS leaders and technology developers**
- **Identification of key resources (scares resources, problematic resources/waste, by products generated, valuable materials, big volumes)**

2.1.2. Step 2 Synergy Identification

Once an opportunity and resources to target are found, the synergy research is engaged. Several tools and methods can support this second step:

- **Platforms to mutualise equipment.**
- **Platforms to substitute resources (materials, services, stocks, furniture, etc.).**
- **Tools to identify synergies (with collaborative platforms, territorial approach, or process optimisation).**
- **Databases and knowledge repository of resources, synergies and case studies**
- **Matchmaking tools.**

To perform an efficient synergy identification, the STRANE's automatic tool gathers data on primarily 18 heavy industrial sectors (Ceramics, Steel, Cement, Lime production, Non-ferrous metals, Food processing industries, Slaughterhouses and animal co-production industries, Paper production, paper pulp and paperboard, Fertilizers, Waste treatment industries, Waste incineration, Glass, Power Plants, Organic Chemistry, Inorganic Chemistry, Chemical Industry Wastewater Treatment Plants, Wastewater Treatment Plants) with over 2,000 characterised input and output resources and matching algorithms that help identify promising synergies based on resource ontology and chemical composition (schematic representation in Figure 3). For ULTIMATE, alternative supply for raw materials, waste valorisation and the sectors concerned were identified using this matchmaking tool, as well as European NACE database, University of Cambridge IS database, the SCALER D3.5 "Quantified potential of industrial symbiosis in Europe" and other STRANE/Seitiss internal databases.

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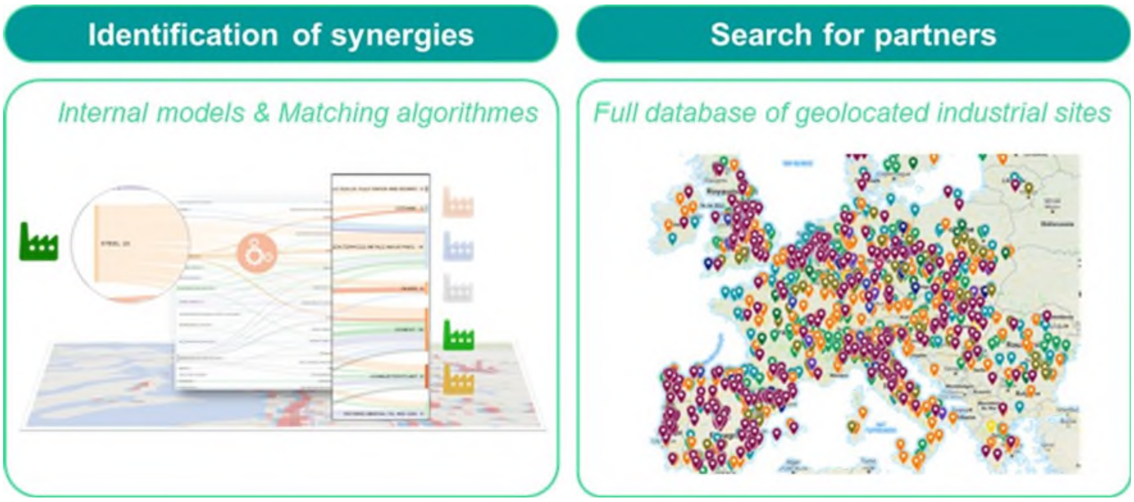

Figure 3 Matchmaking tool for resources and site identification. (Source: Strane)

The use of these tools is not a total solution and background knowledge is required to analyse the relevance and feasibility of the synergies.

For this step, the analysis was carried out CS by CS and a synthesis is exposed in **Section 5** to summarize the opportunities found, the ones that were further explored and the reasons behind the decision-making.

Once ideas for synergies are identified and industrial sectors of interest have been chosen, a map of the concerning industrial facilities can be made. This task is dedicated to evaluating if there is an acceptable density of actors that could participate in resource exchange. To partially automatise the process of building a map of potential industrial partner's sites, tools like diverse European/National activities databases such as NACE but not limited to, and all other geolocated data available are to be used. This includes the use of Strane's internal databases. The time and effort required to complete this step as well as the volume of the sites found depend on the type of resource and the sectors involved. This step is crucial to optimise the transport resource and make economic and environmental impacts as small as possible. If distances between partners are too large and the monetary value of the resource is not sufficient, the project could be declared not viable. An example of this can be found in Figure 4.

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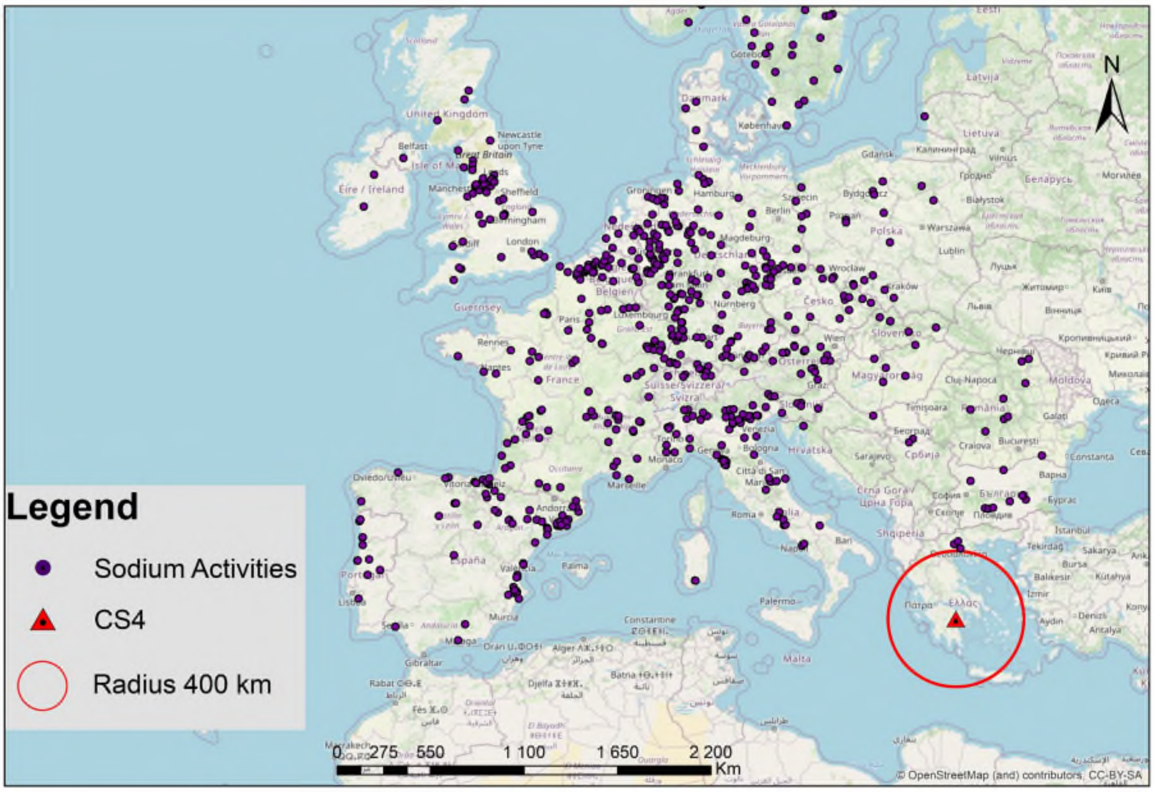

Figure 4 Example of mapping of industrial sites to search for potential partners. (Source: Strane)

2.1.3. Step 3 Synergy Assessment

In this step, each synergy will be evaluated to prove its relevance and feasibility. For the 9 CS, the initial list of potential synergies will be screened. This screening will allow to obtain an overview of the synergy potential in both local (when possible) and European context to maximise its impact. The parameters considered for this screening are:

1. **Pre-assessment of the technical feasibility**
   a. **Technical assessment of the resource**
   b. **Technical review of potential applications**
   c. **Maturity of the technologies involved.**
2. **Evaluation of the economic feasibility**
   a. **Economical assessment of the resource and the alternatives**
   b. **Definition of a theorical transportation radius of viability**

Truck transportation generic price was provided by an industrial partner and it's shown in Table 1. It is assumed that the truck transportation costs are between 0,15 and 0,2 €/t/km. This generic price is not applicable for specific or exceptional lorry transportation (e.g., pressurised gas transportation).

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Table 1 Transportation modes cost. (Source: Strane)

Transport modes	CAPEX	OPEX	Unit	Source
Trucks		0,0298841	€/t/km	Strane
Trucks		15 – 20 0,15 – 0,2	€/t/100km €/t/km	Industrial partner

In this study, the viability distance assessed for lorry transportation is a rough estimation. It only considers the viability radius for one ton of resource. The distance radius of viability is a data made in relation with the price of the resource studied. The formula used does not depend on the resources volume. To estimate the maximum transportation distance a viability radius is proposed. It is assumed that the transportation costs do not exceed 10% of the transported merchandise value to be profitable. [1]

3. **Evaluation of the environmental impact.**
4. **Evaluation of other values that can be generated by the synergy implementation (i.e., development of the local community, job creation, supply chain stability, etc.).**

Evaluations 3 and 4 did not enter the scope of this study so they were not performed in task 5.1.

5. **Evaluation of Regulatory Status**

This step is not within the scope of ULTIMATE. Nevertheless, a preliminary regulatory assessment concerning the legal status of some of the materials will be done when relevant.

There are a few regulatory statuses relevant for synergy creation: by product and waste as well as the “end of waste” procedure.

During the production process, different elements are created: products, waste and sometimes by-products. A by-product can be reused in a new production process to the extent that it complies with the by-product regulations while waste, to be reused in a circular economy approach, must either be reused as waste if the structure has the required authorisations, or require a change of status.

a) By-product

A by-product is a material initially destined to disposal but having a proven intrinsic value for which there is a demand for a specific use. By-products are defined in article 5 of the Directive 2008/98/EC of 19 November 2008 on waste (modified in 2018). This directive details four required conditions for substance to be considered as by-product:

1. **“Further use of the substance or object is certain.”**

According to the European Commission: a contract is proof and also a high merchandising price (A low price is not sufficient to ensure the value in the market)

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2. **“The substance or object can be used directly without any further processing other than normal industrial practice.”**

The European Commission gives examples: after production, the material may be washed, dried, refined, or homogenised, have properties or other materials added, be subject to quality controls, etc. On the other hand, if a major operation is required then the substance is considered as waste until this operation is completed.

3. **“The substance or object is produced as an integral part of a production process” ; and**

A production residue is an element resulting from a production process, but which was not primarily sought as such. [2]

4. **“Further use is lawful, i.e., the substance or object fulfils all relevant product, environmental and health protection requirements for the specific use and will not lead to overall adverse environmental or human health impacts” .**

The substance must be compliant with the health and environmental requirements. A by-product may require REACH registration for certain types of reuses. REACH is a regulation of the European Union, adopted to improve the protection of human health and the environment from the risks that can be posed by chemicals, while enhancing the competitiveness of the EU chemicals industry. REACH stands for Registration, Evaluation, Authorisation and Restriction of Chemicals.

In the judgment of the European Court of 18 April 2002 (Palin Granit Oy), at the paragraph 37 it was said: *“for determining whether that substance is waste for the purposes of Directive 75/442 is the degree of likelihood that that substance will be reused, without any further processing prior to its reuse. If, in addition to the mere possibility of reusing the substance, there is also a financial advantage to the holder in so doing, the likelihood of reuse is high. In such circumstances, the substance in question must no longer be regarded as a burden which its holder seeks to `discard', but as a genuine product”.*

From a regulatory point of view, by-products are considered to be products and must therefore comply with all regulations applicable to common products.

Another regulation relevant to this point is CLP. The Classification, Labelling and Packaging (CLP) Regulation ((EC) No 1272/2008) is based on the United Nations’ Globally Harmonised System (GHS) purpose is to ensure a high level of protection of health and the environment, as well as the free movement of substances, mixtures, and articles.

b) Waste and end of waste criteria

According to the Article 3 of the Waste Framework Directive, “waste” means any substance or object which the holder discards, intends or is required to discard” . Even

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if another industrial installation can reuse the material, the status does not change, and the waste regulation is applied.

If a company needs an end of waste status because its process doesn't accept waste, its necessary to follow the procedure determined at the national level, which is based on the European regulations. The end-of-waste criteria are used to determine when a waste, that ceases to be one, becomes a product. They are based on article 6 of Directive 2008/98/EC of the European Parliament and of the Council on waste (called Waste framework Directive: WFD):

Member States shall take appropriate measures to ensure that waste which has undergone a recycling or other recovery operation is considered to have ceased to be waste if it complies with the following conditions:

(a) the substance or object is to be used for specific purposes.
(b) a market or demand exists for such a substance or object.
(c) the substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products; and
(d) the use of the substance or object will not lead to overall adverse environmental or human health impacts.

For some member states a procedure has been put in place: the European criteria are kept but a file must be submitted containing several elements. This procedure is often long and costly.

Following this sequence is important to avoid spending time on unpromising synergies. The evaluation highly depends on the information available. At this stage of the ULTIMATE project there is an important gap on the information available to properly make a thorough assessment.

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3. CS analysis

For the ULTIMATE project, the search for opportunities started with an analysis of each CS based on the information in the Grant Agreement and technical documents prepared in collaboration by the CS leaders and ULTIMATE's WP1. Based on that, STRANE made a first inventory of inputs and outputs per CS and per technology to be developed. This first screening supported the preparation of subsequent interviews with the CS technical leaders to better target missing information and promising resources. All information collected and the first analysis are presented in this section case by case.

3.1. Case Study 1 – Petrochemical Cluster in Tarragona, Spain

CS1 is located in Tarragona, Spain, in an industrial area hosting a petrochemical complex since 1072. This petrochemical activity started with a refinery construction and has been growing ever since to become one of the most important clusters in southern Europe with more than 30 companies conforming it. Some of the most important members of this cluster are Repsol, Bayer, BASF, ERCROS, Cepsa and The Dow Chemical Company. Main activities are related to the production of chlorine, alkaline salts, oxygen gas, fertilizers, insecticides, fuels, plastics, and synthetic essences. This Ultimate CS focuses on AITASA Water Reclamation Plant.

3.1.1. Overview and interview summary

Table 2 CS1 and STRANE interview practical information.

CS1 Partners	**Eurecat, AITASA**
Date of interview	**08/03/2021**
Interviewees	▪ **Andrea Naves Arnaldos - Eurecat** ▪ **José Espí - AITASA**

AITASA is a private company held by shareholders from the Tarragona Industrial Cluster. AITASA is running a Water Reclamation Plant (WRP). This installation treats water from two urban Wastewater Treatment Plants (WWTP). In the WRP water is treated then pumped to the Tarragona petrochemical complex companies to be treated as reclaimed water mainly as industrial quality water dedicated to cooling towers.

Wastewater treatment in the Tarragona complex is separately managed by each industrial or group according to the current legislation to be compliant with the rejection into nature. The output effluents are salt and organic matter laden.

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European legislation is changing and becoming stricter for wastewater treatment (WWT). AITASA is currently building a new wastewater plant to perform a secondary treatment and be compliant with future European and local regulations. This treatment will be flexible in order to properly and efficiently treat effluents from different chemical plants. It will involve a Membrane Bioreactor, a Dissolved air flotation treatment (occasionally) and an Activated carbon filtration.

In ULTIMATE, AITASA and EURECAT are jointly developing a tertiary treatment to reuse and reintroduce treated water into other Tarragona's installations. Technologies being implemented aim at reaching Zero Liquid waste discharge. One main challenge of the technology development is the treatment of industrial effluents' high ammonia content.

3.1.2. Case study summary analysis

The table below represents a summary of the most relevant Information for the synergies research. As the main objectives of the ULTIMATE's developments of this CS are the reclamation of water from industrial treated WW effluents and internal reuse, there is little opportunity for exploration of new IS.

Table 3 Summary Table of Case Study 1

CS1 Tarragona (ES)	
Technologies applied	✓ T1: Zeolite adsorption for ammonia removal from urban reclaimed water, reducing energy consumption of urban wastewater reclamation plant (WWRP). ✓ T2: near Zero Liquid Discharge (nZLD) systems (membranes) for industrial water reuse.
Key Circular Economy innovation	Full-scale water recovery to achieve near Zero Liquid Discharge (nZLD) at petrochemical industrial complex.
Input Flow material	▪ WW from urban WWTP (High Ammonia Content) ▪ Pre-treated IWW from IWWTP ▪ Concentrated water from Inverse Osmosis treatment
Output Flow materials	▪ Treated wastewater (to be rejected in nature) ▪ Treated water for industrial reuse. ▪ Brine ▪ Sludge 1.01 m^3/h ▪ Ammonia

Figure 5 shows the most relevant inputs and outputs of the water treatment before and after the ULTIMATE project. Streams to focus on for this CS are:

- **Brine: the exact composition is not yet known (as the WWTP is not yet operational) but if processed it could be valorised in the soda ash process.**
- **Sludge coming from the biologic WWT: the composition is not yet known. A composting solution can be considered in the future.**

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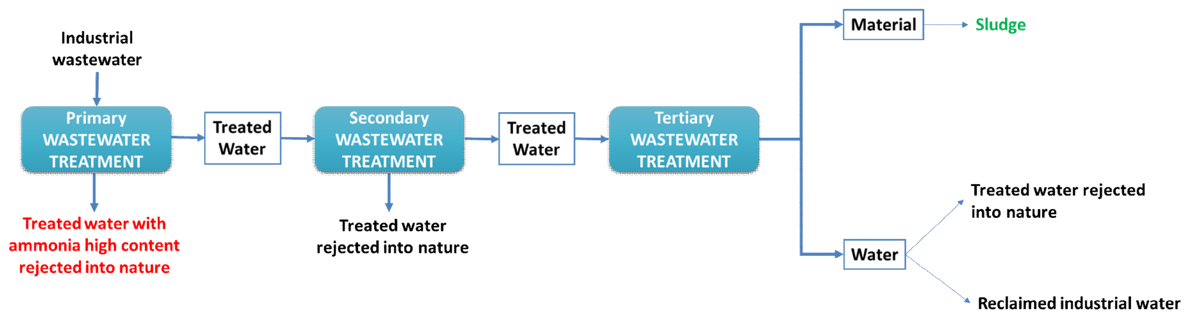

Legend

Flow	Material or water stream inaltered after Ultimate
Flow	Material or water stream removed after Ultimate
Flow	New material or water stream added after Ultimate
Flow	Flow with potential synergy

Figure 5 Schematic representation of CS1 Input and Output flows

3.2. Case Study 2 – Industrial and Greenhouse Symbiosis. Westland, Netherlands

CS 2 is located in the Westland in the Netherlands. This region is among the most important greenhouse horticulture in the world. Greenhouses in this region are known for growing vegetables and flowers with a state-of-the-art technology, and for its continuous innovation development. CS2 demonstrator is developed in a group of around 60 greenhouses that are organised in a cooperative sharing a common WWTP.

3.2.1. Overview and interview summary

Table 4 CS2 and STRANE interview practical information.

CS2 Partners	KWR
Date of interview	01/04/2021
Interviewees	▪ Joep Van den Broeke (CS Leader and Project Management) – KWR

This Case Study is centred around the water cycle in greenhouses and the development of technologies oriented to close the loop of water, material, and energy use. The main goals of this CS are to:

- Purify and make the water compliant a direct reuse for greenhouse's irrigation purpose.
- Recover nutrients from the greenhouse WW.
- Apply a sustainable source of heat for the greenhouses needs in winter.

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The WWT of the Greenhouses effluents is shared by the cooperative. Most of the water, around 70%, coming out of that treatment can be reused in some of the Greenhouse's activities. It is estimated that only 10% of the wastewater is poured into the sewers, while around 20% is an effluent charged in salt ant pathogens needing further treatment. This water management still generates water and nutrients losses. The greenhouses owners want to increase the efficiency of the system and avoid those loses by reusing water and nutrients.

This is the main motivation to develop the near Zero Liquid Discharge (nZLD) technology. This solution targets to reduce water losses and use the nutrients remaining in the water while removing problematic salts and sanitizing it to make it safe for the plants. Whether this is technically viable or not remains a research topic. Technologies to be implemented to recover the nutrients of interest and proceed to the disinfection of the WW are selective membranes and UV treatment.

Additionally, the technology used for the nutrient recovery and the form of the nutrients are not yet defined (ongoing work of KWR). The main interest in this technology for the Greenhouse owners is the savings in synthetic fertilisers. At the moment, this solution is not yet clear and more information on nutrient composition or quantities expected is not available.

One of the main challenges in the water treatment is the elimination of the salt content to ensure a possible reuse for irrigation.

The heat needs for the greenhouses in the Netherlands are high in winter and near-zero during the summer. These needs are currently being fulfilled by natural gas boilers. This solution is not sustainable due to the use of a fossil fuel but has the benefit to produce carbon dioxide that is consumed by the plants.

KWR aims to change the current heat generation (either supplement or completely replace the boilers) and implementing a sustainable solution. Most of the heat produced during the summer will not be directly used. Due to the offset of heat production/use, the technology to be developed requires a long-term heat storage. Therefore, it will be stored in a local aquifer during the summer and autumn until the ambient temperature decreases. In winter and spring, the stored energy will be used to feed the greenhouses. The summer heat source will be the surplus of a future local geothermal power plant (operating continuously all year long) to be built in 2022 in the Westland area.

The technology being developed is a high-temperature aquifer thermal energy storage (HT-ATES). Drillings made to exploit geothermal sources can also be used for the aquifer exploration. KWR will do a technical and economic feasibility study of the application of said technology and communicate the results and recommendations to the contractor in charge of building the powerplant as it will be also assigned to build the HT-ATES system.

The current WWTP works with a classic treatment including sand filtration and coagulation (using ferric chloride). Concerning the new treatments, the ultraviolet (UV)

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disinfection could have a need for hydrogen peroxide. There could be an interest to find an alternative source for these consumables.

3.2.2. Case study summary analysis

The table below represents a summary of the most relevant Information of the CS for the synergy research. This CS applies the three areas of action of the ULTIMATE project: water recovery, material recovery and energy recovery. The energy recovery is already part of the Ultimate specific developments and will not be further investigated in this deliverable. The water and nutrient recover technologies are in development and the resulting treated water and materials will be reintroduced in the greenhouses processes. As for the water and the nutrient recovery, the full project is not yet completely defined, particularly the technical implications to recover, but they will be both used internally, so there is no need to look for a synergy at this stage of the project. The implications of this are that for synergy research, the potential opportunities concern the consumables of the WWTP.

Table 5 Summary Table of Case Study 2

CS2 Nieuw Prinsenland (NL)	
Technologies applied	✓ T3: HT-ATES for use in greenhouse. ✓ T4: Water treatment solution for recycling of drain water from greenhouses allowing safe reuse in horticulture. ✓ T5: Closed loop greenhouses with water and nutrient recycling.
Key Circular Economy innovation	Reuse of greenhouse drain water for irrigation, nutrient recovery (nZLD), and subsurface heat storage.
Input Flow material	▪ Wastewater stream from the greenhouses ▪ Power Plant residual heat ▪ Hydrogen peroxide ▪ Coagulant: Ferric Chloride
Output Flow materials	▪ Heat for greenhouses during winter and (partly) spring and autumn ▪ Irrigation water ▪ Phosphorus, nitrogen, antioxidants, and fertilizers
Other Topics of interest	Potential collaboration with national organization that supports the greenhouse industry in The Netherlands for the replication of WSIS or IS research outside of ULTIMATE project

Figure 6 shows the most relevant inputs and outputs of the water treatment before and after the ULTIMATE project. The three objectives of this CS are shown in green: water for irrigation, the heat recovery system and the nutrients extracted from the WW. There is also in red, the elimination of the treated water going to the municipal drain, which is of most relevance to the CS goals.

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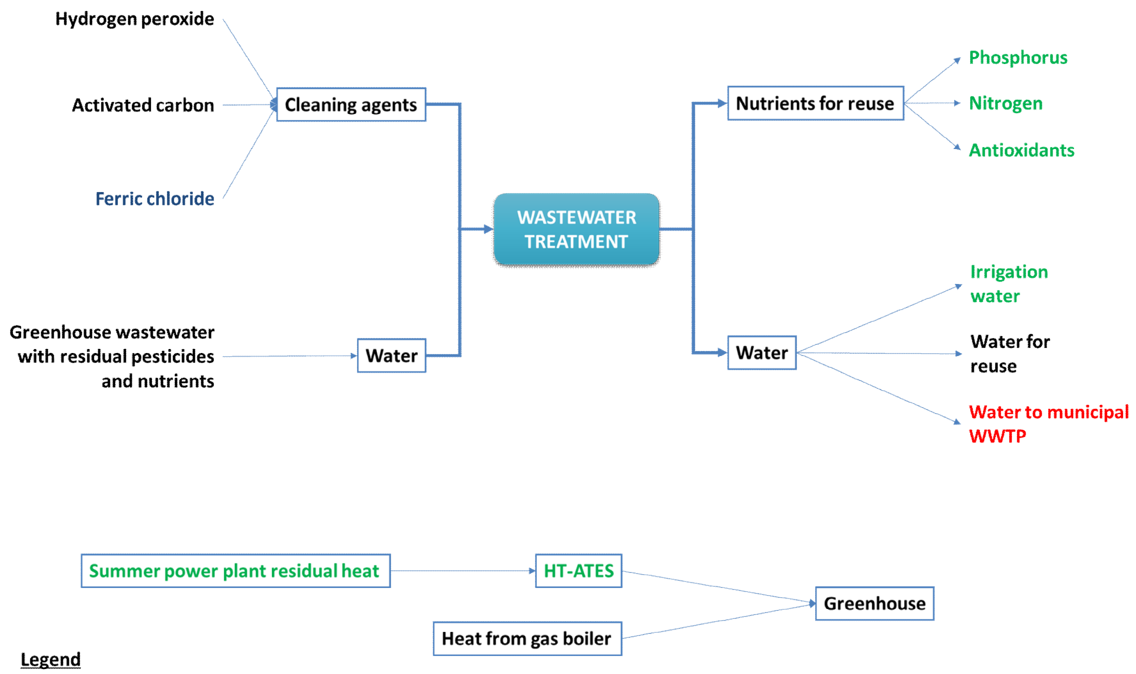

Legend

Flow	Material or water stream inaltered after Ultimate
Flow	Material or water stream removed after Ultimate
Flow	New material or water stream added after Ultimate
Flow	Flow with potential synergy

Figure 6 Schematic representation of CS2 Input and Output flows

For this CS, STRANE focused on the potential of synergies for two resources:

- **Ferric chloride coagulant**
- **Hydrogen Peroxide**

3.3. Case Study 3 – Municipal Utility and Industrial site water Symbiosis. Rosignano, Italy

CS 3 is located in Rosignano, Italy and is part of a bigger project dedicated to the improvement of a WRP producing industrial water for Solvay from municipal wastewater treatment. The CS is already involved in a symbiotic relationship called ARETUSA which is active since 2001. Members of the consortium are the municipal utility ASA (ASA Azienda Servizi Ambientali Spa), which operates the urban water cycle infrastructures in Rosignano and Cecina (and in the Livorno province) catchments , a technology provider (TME Termomeccanica Ecologia Spa) and the main water (re)user Solvay Chimica Italia Spa. Solvay exploits the Rosignano site since 1912 and produces sodium carbonate, sodium bicarbonate, calcium chloride, peracetic acid and hydrogen peroxide.

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3.3.1. Overview and interview summary

Table 6 CS3 interview practical information.

CS3 Partners	UNIVPM (Università Politecnica delle Marche), ARETUSA, WEST, CPTM
Date of interview	01/04/2021
Interviewees	▪ Camilo Palermo (Case Study Leader)– ARETUSA ▪ Assunta De Nisi (Research Engineer)– CPTM ▪ Cecilia Bruni (Junior team leader)– UNIVPM ▪ Francesco Fatone (CTG leader for Material recovery)– UNIVPM ▪ Mattia Ciampechini – ARETUSA ▪ Chiara Cusenza – ARETUSA

Case Study 3 works in the development and expansion of the symbiotic relationship, ARETUSA, already existing between the Municipal utility ASA and Solvay. This symbiotic process involves the treatment and reuse of water coming from the Italian municipalities of Rosignano and Cecina for Solvay industrial activities. The water is initially treated by two separate WWTPs (one for each municipal catchment) operating the conventional activated sludge systems, then tertiary treatments are implemented by the ARETUSA reclamation plant, and then delivered to Solvay. In return, Solvay uses less groundwater form its own wells, to increase the availability of good quality groundwater to the ASA water utility for the potable water use for both Rosignano and Cecina municipalities.

Intermittent, unmonitored and unpredicted chlorine contamination issues have been detected in the water from the municipalities. The main hypothesis currently studied concerns marine water intrusion in the sewer system due the proximity to the sea. Another issue concerns a too high level of the Chemical Oxygen Demand (COD) in the treated water compared to the quality standard required by Solvay. Both issues sometimes prevent from reaching the Solvay's processes required water quality. When the treated water does not comply with Solvay activities, it is diluted/mixed with groundwater until it reaches the desired concentration levels. ASA plant is responsible to ensure the water quality for Solvay.

Solvay is also expanding its activities which will increase its water needs as well, which directly impacts the ARETUSA consortium of which Solvay is a key partner.

The goal for the project is to create a system that can meet the demand, in quantity and quality, of Solvay's site in a consistent way and, when this is not possible, find other uses for this water. CS3 is studying different strategies to attain these objectives:

- An hybrid (data-driven and model-based) early warning system that will identify when the salinity intrusion is occurring in the sewer system before it attains the WWTP by monitoring the water conductivity.
- Increase the capabilities of ARETUSA WWTP. This activity is also associated with the full-scale plant revamping, which is currently underway. The revamping activity, carried out by the Public Private Partnership (it is not directly part of the ULTIMATE project, but it is developing in parallel and potentially synergically

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with it to uptake ULTIMATE results) will allow to increase the water supply in Solvay up to 4 Mm3 / y.
- Development of a digital matchmaking tool that will make an early match of the water offer (based on water quality) and demand (best possible use, including irrigation or other allowed and sustainable reuse).

Alternative technologies and alternative WW treatment agents will be studied and tested for the improvement of the WWTP. Some of the validation of the potential will take place in the facilities of the current ARETUSA WWTP.

If the problem is found to be not solvable for the ARETUSA consortium then, a different application for the treated water, produced by the ARETUSA reclamation plant, will be considered. One of the options is to use it in agriculture for irrigation. The quality that it is possible to produce matches the requirements for this application (class B).

One of the circular economy strategies applied in this project is the use of by-products resulting from the industrial economy of Solvay and other actors in the proximity for the improved water treatment in the ARETUSA plant. CS3 is screening (particularly in Solvay) and will experiment with different materials that could be used. Some of them are:

- Hydrochar from a local industry (which could treat sewage sludge and biowaste from the region) for the Granulated Activated Carbon (GAC) system
- Bentonite from the local chemical industry (Laviosa factory) for the coagulation and adsorption treatment
- Organoclay also from Laviosa for the coagulation and adsorption treatment
- Resins from Solvay
- Hydrogen peroxide and peracetic acid from Solvay for chemical disinfection and advanced oxidation processes (AOP) to mineralize the COD up to water quality standard acceptable by Solvay or other water (re)users l

ARETUSA plant has three tanks with different mixing speeds for coagulation and flocculation, there, some of the treatments with the by-products can be tested in full scale. The modified GAC system will be only tested in a pilot scale.

CS3 is currently working on the confirmation of the feasibility of the use of the by-products mentioned in the WWT. One example is the resins coming from Solvay's production which are generated in enough quantity for the use, but it is not sure that the quality can match the needed one.

Another reuse material that is being investigated is the aluminium and/or iron sludge coming from ASA's potabilization plant for coagulation. This part will only be a concept study and not implemented. Potential uses and receivers could come via the Alu Circle initiative and from other regional or national water utilities. One of the challenges of that is that this material is currently classified as a waste product, so an administrative process to change the resource status need to be investigated.

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The matchmaking tool will be able to make decisions on the treated water destination based on monitoring the quality of the water from the sewer network until the ARETUSA Plant. The pipe system that will make possible the operation of the logistics of some other possible reuse of the water outside of Solvay is not set up and it is not part of the project scope. The developers believe that this digital tool will have a high degree of replicability.

The finality of the project is to have a data driven integral solution system that will manage the existing assets to deliver a territorial strategy that is sustainable and economically viable.

3.3.2. Case study diagram (current / upcoming or after Ultimate project)

Table 7 represents a summary of the most relevant Information provided in the information gathered by STRANE.

Main CE innovation for this CS is the combined source (monitoring and control of sewers system) and end-of pipe (tertiary treatment technologies) approach to reduce salinity and COD, including the reuse of industrial by-products and their application to water treatment saving raw resources in the supply chain. Since this CS has already identified some partners of interest, this task will offer CS3 clues on other alternative sources for the by-products being tested and start gathering information needed for a later twinning process and WSIS replication during the project's lifetime or beyond. As for the strategy for the Aluminium sludge subject, this deliverable will present the results found on the research of potential receivers for this resource and some implications of these options.

The rest of innovations will be centred on improving the efficiency of the current symbiotic relationship and increasing its capabilities, so the ARETUSA effluents have a direct receiver for each water quality possibility.

Table 7 Summary Table of Case Study 3

CS3- Rosignano (IT)	
Technologies applied	✓ T6: Use of industrial by-products as wastewater treatment process chemicals in ARETUSA reclamation plant. ✓ T7: Real-time data driven monitoring and process.
Key Circular Economy innovation	Full-scale water recovery and industrial reuse; reuse of industrial by-products as advanced oxidants, adsorbent or coagulants in the WWRP
Input Flow material	▪ Urban wastewater Bentonite, organoclay and other industrial by-products ▪ Sea water in sub catchment area
Output Flow materials	▪ Industrial water (potentially usable also in agriculture) ▪ Monitoring, modelling, and control system to avoid high chloride concentrations in reuse water.

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	▪ Aluminium Sludge from coagulation
Other topics of interest	Study of the replicability and applicability of the real-time data driven monitoring and process and matchmaking digital tool.

The diagram below shows a general graphic representation of the most relevant inputs and outputs of the water treatment before and after the ULTIMATE project. The main changes in the diagram are the addition of by-products for the water treatment that will constitute an IS formation between the ARETUSA plant and several industrials, the constitution of an IS with the Aluminium Sludge coming from the water treatment and the inclusion of the possibility of having irrigation water available.

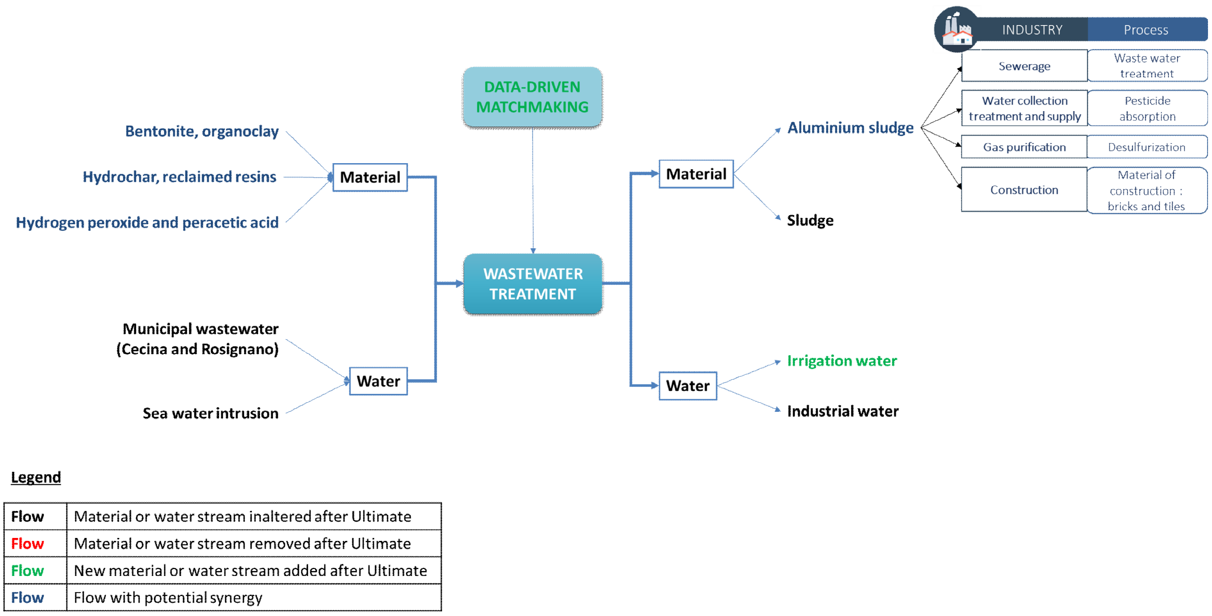

Figure 7 Schematic representation of CS3 Input and Output flows

For this CS, STRANE focused on the potential of synergies for the following resources:

- **Hydrochar**
- **Bentonite and Organoclay**
- **Ion exchange resins**
- **Hydrogen Peroxide**
- **Peracetic acid**
- **Aluminium and / or Iron Sludge (from drinking water plants)**

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3.4. Case Study 4 – Circularity in fruit processing wastewater. Nafplio, Greece

Case Studt 4 is located in Nafplio, Greece and works in a highly productive citrus fruit region in the eastern Peloponnese. This CS is a collaboration for the development of a secondary WWT for the Alberta fruits and vegetables processing plant. Alberta S.A. is a Hellenic Fruit Processing Industry created in 1981 that specializes in the production of fruit and vegetable concentrates for juice, purees and clarified juice. It also produces other tailored lade products and blends. This secondary treatment is being developed by Greener than Green Technologies.

3.4.1. Overview and interview summary

Table 8 CS4 interview practical information.

CS4 Partners	Greener than Green Technologies S.A. (GtG), Alberta S.A, NTUA
Date of interview	05/03/2021
Interviewees	▪ Dimitri Iossifidis (Case Study Leader and GtG technologies CEO) – Greener than Green Technologies ▪ Myrto Touloupi (Research and Development Chemist) – Greener than Green Technologies

For CS 4, the secondary WWT being developed to improve the quality of the effluents and recover valuable materials from Alberta's effluents is a mobile treatment unit. The main task for Greener than Green Technologies (GtG) in the Nafplio CS is to develop and test the capabilities of its mobile and modular unit to treat up to $10m^3$/d of the water effluents coming from Alberta's site. GtG's treatment will accomplish two goals: recover phenols from the wastewater and produce a water that could be fit for reuse. The first one is pertinent because of the high price that these molecules have in the market and the later due to the increasing demand of freshwater in the area.

The research and development of the GtG water treatment technology is directed to broaden the capabilities of the overall water treatment and material recovery so it can be adapted to treat effluents beyond those deriving from fruit and vegetable processing. The material extraction mechanisms to be used are mainly filtration and adsorption.

If the results of the project allow it, the main ambition for water reuse will be the irrigation of the local fields that are managed by small farmers. If this is not be possible, the solution to be looked into will be to have a fit for purpose water to be reinserted in the industrial activity of Alberta.

For the material recovery, the parameters that define the interest in a particular molecule are the market price and the abundance of the product in the effluent. Seasonality and location are also to analyse due to the mobile nature of the treatment

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units and of the wastewater being treated, whose composition will depend on the agricultural production.

The WWT being developed by GtG has a need for the following consumables:

- Resins with affinity to phenols
- A non-chloride coagulant to precipitate solids in suspension.
- pH correctors: NaOH and HCl
- H2O2 30%
- CH_3OH and CH_3CH_2OH
- Ultrapure water

3.4.2. Case study diagram (current / upcoming or after Ultimate project)

The table below shows a synthesis of CS4 activities in ULTIMATE. In this demonstration, the innovation application will reduce Alberta's freshwater demand and reduce the cost of production by reducing the cost of the primary treatment and creating revenue with the extracted molecules. At this moment, the molecules that could be recovered are not yet fully identified. They will be further in the future as more testing is performed. Furthermore, if the treatment reaches the quality demanded by the legislation, Alberta effluents could become a reliable source for irrigation water. Since this is a completely new treatment, it could be convenient to investigate potential alternative supply that is more sustainable than primary raw materials.

Table 9 Summary Table of Case Study 4

CS4 Nafplio (EL)	
Technologies applied	✓ T9: Extraction of value-added compounds from fruit processing wastewater by filtration, adsorption, and supercritical fluid extraction. ✓ T10: Mobile WWT unit.
Key Circular Economy innovation	Water reclamation and reuse in agriculture/juice industry combined with the recovery of high-added value compounds
Input Flow material	▪ Agro industry WW ▪ Resins with affinity to phenols ▪ A non-chloride coagulant to precipitate solids in suspension. ▪ pH correctors: NaOH and HCl ▪ H2O2 30% ▪ CH3OH and CH3CH2OH ▪ Ultrapure water
Output Flow materials	▪ Treated water for reuse ▪ Irrigation water ▪ Value added compounds (polyphenols, flavonoids, anthocyaninsm, tocopherols, carotenoids, lycopene, chlorogenic acid, procyanidins/catechin compounds, phloridzin, naringenin etc)

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The diagram below shows a general graphic representation of the most relevant inputs and outputs of the water treatment before and after the ULTIMATE project. The main changes are the addition of the consumables of the WWT since this is a completely new treatment but also the phenols since they will be recovered and sold. The water entering the municipal biological treatment will not disappear in its entirety, but the composition of the effluent will change, relieving the system.

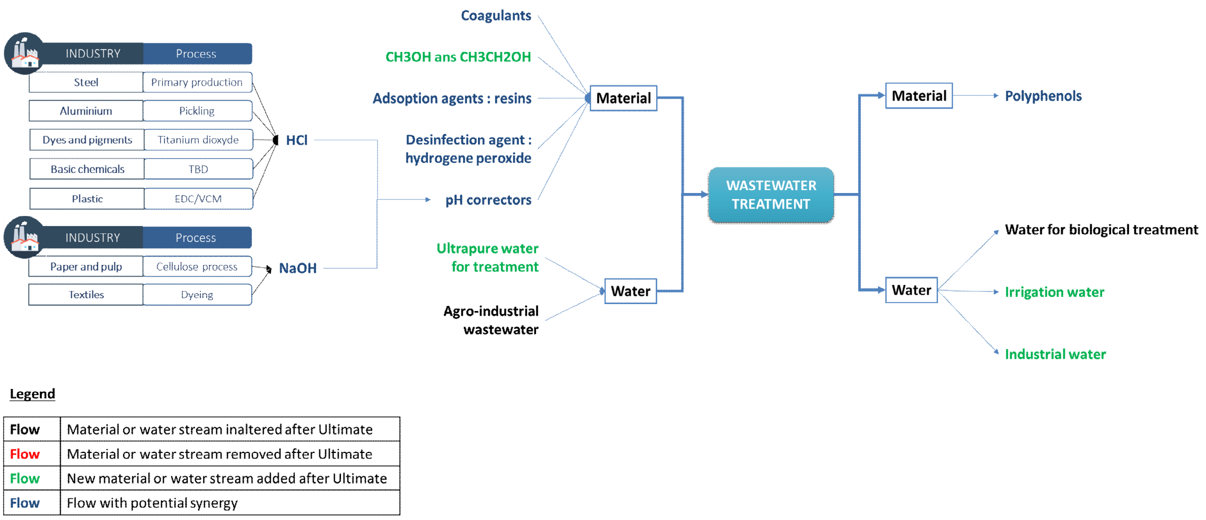

Figure 8 Schematic representation of CS4 Input and Output flows

For this CS, STRANE focused on the potential of synergies for the following resources:

- **Resins with affinity to phenols**
- **A non-chloride coagulant to precipitate solids in suspension.**
- **pH correctors: NaOH and HCl**
- **H2O2 30%**
- **CH3OH and CH3CH2OH**
- **Ultrapure water**

3.5. Case Study 5 – Public Private Symbiosis. Lleida, Spain

3.5.1. Overview and interview summary

CS 5 is located in Lleida, Spain and works in the improvement of the WWT that is provided to the Mahou San Miguel Brewery from Aqualia. This symbiotic relationship was established in 2009 and has been the origin of innovation in WWT. The Mahou San Miguel brewery in Lleida started operations in 1957 and has a production capacity of 2 million Hl/year. This fabric, along with the other production's plants of Mahou produce a beer which partially represents the 32% of all beer consumed in Spain.

The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

Table 10 CS5 interview practical information.

CS5 Partners	**FCC Aqualia**
Date of interview	**03/03/2021**
Interviewees	▪ **Antonio Gimenez (Case Study Leader) – Aqualia**

CS 5 lead partner Aqualia is developing a WWT that will allow for the reuse of the water effluents of the Spanish brewery Mahou San Miguel in its own processes. Aqualia is the main investor in this technology development.

Aqualia and Mahou Brewery are partnering in the scaling up of a technology previously developed by Aqualia: The Bio Electrochemical Fluidized Bed (BEFB). This technology allows for a biogas production from an anaerobic water treatment. For the ULTIMATE project, Aqualia investigates the scaling up of this technology to an industrial scale by treating 500 m^3/d of wastewater which accounts for a third of the brewery's effluents. Another technology, the Anaerobic Membrane Bioreactor (AnMBR), will be used to treat a smaller effluent (50m^3/d). This is an improvement from the previous treatment that consists in a traditional technology of activated sludge.

The application of technologies on this CS follows a circular economy logic by generating biogas, and potentially reusable water that could be latter reintroduced into Aqualia's or Mahou's own processes, particularly, water for cooling. This would, however, require an additional treatment to eliminate salts and microbes with a nanofiltration and reverse osmosis treatment. Spain is currently a country with scarce water resources. This is one of the motivations to develop technologies that will allow the reuse of industrial water.

The Biogas produced by the technologies will be used to feed the thermal needs of the water treatment. There will be no surplus of biogas after this usage.

The excess sludge produced by the new technology will be reduced in quantity, about 4 or 5 times, compared to the current treatment. It will be in a granular state and will not be rich in nutrients which makes it ill-fitted for use in agriculture as a fertilizer. It could, however, be used as a starter for high rate anaerobic digestors that treat wastewater and be commercialized as such. The study of this, the production and composition of the sludge, is in the scope of the project only as a concept study, meaning no testing will be done.

The sludge that is currently being produced by the activated sludge process is composted and used by a third party. There is no need to find receptors or treatment for this waste.

Aqualia's treatment will have a need for some consumables:

- NaOH in the common commercial composition of 25%. About 1 kg/m^3 of treated water which will amount to about 550 kg/day of NaOH.

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- Hydrochloric acid or sulphuric acid in the common commercial composition of 35%. About 0.5 kg/m^3 of treated water which will amount to about 275 kg/day of acid.
- Granulated Activated carbon for the reactor 10m^3 to start the reactor.

These quantities are based on test done for other anaerobic water treatments, so they are realistic estimations. They could however change according to the quality of the water being treated.

3.5.2. Case study diagram (current / upcoming or after Ultimate project)

The table below represents a summary of the most relevant information for task 5.1. In this CS, the most relevant CE innovations are the reuse of water coming from the industrial production and the increase in energy generation via the biogas production. Since these both have an internal use, they do not fit the scope of this task, however, the list of consumables for the treatment could be explored, particularly as they involve important amounts of material.

Table 11 Summary Table of Case Study 5

CS5- Lleida (SP)	
Technologies applied	✓ T11: Water reuse after treatment with AnMBR with fit for purpose posttreatment in combination with an online control system to reduce membrane fouling. ✓ T12/T13: BEFB reactor with membrane filtration for increased biogas yield AnMBR with improved methane extraction from the water phase.
Key Circular Economy innovation	Anaerobic Membrane BioReactor (AnMBR) and Bio Electrochemical Fluidized Bed (BEFB) for nutrient recovery, biomethane production and water reclamation and reuse for irrigation.
Input Flow material	▪ Brewery WW ▪ Caustic Soda (NaOH) ▪ Hydrochloric acid (HCl) ▪ Sulphuric acid (H_2SO_4) ▪ Granulated activated carbon
Output Flow materials	▪ Treated water for reuse. ▪ Granulated sludge ▪ Biogas

The diagram below represents the most relevant input and output flows of this CS. The main material flows appearing are the new need for pH correctors for the new treatments and the granulated sludge being produced. The pH correctors could be eligible for an IS in alternative supply and the granulated sludge could open an opportunity for a receiver's research. The biogas production will be significantly increasing and improving its quality with the anaerobic treatment. The effluent to the municipal drain in red would be either an important reduction, as the water becomes fit for industrial reuse, or an elimination.

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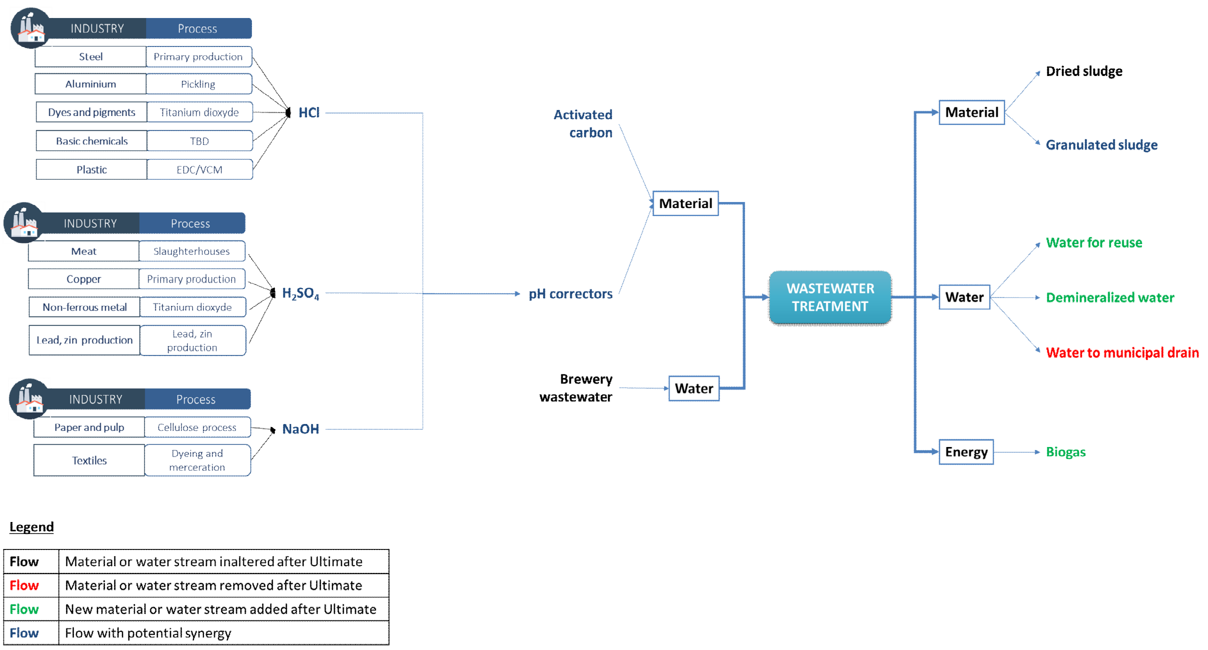

Figure 9 Schematic representation of CS5 Input and Output flows

The first preliminary evaluation of synergy opportunities for CS5 will consider the following resources:

- **Caustic Soda (NaOH)**
- **Hydrochloric acid (HCl)**
- **Sulphuric acid (H_2SO_4)**
- **Granulated activated carbon.**
- **Granulated sludge**

3.6. Case Study 6 – Public Private Agro-food and urban water Symbiosis. Karmiel and Shafdan, Israel

CS 6 is located in two different demonstration sites: Karmiel and Shafdan, both in Israel. In both sites, CS partners work to improve and increase the capabilities of the urban WWTP of Mekorot (MEK), the National Water Company of Israel for 80 years, and make it fit to receive agro-industrial effluents. Mekorot provides diverse types of water related services including urban and industrial wastewater treatment. This symbiosis connects Mekorot, 2 technology providers from the agro-food sector, AGROBICS LTD (AGB) and Greener than Green Technologies (GtG), and The Galilee Society Institute of Applied Research (GSR). Both AGB and GtG are companies of recent creation innovating in the circularity of wastewater treatments. As for GSR, it was created in 1995 as Research and Development Center in the Palestinian-Arab community in Israel

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and it focusses on community-centred projects that address environmental and health issues.

3.6.1. Overview and interview summary

Table 12 CS6 interview practical information.

CS6 Partners	AGROBICS LTD (AGB), Galilee Society Institute of Applied Research (GSR), Mekorot company (MEK), and Greener Than Green Technologies AE (GtG)
Date of interview	04/03/2021
Interviewees	▪ Isam Sabbah (Case Study Leader) – The Galilee Society

CS6 is centred around the treatment of the wastewater of the Karmiel and Shafdan regions in Israel. Both regions have an important agro-industrial activity that, for the moment, lack an integral solution for the treatment of wastewater. In this CS, Mekorot, treats the effluents in the domestic network of both regions. This means that those WWTP were designed and equipped to treat urban effluents and not agro-foods effluents.

The goals of the project are:

- Protect the domestic water system from the effluents that are coming from some industrial activities such as olive oil mills and slaughterhouses in Karmiel, and wineries and dairy factories in Shafdan. The expectation is that a pre-treatment and a management system will allow for a good control of the combination of streams coming from industrial activity and the municipalities.
- Recover valuable molecules from the agro-industrial WW effluents and improve the biogas production if the WWT.

The Galilee Society Institute of Applied Research (GSR) is leading this CS. The interest of GSR in this project is to find a solution to the irregularities that the domestic WW system is suffering from and give a response to the needs in WWT for small agro-foods producers. These irregularities include an overload, in both volume and composition, of the effluents being discarded into the system by the discharge of industrial effluents from the olive oil industry, slaughterhouses, small dairy producers and wineries, most of them irregular or illegal, due to lack of resources or unwillingness.

Treating effluents from agro-industries is complex for different reasons:

1. Seasonality: agricultural activity is highly dependent on the harvest and processing seasons which means the treatment system would be overloaded or operating at low capacity intermittent.
2. Composition of effluents: The effluents have a high content in organic matter and antioxidants. This is hard on the system because of a matter overload but also because the antioxidants (phenols) in the stream are toxic for the biological

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treatment. These molecules would collapse the system as it is right now, which means there is an interest to reduce the organic matter and remove the phenols.

The technologies proposed will stabilize and protect the system. It will then be able to treat the industrial wastewater peaks, treat the excess organic matter, reduce the energy needed for the aerobic system, increase the biogas production (by AgRobics), recover value-added products (by GtG), and reduce the amount of sludge generated by the system. That sludge is already being collected and composted by a third party.

The uniqueness of this CS is that it looks to make adaptations to the existing urban system to make it capable of dealing with the technical challenges that industrial effluents pose, instead of having each industrial dealing with their own effluents. It is also the hope that this can help regularize the administrative situation of the industrials and farmers concerning their wastewater production. One of the expected results from the project is the capacity to estimate the amount of industrial or farm effluents that could be treated to estimate how many producers can be attached to the system.

GtG will be the actor that implements the material recovery to collect the polyphenols present in the OMW in Karmiel. This material recovered will need a destination market. For the Shafdan site, the industrial wastewater has a high salinity, and is rich in residues like fat and proteins from the dairy industry and tannins from the wineries of the region. However, they will not be recovered.

According to the Galilee Society, the wastewater technology being tested for this case study is not in need of a particular consumable material.

3.6.2. Case study diagram (current / upcoming or after Ultimate project)

The table below represents a summary of the most relevant Information provided by CS6. In this CS locations, the innovation applications will allow the WWTPs of Mekorot to properly treat all effluents coming into its network and protect it. It will also allow to further advance in its EC strategies, as besides the biogas and water recovery, there will be an opportunity for material recovery. The biogas and water recovery are already being dealt with by Mekorot and AGB, but the material recovery is still early in the development. There are some sectors identified but no concrete knowledge on the particular molecules that will be recovered, GtG is in the process of analysing the effluents and their technology to concretize this knowledge for exploitation.

Table 13 Summary Table of Case Study 6.

CS6 ISRAEL	
Technologies applied	✓ T15: High rate anaerobic biofilter (AAT) for biogas production from WW with poorly degradable organic matter. ✓ T16: Combine AAT with membrane filtration and activated carbon to prevent biomass inhibition from shock loading.

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Key Circular Economy innovation	Energy recovery via biogas production; recovery of high-added value compounds via Ion Exchange (IEX) and Supercritical Fluid Extraction (SFE).
Input Flow material	▪ OMWW ▪ Brewery WW ▪ Dairy industry WW ▪ Urban WW
Output Flow materials	▪ Treated Water ▪ Reclaimed water for irrigation. ▪ Sludge ▪ Biogas ▪ Polyphenols

The diagrams below show a general graphic representation of the most relevant inputs and outputs of the water treatment before and after the ULTIMATE project in both the Karmiel and the Shafdan locations.

Karmiel

For the Karmiel CS, the most relevant changes in the input and output flows will be the addition of the added value molecules extraction, said molecules come into the system in the OMWW. The Sludge production will be reduced but not eliminated.

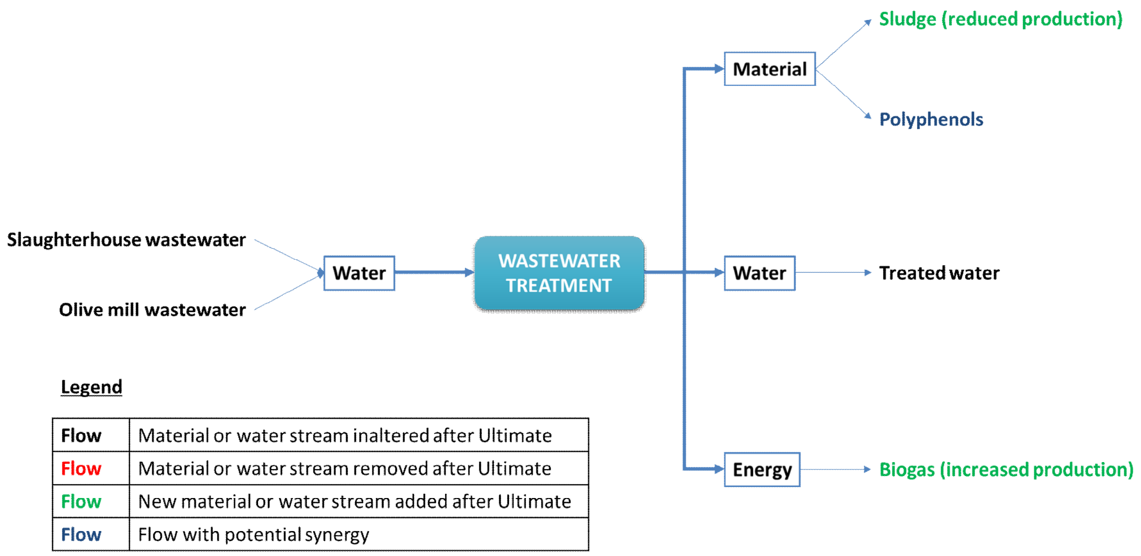

Figure 10 Schematic representation of CS6 Input and Output flows in Karmiel's location

Shafdan

For the Shafdan location, ULTIMATE will not be adding any new recovery material. It will however see changes in the amounts of sludge production by reducing it and an increase in the biogas production.

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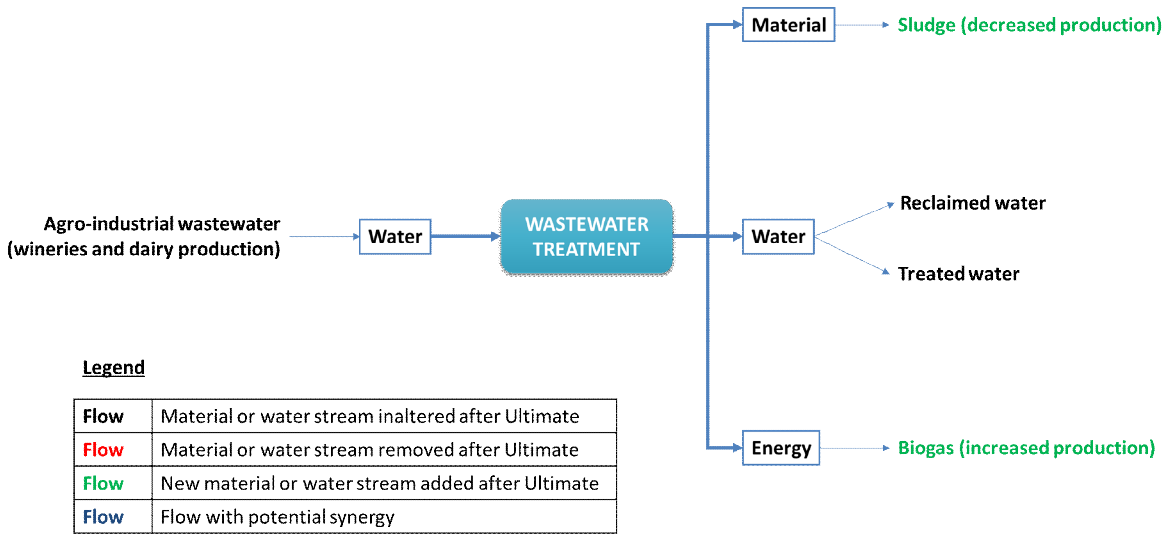

Figure 11 Schematic representation of CS6 Input and Output flows in Shafdan's location

The input and output flows do not change in a radical way because the main benefit coming from this project will be the increase in the capabilities of the which will have a big environmental and social impact by reducing the discard of toxic effluents in nature and providing small agro-food produces with affordable WWT.

The first preliminary evaluation of synergy opportunities for CS6 will consider only one resource:

- **Polyphenols**

3.7. Case Study 7 – Tain, United Kingdom

CS 7 is located in Tain, United Kingdom and works in the improvement of the circularity of the current WWT of the Grenmorangie whiskey distillery founded in 1843 and currently belonging to the Louis Vuitton Malletier Holdings. The distillery is not a partner in the ULTIMATE project but an industrial stakeholder. In this distillery Crandfield University and Aquabio have partnered to work in the current WWT system to improve its EC capabilities. Aquabio, a pioneer in advanced treatment and reuse industrial WW treatment systems for more than 20 years was the technology provider for the WWT of Grenmorangie.

3.7.1. Overview and interview summary

Table 14 CS7 interview practical information.

CS7 Partners	**Crandfield University, Aquabio**
Date of interview	**12/03/2021**
Interviewees	▪ **Marc Pidou – Cranfield University** ▪ **Angel Aguilera – Aquabio**

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The objective of this CS is to build upon the current WWT of the distillery to increase its energy and material recovery capabilities. Aquabio was the designer/provider of the Anaerobic Membrane Bioreactor (AnMBR) WWT used in the distillery today. As it is Aquabio expertise, there are already implemented mechanisms for energy and material recovery. They consist of:

- Recovery of biogas rich in methane that is burned boilers that generate steam to heat the processes in the distillery.
- Recovery of a copper rich sludge that is used in the local agriculture as the land has a copper deficiency.

Material recovery for CS 7 is centred around ammonia since a considerable amount is available in the effluent. The goal is to remove ammonia from the whiskey distillery effluent. Neither the technology that will be used to recover this nutrient nor the form on which the material will be recovered are decided yet. Despite this, based on early analysis of the effluent, CS 7 can make an assumption on the amount of ammonia that could be extracted:

Considering a typical flow out of the current AnMBR system (325 m3/d) and concentration of ammonia (789 mg NH4-N/L) and assuming a conservative performance of the recovery system of 70%, The estimation for recover is approximately 180 kg/d as NH4-N.

This will be done by one of two technologies that are currently being researched: a stripping column and an ion exchange process. The recovered ammonia could have one of two forms: an ammonia solution or an ammonium sulphate precipitate.

Depending on the development of the project, there could be a need for consumables for the WWT and the ammonia recovery:

- Sodium Hydroxide for pH increase in a pre-precipitation process.
- Magnesium for a precipitation process.
- Hydrochloric Acid for pH correction after precipitation process.
- Sulphuric Acid for further processing of the ammonia after recovery in case of an ammonium sulphate precipitate.
- Potassium chloride brine in the case of the use of ion exchange process.

Current energy recovery is limited to biogas recovery. The technologies to be implemented will also recover the heat that is in the effluents coming out of the AnMBR treatment which has a temperature of 38°C.

As for water recovery, the treated water will be filtrated with the membrane technology, so it is fit to be used in the distillery.

There will be a final concentrated effluent after treatment that will be discharged in the environment in the Dornoch Firth. Because of its composition, this effluent could be exploited if it is further processed. The volumes and characteristics of this effluent are not known at this stage in the project.

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Current WWTP

The current WWTP that was designed and build by Aquabio is operated by the distillery. The current treatment has consumables such as: chemicals for cleaning, nutrients, sodium hydroxide and sulphuric acid. More specific information is unknown to Ultimate partners.

The copper rich sludge that is produced by the WW treatment is currently being used by the local farmers that produce the barley. Closing the loop for this material.

3.7.2. Case study diagram (current / upcoming or after Ultimate project)

The table below represents a synthesis of the most relevant information for task 5.1. It becomes evident that even when this location and CS have strong CE objectives and activities, there is still a number of resources that could be interesting to explore and evaluate if there is an opportunity to find for them a more sustainable solution on its supply or destination as system outputs.

Table 15 Summary Table of Case Study 7.

CS7 Tain (UK)	
Technologies applied	✓ T18. Heat recovery from AnMBR effluent. ✓ T17. Zeolite based ion exchange (IEX) for ammonia recovery from distillery WW or a Stripping packed column
Key Circular Economy innovation	Recovery of ammonia via IEX or packed columns, biogas production via AnMBR and heat recovery from its effluent, Reverse Osmosis treatment of AnMBR effluent for water reuse for cleaning purposes
Input Flow material	▪ Distillery WW ▪ NaOH for biogas scrubber ▪ NaOH as pH corrector for a pre-precipitation stage ▪ Magnesium Chloride (for struvite precipitation) ▪ HCl for pH corrector after precipitation stage ▪ H_2SO_4 in case of the ammonium precipitate production ▪ Potassium chloride brine in case of ion exchange technology use
Output Flow materials	▪ Sludge (High copper content) ▪ Treated water for reuse (for cleaning purposes) ▪ Biogas ▪ Ammonia ▪ Concentrated effluent into nature

The diagram below shows a general graphic representation of the most relevant inputs and outputs of the water treatment before and after the ULTIMATE project. The most relevant information that can be found in Figure 12 is that the current high ammonia content present in the distillery effluent will be substituted for an ammonia product after an extraction process and that treated water for reuse will be available.

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The diagram also shows the materials that would be needed in order to perform the treatment and material recovery actions that will be implemented after the ULTIMATE project.

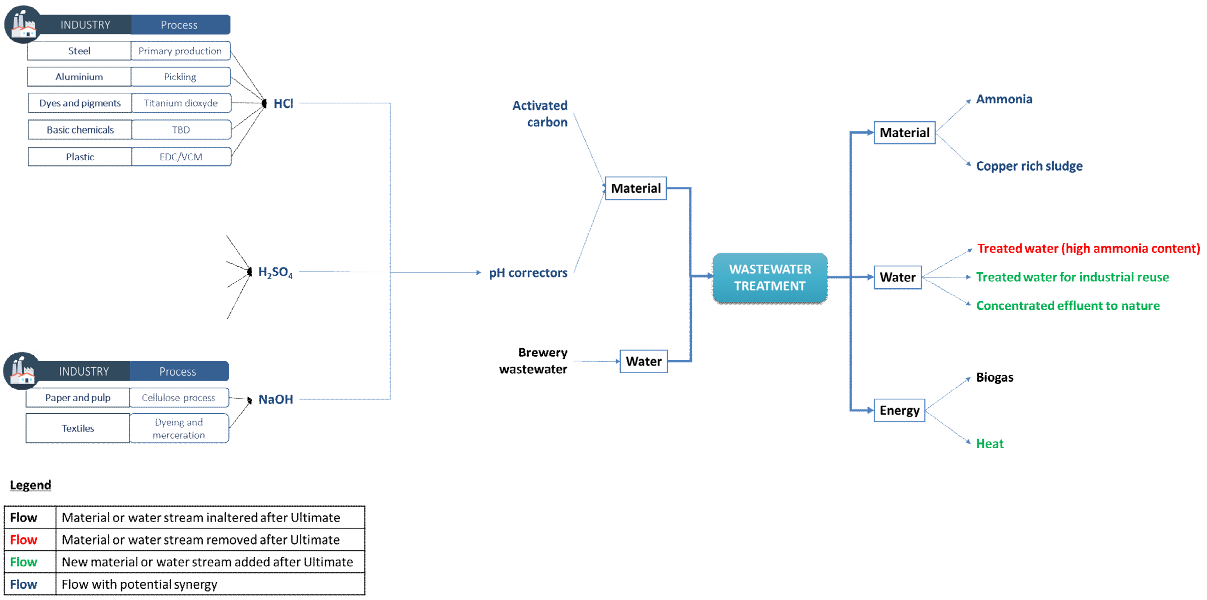

Figure 12 Schematic representation of CS7 Input and Output flows

The first preliminary evaluation of synergy opportunities for CS7 will consider the following resources:

- **pH correctors: NaOH, HCl and H_2SO_4**
- **Copper concentrated sludge**
- **Ammonia**

3.8. Case Study 8 – Saint Maurice l'Exil, France

Case Study 8 is located in Saint Maurice l'Exil in the south-east of France. This CS is a two-partner project which are SUEZ Roches-Roussillon and SUEZ Smart Solutions. The demonstration site is the Hazardous waste treatment and recovery facilities that is within the Roches-Roussillon chemical platform. Said platform exists since 1915 and is formed by 15 companies such as Saqens, Blue Star, Adisseo and Solvay.

In the platform SUEZ exploits two hazardous waste incinerators and a biomass recovery unit.

3.8.1. Overview and interview summary

Table 16 CS8 interview practical information.

CS8 Partners	SUEZ Roches-Roussillon and SUEZ Smart Solutions
Date of interview	15/03/2021

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Interviewees	▪ **Anne Reguer – Senior Process Engineer** ▪ **Priscilla Pareuil – Waste Technical Manager**

The objectives of this CS demonstrator are to recover valuable materials and heat from SUEZ's incineration of waste process.

The recovery material strategy is primarily centred around the recovery of sulphur from flue gas as sodium bisulphite. This flue gas comes from the incineration of liquid dangerous waste charged in salt in an incinerator specialized in salty water and sulphured odorous waste. For the incineration process, SUEZ uses organic matter with an important sulphured fraction (70% aqueous waste and 30% of organic wate).

SUEZ's objective is to produce a solution of sodium bisulphite at 38% from the SO_2 and SO_3 recovered from the fumes. It is the goal of the pilot that will be installed to reach a commercial product (compatible with the secondary raw material market). The production will reach 3,000 tonnes a year in full scale. A market study will be necessary to gain a better knowledge on the pricing, the demand and other market conditions.

For this production, Suez will use as raw material sodium hydroxide in a commercial composition and no particular purity. This is already being in use for the flue gas treatment (soda scrubbing). The quantities used will stay the same for the production of sodium bisulphite. It is in the interest of Suez to explore an alternative source of this material. Sulphur recovery from flue gas is the main topic for CS8 as well as the most advanced one.

If the sulphur cannot be recovered from the fumes, it will end up in the wastewater where it could be potentially recovered as barium sulphate with a selective precipitation. For this solution, barium chloride will be needed. The prices for this raw material are elevated and market size and price of barium sulphate are not as interesting.

There is a secondary objective of recovering various materials, especially metals form the WW effluents of the incinerator, however, the development of the project is not yet advanced enough to predict which materials or in which quantities they could be recovered.

For the energy recovery part of this project, heat will be recovered from the wastewater from the gas scrubbing, SUEZ has not yet chosen the specific method to use, nor the final usage of the energy (as heat or electricity). Nevertheless, it has already been decided that this energy will be used in SUEZ internal processes or sold to other members of the Chemical Platform of Roussillon.

Raw materials

In the WWTP the following raw materials are needed as pH correctors:

- HCL

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- Lime

An alternative solution for the supply could interest Suez.

3.8.2. Case study diagram (current / upcoming or after Ultimate project)

Table 17 is a summary of the most relevant information on CS8. In this particular demonstrator, the goals and the WWT are very specific. There is, however, an issue on a lack of specifics in respect to what can be recovered from the WW stage of the project. In the years to come, as the project progresses there will be a clearer picture on the true CE potential of this CS. For the moment the flows to analyse are the ones that are most relevant for the sulphur recovery.

Table 17 Summary Table of Case Study 8.

CS8 - Saint Maurice l'Exil (FR)	
Technologies applied	✓ T19: Flue gas scrubbing & dust removal for sulphur recovery as sodium bisulphite
Key Circular Economy innovation	Reduce pollutant load in flue gas cleaning water by recovery of sulphur and metals, heat recovery from flue gas for steam/electricity production
Input Flow material	▪ Sulphured organic waste ▪ Lime ▪ Hydrochloric acid
Output Flow materials	▪ Sodium bisulphite – 3 000 t/an ▪ Sulphur and metals from scrubbing WW ▪ Brine

The diagram below represents the most relevant inputs and outputs of the water treatment before and after the ULTIMATE project. New flows will be the Sodium Bisulphite and the recovered metals as well as the addition of the energy recovery. They are shown in green and blue. The lime currently used to treat the flue gas will be used in the Sodium Bisulphite production, so it remains unchanged.

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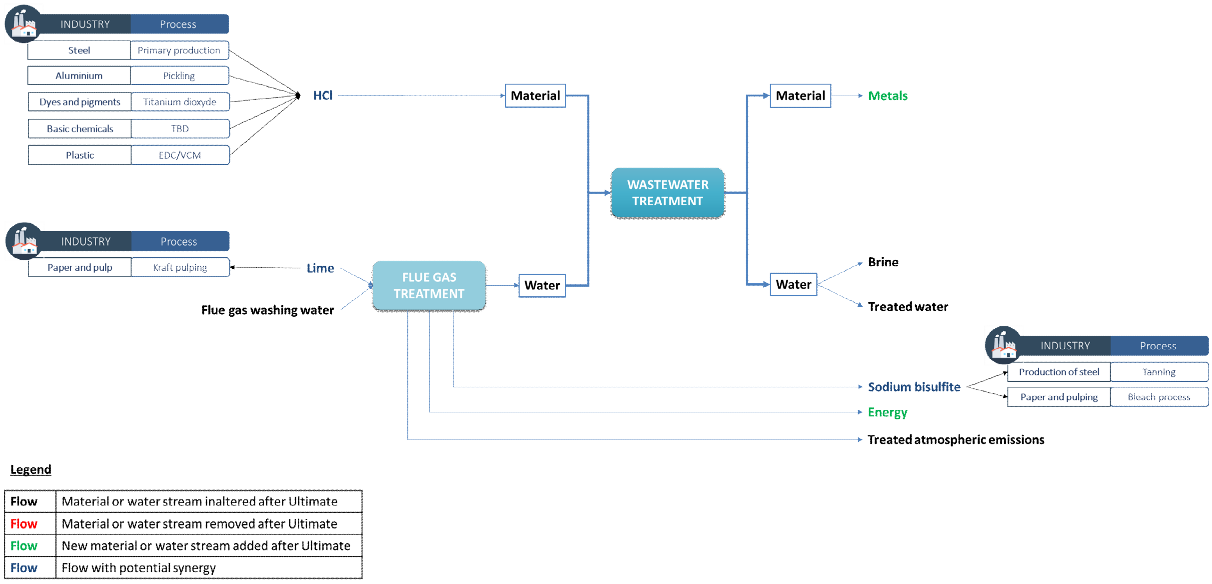

Figure 13 Schematic representation of CS8 Input and Output flows

The first preliminary evaluation of synergy opportunities for CS8 will consider the following resources:

- **Sulphured organic waste**
- **Lime**
- **Hydrochloric acid**
- **Sodium bisulphite**

3.9. Case Study 9 – Kalundborg, Denmark

Case Study 9 is located in Kalundborg, Denmark. The partners participating are Kalundborg Symbiosis, NOVO, X-Flow and KWB. The Kalundborg site is an Industrial Symbiosis that started in 1972 and have several members from public and private companies. The partners of this IS belong to different industrial sectors including petrochemical, construction material, energy, and waste processing.

3.9.1. Overview and interview summary

Table 18 CS8 interview practical information.

CS9 Partners	**Kalundborg Symbiosis, NOVO, X-Flow and KWB**
Date of interview	**08/03/2021**
Interviewees	▪ **Lars Lundgaard -**

The objectives of this Case Study include material, water, and energy recovery, as well as the application of a control system that can improve the management of the WWT.

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The Kalundborg's wastewater treatment plant treats the effluents from Kalundborg municipality, Novozymes WWTP and other Industries. These different effluents have an ensemble of complexities that will be the study subject of the Joint Control System that will be analysed in the ULTIMATE project. One expected result will be enough information to plan for new infrastructure needed to have an optimal effluent treatment and apply a broader approach on circular economy to the water usage.

Kalundborg's WWTP treats a mixture of the industrial and the urban water plant. This makes that the water that could result from this treatment, could not be fit for reuse, notability for the pharmaceutical industry. One of the subjects that will be studied will be the possibility of treating both effluents separately to make a portion of the treated water usable. The technologies tested for this treatment are ultrafiltration and reverse osmosis.

Another issue for which a solution will be studied will be the affluent water peaks that the WWTP must sustain when there is heavy rain in the city. One potential solution would be to retain industrial water from entering the WWTP during the rains.

As for material recovery in this demonstrator, the pretreated WW from Novozymes still contains valuable compounds, which are not recovered yet. Some of the materials that could potentially be recovered from Novozymes effluents are:

- **Phosphorus (can be recovered but in limited quantity, because some amount of phosphorus would be used in water for further operations)**
- **Sulphur (can potentially be recovered in a limited quantity)**
- **Acetic acid (coming in peaks occasionally)**
- **Ethanol (looking for a solution to recover it)**

An internal use for this will be analysed by Kalundborg utility in priority.

The data on the potential amount of material recovery and other details will not be known in the near future, as the material recovery tasks are planned to be caried out during the year 2022.

3.9.2. Case study diagram (current / upcoming or after Ultimate project)

Table 19 represents a summary of the most relevant information for this task. At the current stage of the project, the general objectives are well defined but not the specific objectives and process to install, nor the material recovery strategies. The first year of the project consists of data collection and goal definition. In the years to come, as the project progresses there will be a clearer picture on the true CE potential of this CS. Most of the subjects will be treated internally, as the cluster has a strong knowledge and expertise in creating symbiotic relationships. For this task, the flows to analyse are not yet defined and it won't be possible to explore any specific IS for this CS.

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Table 19 Summary Table of Case Study 9.

CS9 Kalundborg (DN)	
Technologies applied	✓ T20: Combination of novel ultrafiltration membranes, reverse osmosis, biofiltration, ozonation and powder activated carbon. ✓ T21: Data driven cloud-based control system for WWTP operation.
Key Circular Economy innovation	Novel UF/RO treatment for reuse of WWTP effluent with high share of non-degradable organic matter, nutrient, or high-value product recovery, increasing energy efficiency via synergetic operation of two WWTPs and heat recovery
Input Flow material	▪ Urban WW ▪ Industrial WW
Output Flow materials	▪ Not yet defined valuable molecules ▪ Treated water for industrial reuse

The diagram below shows the before and after ULTIMATE of the most relevant flows. The most relevant information that can be found in Figure 14 is the addition of the Joint Control System, and the new flows emerging after the new WWT, and recovery technologies are installed, which are: Industrial water, nutrients, high -value materials and heat.

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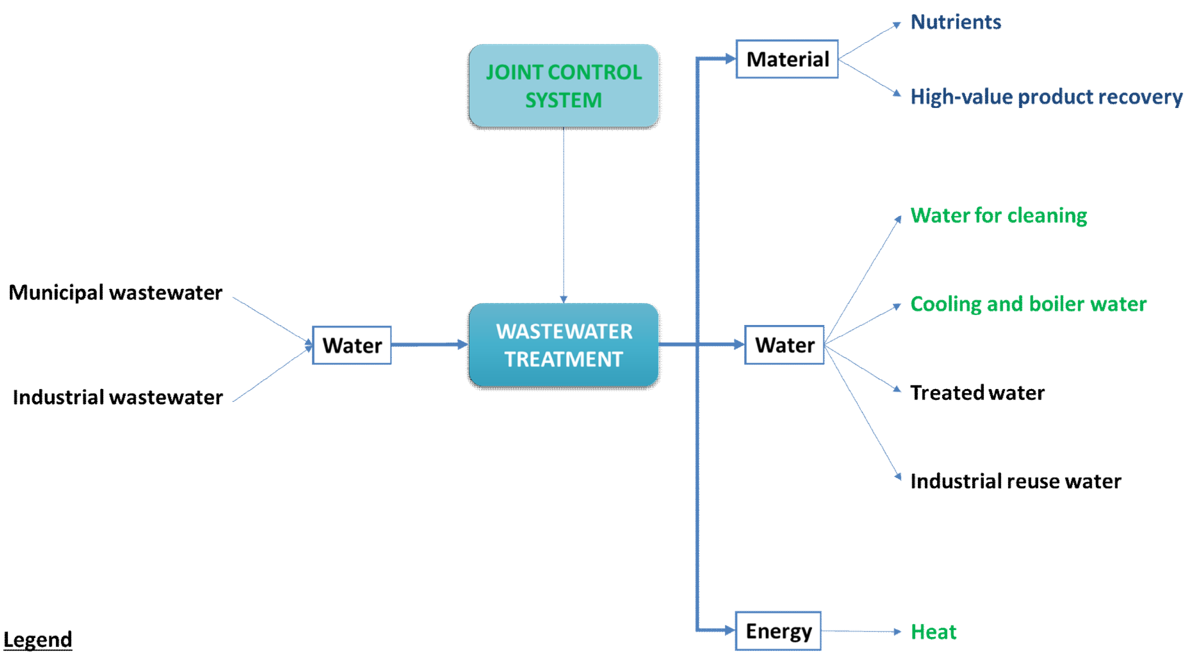

Legend

Flow	Material or water stream inaltered after Ultimate
Flow	Material or water stream removed after Ultimate
Flow	New material or water stream added after Ultimate
Flow	Flow with potential synergy

Figure 14 Schematic representation of CS9 Input and Output flows

The first preliminary evaluation of synergy opportunities for CS9 will consider the following resources:

- **Sulphur (can potentially be recovered in a limited quantity)**
- **Acetic acid (coming in peaks occasionally)**
- **Ethanol (looking for a solution to recover it)**

3.10. Final Matrix

The table below represents a synthetic representation of all input and output flows for each case study that are relevant for task 5.1. This table is not an exhaustive representation of all materials, water and energy coming out of CS activities. It condenses the information that was deemed interesting during the bilateral interviews with CS leaders. It was reviewed and confirmed by CS leaders. The matrix will help to get a detailed understanding of flows and make a selection by choosing repeated flows, big volumes, and valuable resources to investigate promising synergies. These exchanges have also help to magnify the information and understanding of the industrial processes associated with ULTIMATE technologies.

To facilitate the analysis, a further categorisation of input and output flows of material and nutrients was done. These flows have been divided into a different category:

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- **Coagulants**
- **pH correctors**
- **Filtration/Adsorption agents**
- **Disinfection agents**
- **Other types of materials flows.**

A good number of WWT technologies require pH correctors. These pH correctors have been identified in different use cases (CS4, CS5, CS7 and CS8) and technologies. The pH correctors used the most in these processes are NaOH (Sodium Hydrochloride), HCL (Hydrochloric acid) and H2SO4 (Sulfuric acid). HNO3 is also used but only in one CS.

Another relevant type of material currently used in the treatment of water are coagulants. Three CS (CS2, CS3 and CS4) require coagulants for the flocculation and coagulation step: Ferric chloride, Bentonite, Organoclay and other not specified or not yet defined coagulants. These coagulants can be analysed as per requirements and nearby supply of the material.

Furthermore, filtration/adsorption and disinfection agents as input material to treat WW have been identified in some CS. The most commonly use of filtration/adsorption agents are Activated Carbon (AC) and Granulated Activated Carbon (GAC), Hydrocar (as substitute for GAC), for CS2, CS3, CS4, CS5 and disinfection agents are hydrogen peroxide for CS2, CS3, CS4 and peracetic acid for CS3.

As other input material not included in the categories above, we can mention CH3OH and CH3CH2OH required by CS4, then lime and organic waste for CS8.

The type of WW entering the WWT of the CS is also signalled and classified in the table. For different CS, the input water effluents differ based on the industrial activities which are municipal WW, greenhouse WW, Agro-industrial WW, Brewery, and distillery WW, and scrubbing WW.

Regarding the output materials from the different case studies, a few are repeated with more than one CS: Polyphenols and WT sludges with various compositions. The rest of the outflow of materials are Ammonia, Sodium Bisulphite and Nutrients (phosphorus, nitrogen, and antioxidants). Water output flows are Industrial water for reuse, Irrigation water and treated water for further treatment of to be discarded in nature.

Most repeated input and output flow of materials and water are marked in green in Table 20. They are activated carbon, Hydrochloric and sulphuric acids, irrigation water, and sludge. Although sludges are present in different types and compositions, so it is difficult to group them in a single category.

Some streams highlighted in orange colour are prioritized for evaluation to find potential users because they are part of the ULTIMATE project's objectives for the CS:

- **Bentonite and Organoclay (CS3)**

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- **Aluminium Sludge (CS3)**
- **Ammonia (CS7)**
- **Sodium Bisulphite (CS8)**

Some input materials (in yellow) present a particular interest for some CS and could help increasing their EC level. They are mentioned in Table 20:

- **Lime (CS8)**
- **Hazardous or non-hazardous industrial liquid waste (aqueous and organic and preferably charged in sulphur) (CS8)**

As there are common resources of interest for different case studies, synergies will be studied flow by flow in **Section 5**.

Blank spaces means that there will be no changes or flows relevant for ULTIMATE project that apply to that resource category and that CS

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Table 20 Final inventory matrix for resources to be considered for IS research. Colour code: green for repeated flows, orange for flows related to ULTIMATE tasks, and yellow for flows that are of particular interest to the CS

Case Study		CS1 (Tarragona (ES))	CS2- Nieuw Prinsenland (NL)	CS3- Rosignano (IT)	CS4- Nafplio (EL)	CS5- Lleida (SP)	CS6- Israel	CS7- Tain (UK)	CS8 - Saint Maurice l'Exil (FR)	CS9- Kalundborg (DN)
Partners Involved		EUT, AITASA	KWR	UNIVPM, ARETUSA, WEST	GTG, ALBERTA	AQUALIA	AgRobics (Israel), MEKOROT	Cranfield University, Aquabio, EUT	SUEZ-RR	Kalundborg Utility
Input material	Coagulants		Ferric Chloride (Coagulant Current WWT)	Bentonite, Organoclay (Coagulant and adsoption)	Coagulants					
	pH Correctors				NaOH, HCl (pH correctors)	Caustic Soda NaOH 25% (550 kg/day), Hydrochloric Acid HCl 35% (275 kg/day), Sulphuric Acid H_2SO_4 35% 275 kg/day		NaOH, Sulphuric acid H_2SO_4, Nitric acid HNO_3	Hydrichoric Acid	
	Filtration/Adsorption Agents		Activated Carbon (Pesticides Current WWT)	Hydrochar (GAC), Resins	Resins (FPX66, XAD4)	Granulated Activated Carbon 10m3				
	Disinfection / AOP Agents		Hydrogen Peroxide	Hydrogen Peroxide	H_2O_2 30%					
	Other	Sodium Bisulphite (Industrial WTP)			CH_3OH, CH_3CH_2OH				Lime, Hazardous and non-hazardous industrial liquid waste (aqueous and organic)	
Input Water		Municipal Wastewater (WWTP)	Greenhouse Wastewater	Municipal Wastewater	Fruit & Vegetable processing wastewater	Brewery wastewater	Olive mill wastewater	Distillery Wastewater	Flue gas washing water	Municipal Wastewater
		Industrial Wastewater (IWWTP)	x	x	Ultrapure water for treatment	x	Agroindustrial wastewater (wineries and dairy factories)	x	x	Industrial Wastewater
Output materials		Sludge	Nutrients (Phosphorus, Nitrogen, antioxidants (Fertilizers))	Aluminum Sludge	Irrigation water	Dried Sludge 3.425 t/year Dryness of 17%	Polyphenols	Ammonia	Sodium Bisulphite	Recovered resources (e.g. nutrients, high-value products)
		Amonia	x	x	Polyphenols	Granulated Sludge 250 kg/day	Sludge	Copper rich sludge for soil enrichment	Metals	x
Output Water		Treated water rejected into nature	Irrigation water	Industrial water	x	Demineralized water for cooling towers 8 - 10 m3/h	Treated Water	Industrial Water	Brine	Water for Cleaning and Flushing
		Industrial water	x	Class B Water for Irrigation	x	Industrial Water	Irrigation Water	x	x	Cooling and boiler water
		Brine	x	x	x	x	x	x	x	x

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4. Flows Prioritisation

After the analysis of the data available in the current stage of the project a synthetic table, Table 21 was generated. It contains the most relevant resources to focus on for the synergy investigation.

Table 21 Potential synergy synthesis by flow type.

Material Flow	Input / Raw Material	Output / Waste	CS Involved	Interest	Potential Synergies at first screening
Water		X	CS3: Water for irrigation Class B CS4: Water for irrigation Class B	• High potential for replicability of technology application based on a twinning project in future exploitation tasks.	• Agriculture for Class B water • Cartography of agricultural regions in the proximity and evaluation of size and capacities that match the volumes available.
Disinfection / AOP Agents	X		CS2: Hydrogen peroxide disinfection in the current WW treatment CS3: Hydrogen peroxide and peracetic acid for water disinfection and advanced oxidation processes	• High potential for replicability for hydrogen peroxide as it is a common raw material for water treatment if its effectiveness is proven.	• Sites producing hydrogen peroxide in the vicinity of WWP. • Synergies for peracetic acid to identify
Coagulants	X		CS2: Ferric chloride CS3: Bentonite and Organoclay CS4: Non-specified, non-chlorine	• High potential for replicability as it is a common raw material for water treatment if feasibility is proven.	• Alternative Coagulant materials such as chemical sludge • Bentonite producers
Hydrochar	X		CS3: GAC CS5: GAC for the treatment start	• Hight potential for replicability as it is a common raw material for water treatment	• Biomass and hydrochar producers.
Resins	X		CS3: Partially exhausted ion exchange resins (both anionic and cationic). CS4: Resins compatible with phenols	• Commonality in two CS	• Mineral and other Chemical Industry • Resin reactivation
Phenols		X	CS4: Diverse Polyphenols CS6: Diverse Polyphenols	• High added value compounds • Commonality in two CS	• Superfoods Industry • Cosmetic Industry • Pharmaceutics Industry
Aluminium Sludge		X	CS3: Coming from ASA potabilization plant where it is used as a coagulant.	• Environmental gain by diverting a non-hazardous waste from landfill, incineration and other disposal solutions. • Savings on clay raw materials.	• Water treatment plants • Ceramic tile and brick producers

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pH Correctors	X		CS4: NaOH CS5: NaOH, HCl and H_2SO_4 CS7: NaOH, H_2SO_4 and HNO_3 CS8: Hydrochloric acid	• Very important quantities involved for this particular application. • Important replicability potential as these materials is commonly used in water treatment.	• Industrial processes generating acid waste easy to purify.
Ammonia		X	CS7: Ammonia solution or an ammonia precipitate	• A market needs to be found for this by-product as part of the ULTIMATE project.	• Agriculture
Lime	X		CS8: Lime for flue gas scrubbing and sodium bisulphite production	• Important quantities involved. • Resource that has a list of applications and is highly demanded.	• Lime emitting sectors. • Lime sludge emitting sectors.
Sodium Bisulphite		X	CS8: Production of this material as a form of sulphur recovery from waste incineration flue gas	• This would transform a toxic component of an emission in a valuable material. It will help to avoid effort in WWT to eliminate sulphur. • It would represent a revenue for SUEZ instead of a cost in the substance management.	• Paper production • Leather tanning process • Other technical applications
Organic Sulphured Waste	x		CS8: Waste that could be incinerated in SUEZ' site	• If sulphur content is important could help attain the desired sodium Bisulphite concentration. • This type of waste could have a better and more sustainable management substituting simple incineration.	• Organic Chemical Industry

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Information shown in Table 21 are most relevant to make the final selection of flows to be assessed as part of an Industrial Synergy. From the overall analysis carried out up to this point, several key facts can be concluded:

- **Water for irrigation is a repeated flow and the interest was also highlighted by the CS partners. It has also high potential for replicability in a future twinning process and takes part on the pressing issue of hydric pressure in Europe. It will be explored in priority.**
- **Hydrogen peroxide is a repeated flow but has a limited potential of replicability (due to the number of Hydrogen peroxide production sites in EU) if the application is proven to be technically feasible by CS3. That replicability potential will be explored in a twinning process by looking at the density of hydrogen peroxide producers in Europe (in D5.7).**
- **Coagulants are globally needed in high amounts as they are an important part of both water and wastewater treatment. Finding a promising synergy would have a potentially good replicability. It will be explored.**
- **Hydrochar is an innovative adsorption agent that could be a sustainable substitute for classic activated carbon. As this material is increasingly used in WT, this could generate significant environmental gains. This material is used as a consumable in the CS 3 and as a process starter (a onetime need for the material) in for CS 5 it will only require an initial quantity as a process starter. However, the replicability in a future twinning process could be very interesting so it will be addressed in a low priority.**
- **Resins are used in two CS. At the moment, the quantities needed are unknown for both CS 3 and for CS4 this volume will be likely small. Most resins are often high technical specification products. Then, it will not be further explored.**
- **Phenols are a repeated resource, and their commercialisation is one of partners key objectives. However, they are not being prioritized in a specific way for this deliverable as the particular phenols are not yet identified and no precise information is available at the moment.**
- **Aluminium Sludge is a waste product that is being treated as a waste by most of the sites that generate it. Finding potential users and receivers for this material is part of CS3's tasks. As it is being generated by WTP, the replication potential could be very important. A synergy using this material will save non-renewable raw materials and divert a considerable amount of waste from landfill. It will be explored in priority.**
- **pH correctors are another chemical that is commonly used in WWT. They are used by four CS (the most repeated material) so the synergy will be explored.**
- **Ammonia is a nutrient currently used in agriculture. The ammonia produced by CS7 will be extracted from the effluent, thus, recycled, which makes it a sustainable source of fertilizers compared to primary synthetic ones. The ammonia from CS7 is of high relevance for the ULTIMATE project. Receivers for this type of material will be researched.**
- **Lime is a highly demanded material used in many different industries and whose exploitation is not entirely sustainable. It is of particular interest for CS8 as is crucial in its current activity and in the future one. Being a material with many**

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different uses, its potential for replication could be interesting. It will be analysed.

- **Sodium bisulphite is the central material for CS8. Finding receivers early on the project is crucial as it will help consolidate and demonstrate the economic viability of this CS activity. It will be analysed in priority.**
- **Organic sulphured waste is not a priority and will not be analysed in this deliverable.**

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5. Synergies identification

5.1. Analysis of synergies by material

5.1.1. Flow 1: Sodium Bisulphite -$NaHSO_3$

Objective of the synergy

This synergy concerns the CS8 lead by SUEZ RR IWS Chemicals. SUEZ intends to recover sulphur from the flue gas treatment on their hazardous and non-hazardous waste incinerations processes. As indicated in **Section 4**, sulphur will be recovered as a 38% concentration Sodium Bisulphite ($NaHSO_3$) solution. The expected volume of the production is **3 000 t/y**. The objective of SUEZ's case is to commercialise this production locally, which will allow for their emission's sulphur content valorisation. This is an alternative CE approach to the current flue gas treatment.

Sodium Bisulphite is a white solid salt mixture that is commonly commercialised as an aqueous solution of around 40% concentration. It is normally produced as a raw material with the reaction of SO2 with an alkaline hydroxide, such as NaOH or Na_2CO_3 by absorption [3].

5.1.1.1. Sector's identification and technical screening

Depending on its composition, purity, and manufacture process, $NaHSO_3$ is produced mostly in three different grades. The grade of the substance will define its relevancy to be used in specific sectors and applications:

- Food Grade: fit for applications involving human consumption (food or pharmaceutics) or a direct contact with the skin. This is the highest purity grade.
- Photo Grade: industrial specified standard that ensures the substance contains only the impurities that do not interfere with the intended use of the chemical in the photographic processing.
- Technical Grade: suited for general commercial and industrial purposes.

From the consultation of global market studies [4][5], BREF documents [6] and Seitiss Matchmaking tool, an initial list of applications was found:

- **Municipal wastewater and industrial water treatment for dichlorination**
- **Pulp and Paper Industry as bleacher and dechlorinator**
- **Food Industry as an additive and in meat and poultry processing**
- **Flue gas treatment to remove sulphur trioxide (SO3).**
- **Leather tanning process**
- **Photography & Film: Preservative in photo developer process**
- **Cosmetic and pharmaceutical Industry as disinfectant and antioxidant**

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Sodium Bisulphite Market

Sodium Bisulphite market is sub-grouped according to the different grades. A general growth is observed due to several factors such as changes in regulation, the growth of certain end-use industries and change in techniques and practices in these sectors. Specifically, regulation changes on dechlorination of wastewater require less chlorine content in the output effluents for WWTP. It is combined with the restriction of hazardous dechlorinating agent in WWTP effluents imply an increase of the Sodium bisulphite demand. This situation is similar for the pulp and paper production sector. These end-users can use also Sodium Metabisulphite, but Sodium Bisulphite has the competitive advantage to be more easily handled compared to the metabisulphite. [4] [5]

The NaHSO3 is also growing for food application due to the global growth in the processed food market. The same is true for the pharmaceutical and cosmetics market. However, these applications are not likely to be suitable for SUEZ' s product, so they will not be further discussed. [4] [5]

The Suez's Sodium Bisulphite will take part in the secondary raw material market, and it will be suited for technical applications. Applications were prioritized considering the following parameters to find the most adapted to SUEZ's case:

- Grade required for the $NaHSO_3$ used: SUEZ sodium Bisulphite would be technical grade.
- The size of the market of the sector and the probability to find a receiver nearby: according to the market studies consulted, the paper and pulp production is the biggest market and WWTP. [4] [5]

Most promising sectors are presented on Table 22 with their associated NACE CODE.

Table 22 Potential receiving sectors of Sodium Bisulphite and it's respective NACE codes

NACE Code	Sector	Description
15.11	Tanning and dressing of leather; dressing and dyeing of fur	Bleaching
17.11	Manufacture of Pulp	Dechlorination and bleaching, sulphite pulping
17.12	Manufacture of corrugated paper and paperboard and of containers of paper and paperboard	Dechlorination and bleaching

5.1.1.2. Regulatory aspects

For its commercialisation, SUEZ's, sodium bisulphite would likely need to be considered as a by-product.

If Sodium bisulphite respects the 4 criteria of the European directive mentioned in **Section 2,** and the jurisprudence of the court, it can be considered as a by-product.

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Product legislation will then be applied to Sodium bisulphite, such as REACH or CLP. However, the producing company must be able to prove that the stream fits with the criteria.

Some information is missing but we can suppose that:

1. **Certain use:** Sodium bisulphite is used in several industries such as leather tanning and paper pulp manufacturing. The market exists and the use is certain. Figures on the market can support the certain use and are provided in the synergy case. In the same way, a financial advantage will be drawn by SUEZ which will give more value to the sodium bisulphite. To ensure the certain use, the perfect argument is to collect letter of intention, proof of interest or set-up annual or multi-annual contracts with potential receivers.
2. **Direct use without further processing**: In principle SUEZ will produce the sodium bisulphite; and no other external treatment needed. It is still to be confirmed that the internal process applied for recovering the sodium bisulphite will fit the expectations of this criteria
3. **Integral part of a production process**: SUEZ will produce the sodium bisulphite in the same site as the incineration process. But it needs to be confirmed that this production can be considered as integral part of the treatment process.
4. **No impact on the environment or human health**: the sodium bisulphite has to be registered under REACH.

5.1.1.3. Mapping of nearby potential receivers and distance distribution

To start the assessment of the IS case between SUEZ and the sectors mentioned in Table 22, an initial map based on current databases representing those sites is proposed. The process for developing the map in Figure 15 was presented in **Section 2**.

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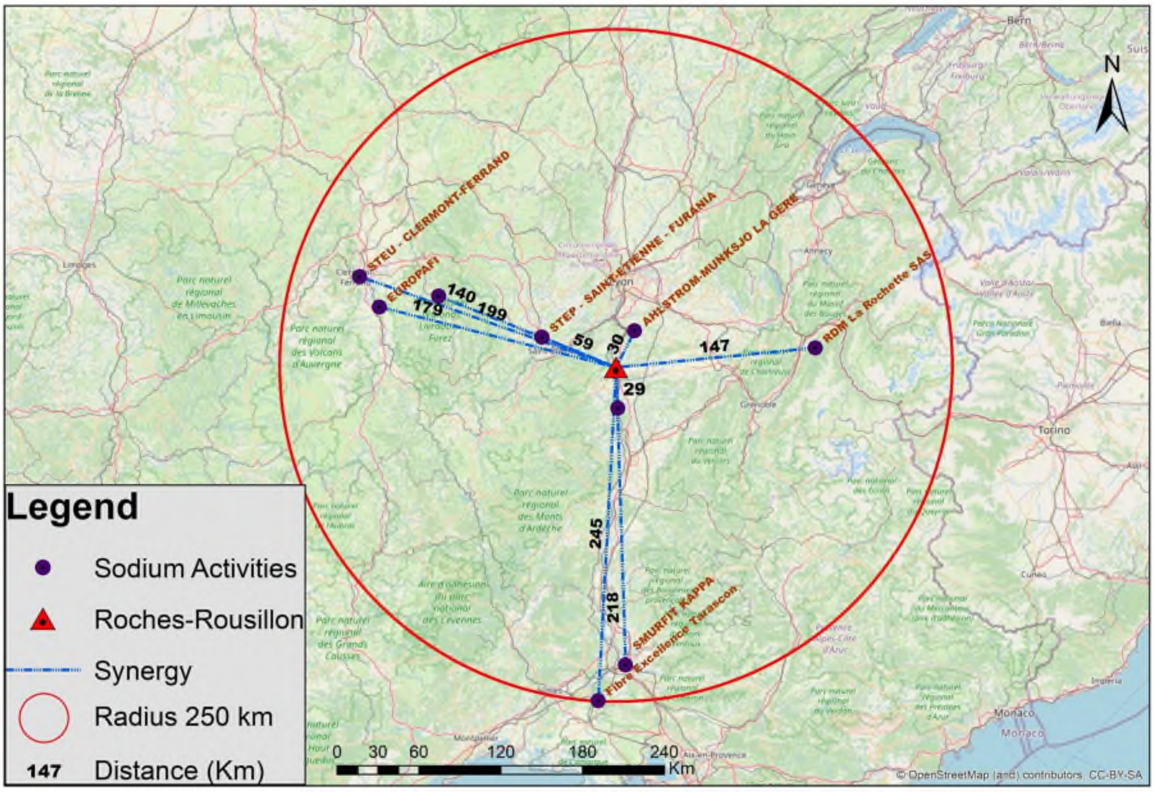

Figure 15 Initial map of potential receiving sites of SUEZ's Sodium Bisulphite within a 250 km radius.

Figure 15 represents the closest sites to SUEZ that have the potential of receiving sodium bisulphite. The map shows a radius of 250 km to illustrate the location of the first sites that could be considered, contacted, and surveyed to privilege a short circuit. STRANE identified at least 9 sites with different activities but mostly paper related production and WWTP. Having the same type of application, these sites could be contacted in parallel to obtain key information on their needs (sodium bisulphite form, quantities, regularity, etc.), technical specifications and their interest to be involved in this symbiotic relationship.

Table 23 shows the cumulated number of potential receivers as the research radius increases.

Table 23 Table of Sodium Bisulphite potential synergies

Distance (km)	Potential synergies
50	3
150	7
250	24
350	52
400	77

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For the viability radius calculation in this preliminary assessment, a reliable pricing for a 38% Sodium Bisulphite solution is not available. However, to have a preliminary indicative viability radius for this study, an alternative assumption was defined. We identified the market value of a similar dried salt of Sodium Metabisulphite. Considering that SUEZ's product could be eligible for the same type of applications as the metabisulphite, we assumed that both resources have a similar economic value. We used this basis to calculate an estimated price, considering:

- **SUEZ's product will be a solution and not a salt so we define a price point of 104 €/t**
- **It is a secondary raw material (30% depreciation)**
- **A security margin to have a conservative approach (10% depreciation)**

Considering these parameters, the final price retained to determine the radius was 62 €/MT. Meaning 186 000 €/year of potential economic value generated by the SUEZ case in the most conservative approach.

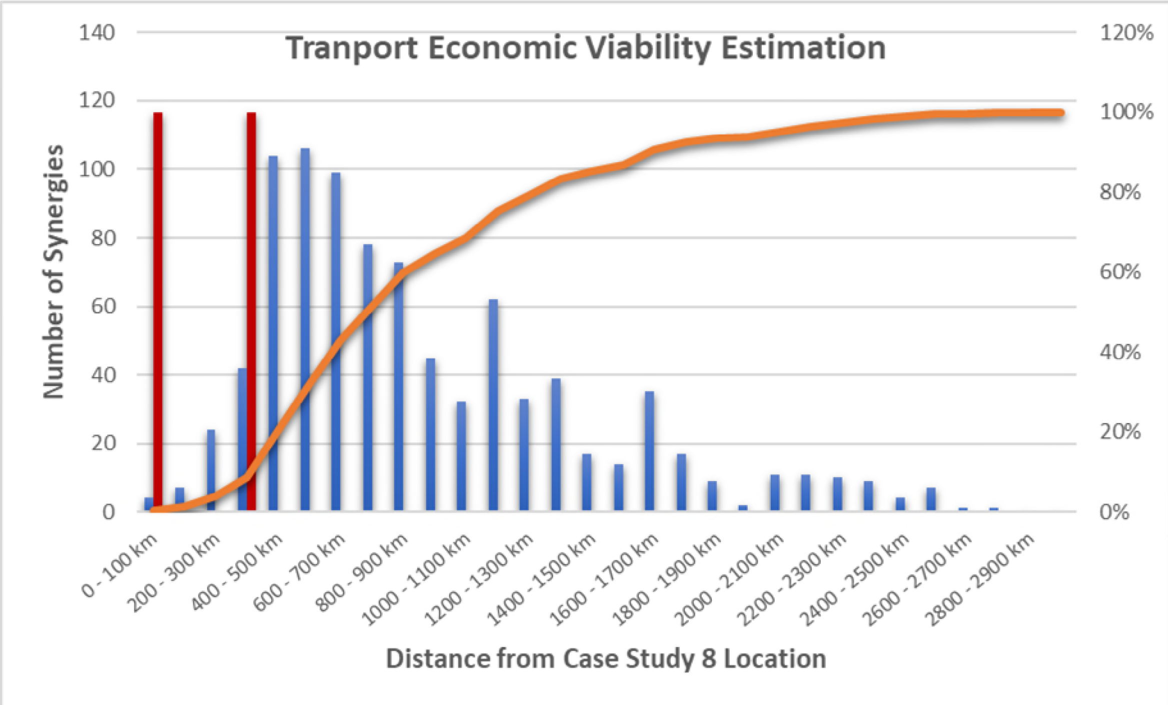

Figure 16 Transport viability estimation for Sodium Bisulphite potential IS.

Figure 16 shows the distribution of the synergy opportunities based on radius ranges. Those within the viability radius between 35 and 360 km are represented between the vertical red lines. We can see that from 100 to 250 km, the number of opportunities remains relatively small (17) compared to the cumulated number within the viability radius (45). However, this number almost doubles when we consider the next 100 km (between 250 and 350 km). For all those 45 synergy opportunities a pipe truck transportation could be adapted.

As the economic viability of the transportation of $NaHSO_3$ is based on a first estimate, a better understanding on the pricing and the secondary raw material market is necessary to have a reliable estimation of the economic viability of this IS project.

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These could allow to better target the receiving installation. This market analysis can be performed in a second step later in the Ultimate project in partnership with the CS leader by surveying nearby installations. The outcome presented in this deliverable only provides first insights and a starting point to be further explored. Even as the demand for $NaHSO_3$ is globally increasing, a field study is recommended as it would directly indicate the volumes of $NaHSO_3$ that are susceptible of being absorbed by the local market, as is SUEZ's preference, and not a more global or extended market.

5.1.1.4. Conclusions

As Sodium Bisulphite could also be employed in wastewater treatment and water treatment or industrial use. If this sulphur recovery could be replicated elsewhere with an adequate purity, it could also be applicable for synergies with urban and industrial WWTP and WTP. This could involve other CS in the alternative raw materials side of a synergy. However, according to SUEZ's feedback, there is not a large number of sites having this type of incineration activity that will allow for the sufficient sulphur recovery required for the production of Sodium Bisulphite.

The environmental impact of the use of this secondary raw material corresponds to the reduction of a pollutant (sulphur) in the WW stream of the SUEZ incinerators and it avoids the need to treat the sulphur content. Additionally, it will decrease the impact of the sector that absorbs the recycled resource instead of a new one. Also, the use of Bisulphite de Sodium on certain sectors represents an additional environmental gain as it can replace the use of other raw materials that have a potentially bigger impact on the health of those who operate with such as, sodium metabisulphite [5] [7].

The probability to find required partners for the implementation in a viable radius is high with 77 potential receivers. An estimated price the sale of the resource could be profitable for SUEZ, but it needs to be confirmed with a deeper market analysis. After a first assessment, it can be concluded that there is a good probability that a path, a business model and required partners for its implementation could be found. The process will a priory not require further treatment after SUEZ's operations as it will have a finished product ready to be conditioned and transported. Two criteria need to be clarified to make the SUEZ's sodium bisulphite compliant with the by-product regulation. A more in-depth study that will conclude in synergy implementation is advised but it seems very promising at this stage. A list of further activities to be performed and aspects to be clarified is provided below:

- **The exact composition of SUEZ's Sodium Bisulphite (and $NaHSO_3$ final content)**
- **Type of transport that is the most adapted to SUEZ's product.**
- **The selling price point with a propter market study**
- **The possibility of adapting the production to make it as best suited as possible for the paper and pulp market that exists in its vicinity. At least 5 paper, carton, and pulp production in the first 250 km.**
- **The rate at which the Sodium Bisulphite will be produced and if this rate could be affected seasonally or not.**

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From a regulatory point of view, Suez's sodium bisulphite productions seem to fit the by-product criteria. This is to be confirmed in a future in-depth analysis of the synergy.

The exact synergy for Sodium Bisulphite production from hazardous waste incineration process is not likely to be widely replicated due to the specificity of the technology that SUEZ is currently developing and the uniqueness of the SUEZ incineration activities.

Economic benefit from the sales revenue as well as the potential of cost savings in pollution related taxes.

It is recommended to go further in this synergy exploration. The global synergy assessment is provided in the next table:

Table 24 Recapitulative table of Synergies related to SUEZ's Sodium bisulphite

Indicator	Qualitative assessment	Quantitative assessment
Technical ease to replicate	A few sites for replication and the requirement a full process deployment. No additional treatment needed.	2 more sites in SUEZ where the same technology could be applied.
Number of potential partners/receivers	Enough sites to launch a field survey.	**45 sites** within a viability radius of 356 km.
Environmental benefits	Eliminates the need to treat SUEZ's WW for Sulphur content Use of a secondary raw material	To quantify with a Life Cycle Analysis.
Value added	Revenue from the sale of Sodium Bisulphite. Potential savings in pollution taxes. Offering clients valorisation for their waste instead of elimination.	Potential conservative revenue: 3000 t/year * 62 €/year = 186 000€/year
Regulation	2 criteria to be confirmed	Does not Apply
General Assessment	Promising Synergy, it is advised to continue the evaluation and implementation of it.	

5.1.2. Flow 2: Aluminium Sludge

Objective of the synergy

This synergy concerns the CS3 in Rosignano, Italy. Part of CS3 project development is dedicated to the reuse of aluminum sludge. CS3 project will include both the analysis of the possibility of its use in ARETUSA WWRP and the identification of potential receivers that would valorize this waste after a pre-treatment. Particularly based on the work of the Alu circle initiative.

Aluminium Sludge is a chemical sludge that is an output material produced by aluminium-based coagulants in drinking water plants and WWTP during the coagulation-flocculation step. Most common used coagulants are aluminium sulphate and ferric chloride.

Dried aluminium sludge from water treatment process has a high content of aluminium and consists of a mixture of organic and suspended matter, inorganic matter, various microbial consortia, coagulant products, and other chemical

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substances. Composition will vary depending on the type of water (freshwater or WW) being treated, the coagulant used as well as any other materials used for the WWT.

This sludge is currently considered a waste and disposed of, mainly in landfills. Or in some locations, it is spread in agricultural applications. Depending on the composition, different treatments can be applied before disposal or reuse. This generates disposal and/or waste treatment costs that are continuously increasing due to legislation and land pressure. [8] The disposal of this material can carry environmental risks due to the high aluminium content and its bioavailability and the presence of other chemicals [9]. These reasons drive research work to target alternatives for the recovery and reuse of this waste material. Since the production of pure water and the treatment of wastewater cannot be restricted, it is difficult to reduce this type of waste, it is then crucial to find valuable applications to use this chemical sludge as a secondary raw material.

5.1.2.1. Sector or sectors identification

After consulting the available literature on this topic and the Alu Circle initiative public information, a list of possible applications for CS3's aluminium sludge was defined:

- **Material for construction: bricks, tiles**
- **Adsorbent of pesticides such as glyphosate**
- **Sewerage**
- **Gas Purification**
- **Decontamination of soils and groundwater**
- **Land based applications**
- **Use in wastewater treatment.**

Most applications of this list are not yet commercialized and in different development and experimental stages.

The main route proposed by the Alu Circle initiative is to use the aluminium sludges as a substitute for clay in the manufacture of tiles and bricks in the construction sector The clay used as raw material is a non-renewable resource. The use of aluminium sludge as a total or partial substitute of it is relevant from an environmental point of view, and an economic point of view as aluminium sludge is currently considered a waste. The experimental production and tests of made partially from aluminium sludge have proven to have acceptable physical properties, and in some cases superior (better insulation and less weight). Different studies continue to explore the optimal proportion of aluminium sludge content in clay bricks. For this reuse, the sludges are treated, blended with binders, compressed and or backed. This technology development is not yet in a commercial phase. [8]

Another route is the use as bad odour management and sulphur abatement from emissions of WWTP. This application is relevant due to its H_2S adsorbing property. This application is at an experimental state but has the advantage that **untreated** aluminium sludge could be used. Adsorption of H_2S can also be applied to gas purification in the desulfurization process although there is very little information

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on this. A concentrated sludge, much cheaper than the components used for this process, could be used for this treatment. [10]

The uses in wastewater treatment are as a sorbent, as coagulant or for conditioning/dewatering of sludge. Due to its aluminium hydroxides high content, studies have shown that it can be reused as coagulant (most effective isolated). As the author's best knowledge, this type of technology and use, although very studied, remains experimental and has not being applied in at large industrial scale. In the same experiments a significant reduction of the Chemical Oxygen Demand and turbidity was also observed. Some of these tests were performed in sewage water and for other industrial wastewater. In summary a mixture of fresh aluminium coagulant and aluminium sludge can be used effectively in wastewater treatment to reduce the need of primary coagulants [8]. For WWT, the aluminium salts content of the sludge needs to be recovered. Recovery treatments proposed in studies that have tested aluminium sludge properties for WWT include: an acidic and alkaline extraction method (a leaching process), ion exchanging (using liquid resins and membranes) and pressure driven membranes (ultrafiltration and electrodialysis) [8].

The sludge's capacity for adsorption can be also applied to pollutants and metals removal in water treatment. Aluminium and Iron Sludge has shown effectiveness in the removal of phosphorus, boron, fluorides, glyphosate, mercury, lead and selenium. As an example, an experiment on Glyphosate (active component used in pesticides) showed that more than 99% of the glyphosate can be removed by using this Aluminium sludge. Localising the WWTP that specifically treat effluents from agriculture or other specific activity is complex, as WWTP databases often do not have such classification. Pollutant and metals removal can potentially be applied for underground water depolluting activities. [8] Ferric-rich drinking water sludge (DWS) on its reactivity and capacity for sulfide removal in sewers and phosphate removal in downstream wastewater treatment plants, Aluminium and Iron Sludge can be used in geotechnical, geoenvironmental and building sectors or as absorbents/coagulants

Land based applications include soil improvement and stabilisation, nutrients supply, toxicity mitigation. This solution represents a cost-effective disposal of the sludge but do not offer a valuable material reuse/recycling. So, these applications will not be considered for this study. [9]

The scaling up of these applications is being researched. The most studied ones with positive results are the ones related to WWT.

The potential applications to be studied in the next step are listed Table 25 with corresponding NACE codes.

Table 25 Potential receiving sectors of Aluminium Sludge and it's respective NACE codes.

NACE Code	Sector	Description
06.20	Extraction of natural gas	Gas purification (desulphurisation).
37.00	Sewerage	Treatment of wastewater to prevent pollution.

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39.00	Remediation activities and other waste management services	Decontamination of soils and groundwater, particularly in the absorption of pesticides from water contaminated by agricultural activities.
36.00	Water collection, treatment, and supply	
23.32	Manufacture of tiles, bricks, and construction products in backed clay.	Manufacture of tiles and bricks.

5.1.2.2. Regulatory Aspects

Legislation on the reuse of water treatment residues consider them as non-hazardous waste.

Aluminum Sludge is currently considered a non-hazardous waste, according to the Waste Framework directive (article 3): “any substance or object which the holder discards or intends or is required to discard”. It must be determined on a case-by-case basis whether or not it requires an end of waste procedure or if it can remain considered as a waste. If the receiving site has a permission to use waste in its facilities, then the end of waste of the sludge is not needed. If the receiver site does not have said permission, then the emitting company has to get an end of waste status.

If the emitting company needs an end of waste status, it is necessary to follow the procedure determined at the national level, Italy in this case, which fits with European regulations. The end-of-waste criteria is used to determine when a waste, that ceases to be one, becomes a product.

In Italy, local or regional authorities take the decisions for the end of waste acceptance, or alternatively, the responsibility is with the industry to self-declare the end of waste status, with random ex-post inspections carried out by the enforcement authorities. Aluminium Sludge must respect the criteria of the Waste Framework directive.

It its very likely that sludge coming from potabilization of water can fit into the end of waste status for most European countries. Nonetheless, the sludge coming from a WWTP is to be evaluated depending on the composition due to its content. This type of sludge could have associated sanitary risks.

5.1.2.3. Mapping of nearby partners and Distance distribution

To assess the viability of IS between CS3 WWTP and WTP and sectors of applicability identified in Table 25, a map representing the corresponding sites in the vicinity is shown in Figure 17. As it can be observed both in the map and in Table 26 a reduced number of potential receivers were found in a limited radius. The closest ones correspond to WWTP and manufacture of clay construction material. Based on the literature review, the application in WWTP is most technically advanced in terms of research and technology development.

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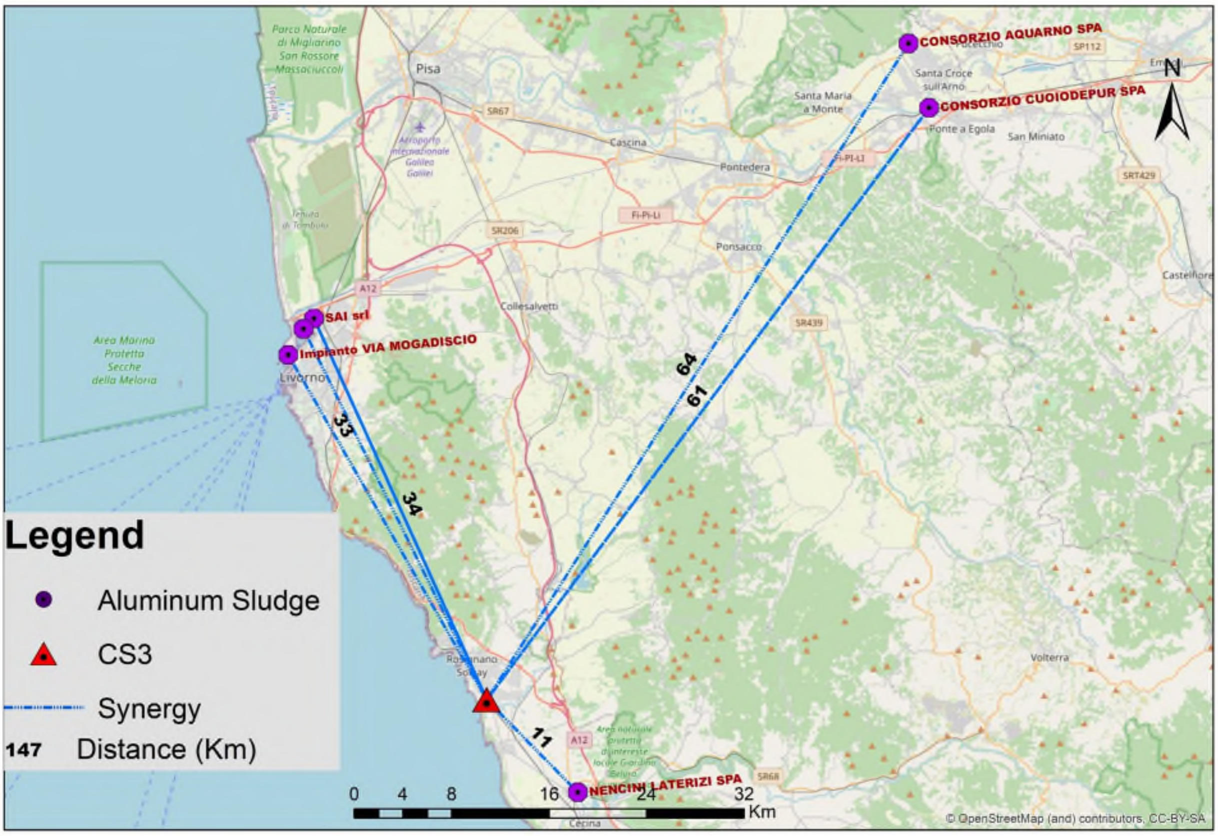

Figure 17 Map of potential receiving sites of CS3 Aluminium Sludge within a 70 km radius. (Source: Strane)

The estimation of the viability radius is complicated in this case as this resource could be applied as a substitute for different materials. In this case, two different raw materials to be substituted where chosen in order to calculate two different viability radiuses. Both Aluminium coagulants and clay for construction material was chosen. These will be considered as two separate synergies.

As it is currently explored by the Alu Circle initiative and the Ultimate CS3, the price of the clay for brick production was considered. On the other hand, the price of aluminium-based coagulant was also considering as many installations are nearby CS3 location. It is also another well studied IS opportunity and the value is widely superior.

Table 26 Table of Aluminium Sludge as clay substitute potential synergies

Distance (km)	Potential Synergies
40	1
50	1
80	3
90	4
100	4

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Table 26 shows the number of potential synergies between the WTP of CS3 and a clay brick or roof tiles producers based on a reduced price of raw clay to consider the use as secondary raw material. We used these bases to calculate an estimated price:

- **A raw material price of 13€/t for construction clay.**
- **It is a secondary raw material (25% depreciation)**

Considering these parameters, the final price retained to determine the radius was **10 €/t**. This material does not have a high price in the market and so a limited viability radius of **56 km**.

Since the intrinsic value of the sludge as well as the economic value of the substituted material are not high, economic benefits of the synergies will be mostly related to cost reduction of the sludge treatment and disposal, that according to the Alu Circle Initiative surrounds 100 €/t. This considered, the evaluation of the potential of the synergy would change.

Table 27 indicates the number of potential synergies between the WTP of CS3 and WWTP that could receive a treated Aluminium Sludge to partially substitute primary coagulant use. The price of coagulants is significantly higher than that of the clay, amounting to a price of around 200-280 USD/t

Table 27 Table of Aluminium Sludge as coagulant substitute potential synergies

Distance (km)	Potential synergies
100	10
200	14
300	47
400	106
500	137
600	152
700	194
750	213

We used these bases to calculate an estimated price:

- **A raw material price of 206/t for aluminium coagulant.**
- **It is a secondary raw material (30% depreciation)**
- **A security margin to have a conservative approach (10% depreciation)**

Considering these parameters, the final price retained to determine the radius was **123 €/t**. This accounts for a viability radius of **700 km**. According to the literature, the use of aluminium sludge as coagulant could require additional treatment steps than for the use as a clay complement. This will also affect the pricing and the economics of the synergy.

Taking into account avoided waste management costs could turn the synergy more viable and increase the transportation radius.

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For the synergy research of clay substitutes, Figure 18**Error! Reference source not found.** shows the opportunities available within the viability radius (between 5 and 56 km). It is evident that this is insignificant. A significant number of opportunities start around 160 km with 20 synergies. A synergy evaluation accounting for the savings of waste management could make this possible. The transport could be done by truck for those distances.

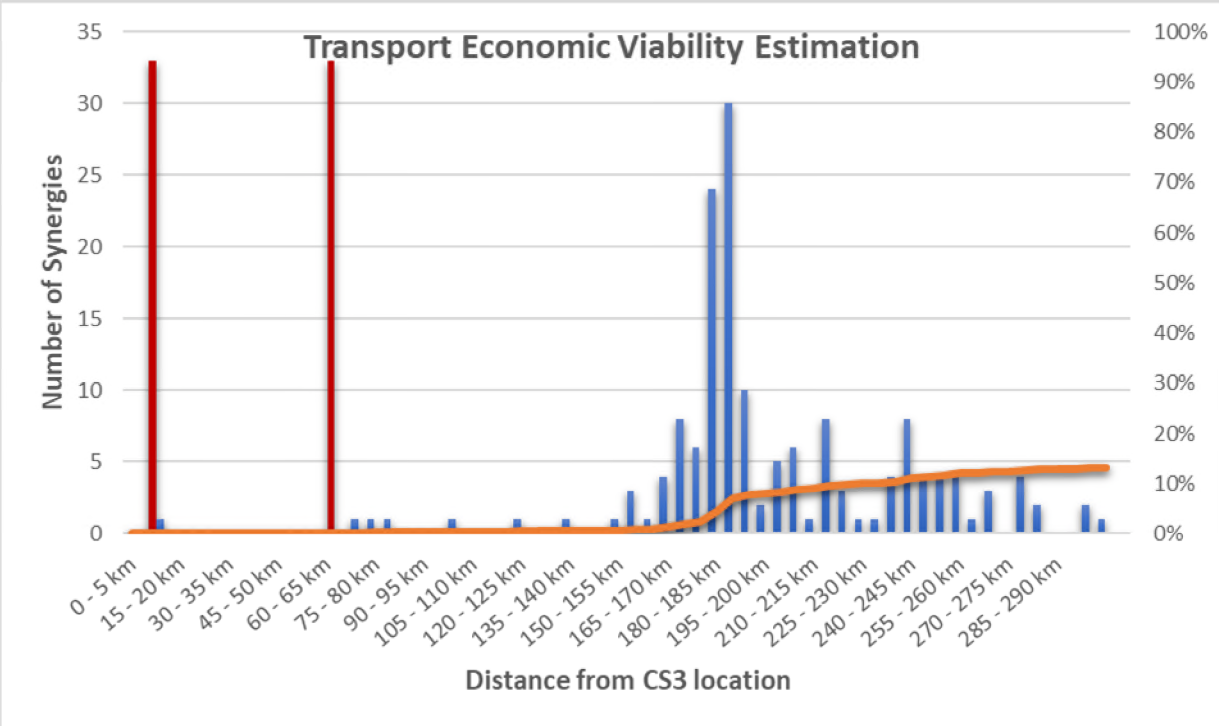

Figure 18 Transport viability estimation for Aluminium Sludge as clay substitute potential IS.

According to the viability calculation, the radius to be explored for synergies with WWTP is presented in Figure 19 between 100 km and 700 km. This involves 184 sites between the red lines. This number is indicative of a high probability of achieving an IS partnership. Though, this number is unusually high for this type of installation so it should be taken with a conservative approach as it could be an overestimation to be verified by a terrain survey. In the first 400 km there are 96 opportunities. This could help to privilege a short circuit with the materials being transported by truck.

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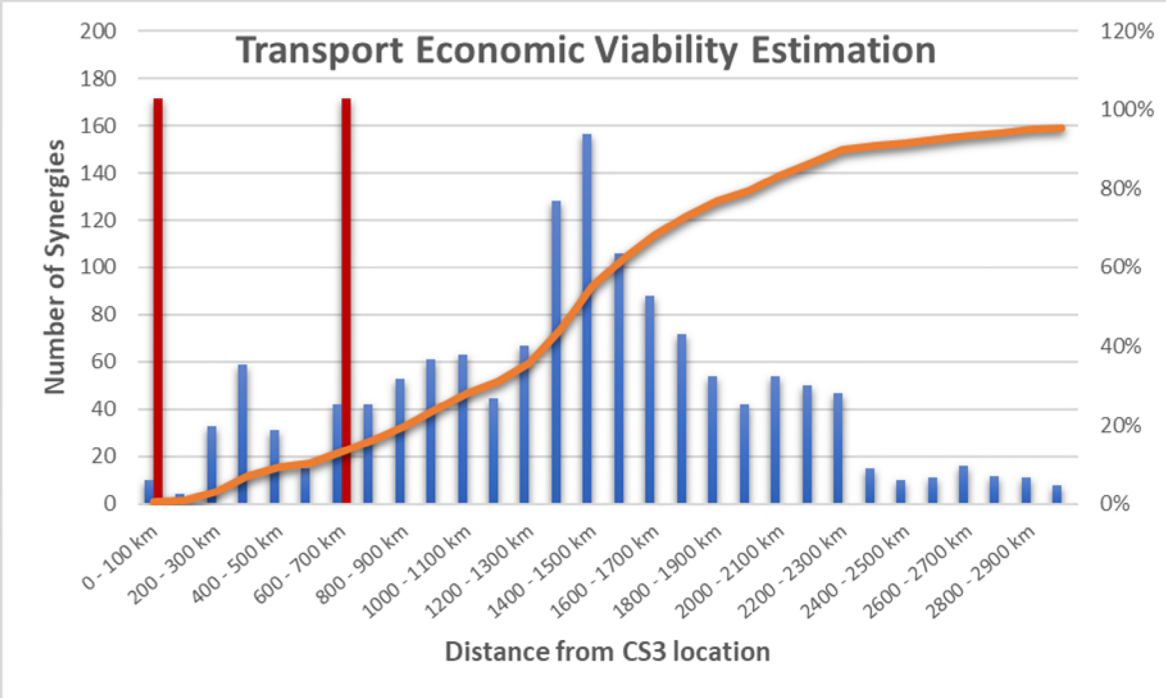

Figure 19 Transport viability estimation for Aluminium Sludge as coagulant substitute potential IS.

Due to the difference in price points of the raw matter and the difference in abundance of sites in both synergy types, Alu Sludge for use as coagulant or coagulant aid seems more promising than sludge for clay substitute. This can be clearly observed in the synergy opportunity distributions of Figure 18 and Figure 19.

5.1.2.4. Conclusions

The most relevant points to further explore for these IS opportunities are:

- **The infrastructure dedicated to the required pre-treatment that it would need to prepare the material for reuse. If a third party to do it is not found. This could be a major investment.**
- **Regulatory aspects to change the current waste status (end of waste criteria). This would depend on the composition of the sludge and the needs and existing regulatory status of the receiving partner (if the receiving partner has authorizations to process waste, end of waste criteria could be unnecessary).**
- **normally and the authorisation needed. This could be a significant investment.**
- **The maturity of the technology and the viability of a scaling up project in the near future.**

For an IS involving this resource there is not a direct opportunity to be immediately exploited. All the applications would require treatment, investment, or administrative procedures.

However, the continuous and unavoidable production of this waste material and its promising potential for reuse encourage the work on this synergy implementation.

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Relevant parameters suggest that finding a solution for this effluent could bring environmental, social, and economic benefits. Next activities to be done are:

- **Obtaining clear information on the actual price of the waste management of the sludge in the WWTP of CS3.**
- **A local field survey or a market study to set an appropriate price point for the resource.**
- **A characterisation of the sludge both in composition as in and production rate, and a comparison with potential receivers needs. Observations of changes in both parameters with seasonality.**
- **Recovery process requirements and cost. Evaluation of the capabilities of CS3 WTP technical and space capabilities to do a pre-treatment to the resource.**
- **Research on partners that could provide additional treatment if needed.**

Survey on the type of coagulant used by the WWTP and requirements for acceptability from brick producers. Including conditioning and transportation options.

The replication potential will depend on the possibility of finding pairs as the sludge composition is variable. This will vary according to the quality of the water treated, processes and complementary chemicals used. This composition needs to be evaluated before considering an application. Furthermore, the success of any synergy involving Alu Sludge will also depend on the willingness of the end user to forego all administrative and technical steps required. Including have their products tested and approved by industry standards and adapting production for the use of a new raw material.

From both an economic and environmental point of view, this synergy could represent important savings if widely applied. Both in the waste savings perspective and in the avoidance of use of virgin raw materials. For both potential uses. Economic benefits are likely to be greater if the chosen use is in WWTP.

From a reglementary point of view, there is a certain need for administrative procedures for both potential uses, but according to the literature, the reuse is possible if those procedures are followed. This will apply particularly to the use of sludge as construction material as indicated earlier.

Implementation potential for a synergy involving the reuse of sludge in WWTP would be far more promising than a synergy involving construction material. Therefore, it is advisable to look in priority at partnerships concerning WWTP.

It is recommended to go further in this synergy exploration. The global synergy assessment is provided in the next table:

Indicator	Qualitative assessment	Quantitative assessment
Technical ease to replicate	The ease of replication of this reuse of material depends on the sludge composition. For the sludge coming from the potabilization plant, the implementation of a synergy should be easier in the technical and	Could be replicated for almost all WTP that produce the sludge. Could be estimated in a survey.

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	reglementary aspects than for the sludge coming from the WWTP. Additional treatment could be needed depending on reuse and sludge composition.	
Number of potential partners/receivers	Enough sites to launch a field survey.	-**184 sites** within a viability radius of 700 km for reuse in WWTP. -**1 site** within a viability radius of 56 km for reuse in construction brick and tiles production.
Environmental benefits	Eliminates the need to dispose most of the sludge volume. Reduce the use of primary raw material for WWTP coagulation and sludge dewatering or for manufacturing of construction material.	To quantify with a Life Cycle Analysis.
Value added	Savings in waste management of sludge and p875otential savings in pollution taxes. Revenue from the sale of sludge. Closing the loop of water treatment.	Current disposal cost amounts close to 100 €/t of sludge. For a WTP. For a WTP processing around 35 000 m^3/day savings could amount to 87 500 €/year. For the same type of plant and an average production of sludge of 875 t/year, a revenue of 8 750 €/year (for construction use) or 107 625 €/year (for WWT use)
Regulation	It its very likely that sludge coming from potabilization of water can fit into the end of waste status for most European countries. Nonetheless, the sludge coming from a WWTP could have associated sanitary risks	Does not Apply
General Assessment	Promising Synergy, it is advised to continue the evaluation and implementation of it.	

5.1.3. Flow 3: Ammonia

At the time of realisation of this study, the research of CS7 was not advanced enough to know what type of ammonia could be recovered from the effluents. Thus, resulting in a lack of enough data to address this flow. Therefore, this flow will not be analysed in task 5.1 but could be updated later on the project. However, as the result will be a finished product ready to be sold and that has a certain market in agriculture and the CS site is located in an agricultural area, it will be considered a promising synergy.

5.1.4. Flow 4: Water for irrigation

Water for reuse is the most important resource to be exploited from the ULTIMATE project wastewater sources. Indeed, almost all case studies have objectives of treating water for reuse, but most of them will have internal industrial

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uses. CS 3 and CS 4 have within its objectives to produce a water that fits the criteria for irrigation purposes. In this way, all or a part of the treated water could be used in nearby agricultural fields. Water for irrigation is a resource of great importance due to the hydric pressure a lot of regions in the world and Europe. The reuse of water for this purpose is within the objectives of the European Commission Circular Economy Plan.

In CS3 of Rosignano, the reuse of water for irrigation is one of the options for using treated water whenever the WWTP cannot be used for industrial reuse. The system being developed will measure when the water available is compatible with agriculture use and redirect it for that use. The volumes of water that would be available and the frequency will be estimated during ULTIMATE's project research, so this information is not available now.

In CS4 in Nafplio, the priority for technology owners of the mobile treatment unit is to be able to produce water that can be used to irrigate local fields that belong to small local farmers.

The purpose of this section is to make a brief review of some regulatory aspects and to find potential receivers within an acceptable distance from the CS generating the water for reuse. As well as presenting the methodology to find those receivers, which is relevant for the replication of this type of reuse.

5.1.4.1. Technical screening of application

For water dedicated to irrigation, the synergy research methodology is different. It uses the database **CORINE Land Cover** (CLC) geographic database that represent a biophysical inventory of land use in 2012. The following methodology has been applied:

1. **Irrigated areas were extracted from the database in the raster format. Table 28 presents all type of irrigated areas extracted.**

Table 28 Type of irrigated areas and their codes from CORINE Land Cover Database

Code	Description
211	Non-irrigated arable land
212	Permanently irrigated land
243	Lands mainly occupied by agriculture, with significant areas of natural vegetation
321	Natural grasslands

2. **It consists in converting the raster (images) into shapefiles (polygons) and create point for each field by select the points that fall in the center of a polygon by using the Select By Location tool (ArcGIS). With this operation, 943 541 points represent irrigated areas at EU scale.**

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3. **A Map was created by adding all large capacity wastewater Treatment plants and water treatment industrial sites. It represents 11 943 points WWTP locations.**

4. **To consider the economic feasibility, to choose a 5km Buffer zone around each WWTP and water treatment industrial site. We used the geodesic buffer zones that consider the real Earth' shape. Distances are calculated between two points considering a curved surface (geoidal shape) with a WGS84 map projection for the input features (irrigated areas and the WWTP).**

The above step provides promising results. It leads to identify **48 773 fields/irrigated areas** located in a 5 km radius around to a WWTP or water treatment industrial site.

5. **An Arcgis tool was used to calculate the distance between each urban WWTP or similar industrial sites as CS4 and the irrigated areas within the 5km. The tool generated a table of distances between the two sets of points.**

6. **Specific search was focused on ULTIMATE CS locations involving water for irrigation to identify potential receivers and estimate feasibility.**

CS3 Rosignano

For CS3 location, four locations were found within a 10 m radius and only one to 6 m as shown in Figure 20. This CS is located in an industrial area. Since there is currently no infrastructure to transport the water other logistics besides the radius distance need to be addressed in an in-detail study.

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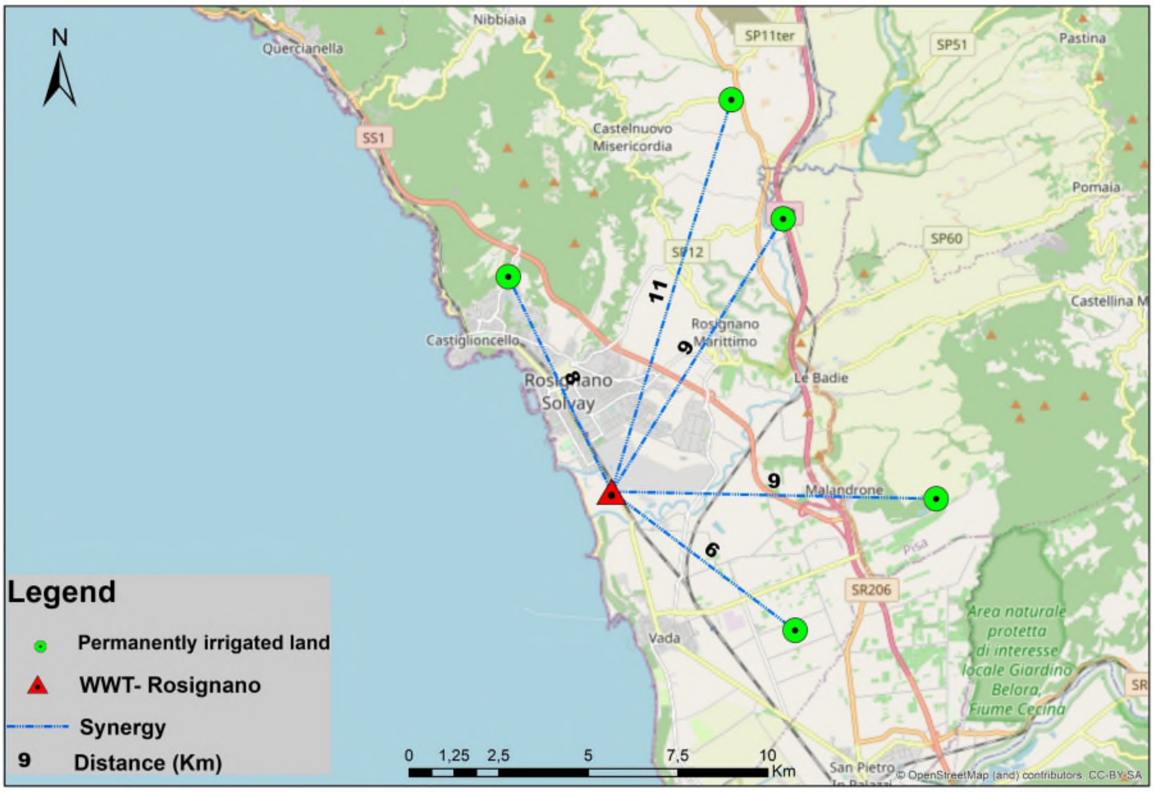

Figure 20 Permanently Irrigated land in the vicinity of CS3 location

CS4 Nafplio

In Figure 21, the 11 first irrigated land that could use the water coming from CS4 as Alberta's factory is located in an agricultural region, which facilitates logistics. Three of those are within 5m or less, which are good options for irrigation strategies. For this synergy there is the possibility to explore if there is irrigation infrastructure that could be reused or complemented to give access to water coming from the mobile treatment unit placed in Alberta's factory.

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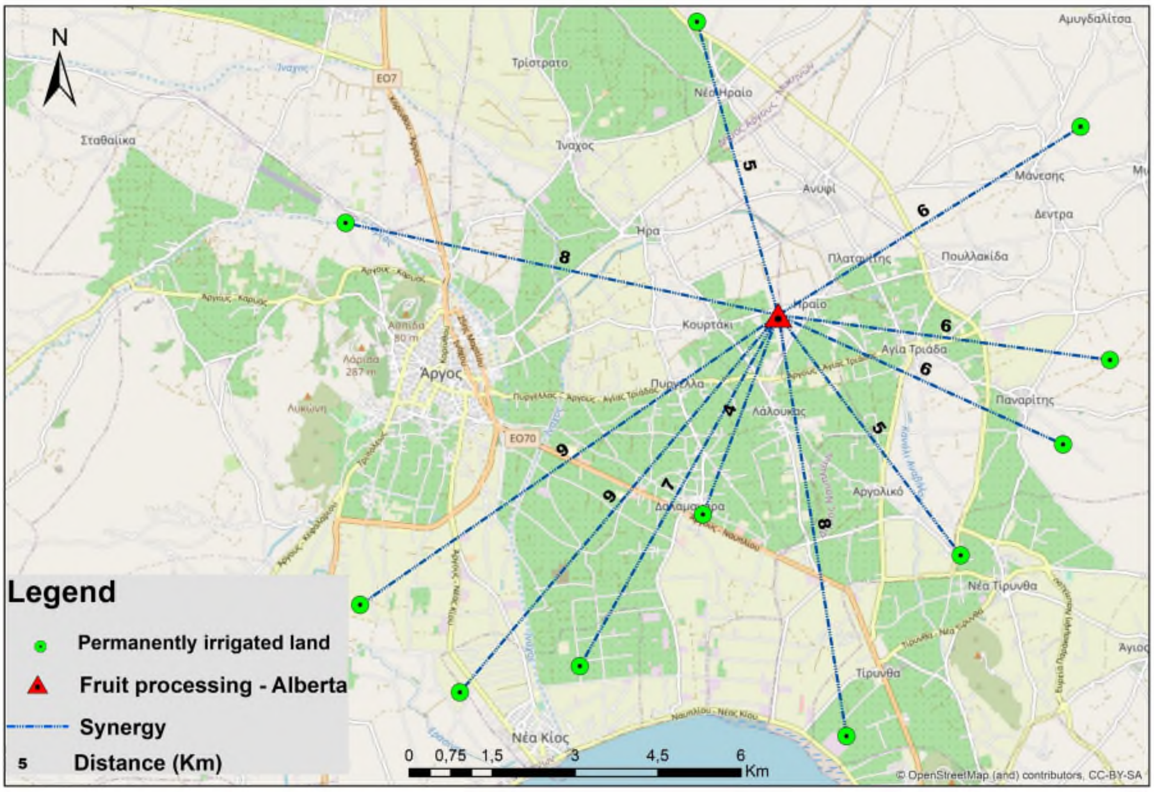

Figure 21 Permanently Irrigated land in the vicinity of CS4 location

5.1.4.2. Regulatory aspects

REUSE is controlled by the Regulation (EU) 2020/741 of the European parliament and of the council of 25 May 2020 on minimum requirements for water reuse. It sets out:

- Harmonised minimum water quality requirements for the safe reuse of treated urban wastewaters in agricultural irrigation.
- Harmonised minimum monitoring requirements, notably the frequency of monitoring for each quality parameter, and validation monitoring requirements.
- Risk management provisions to assess and address potential additional health risks and possible environmental risks.
- Permitting requirements.
- Provisions on transparency, whereby key information about any water reuse project is made available to the public.

The expected treatment and water quality depend on the use (Table 29). There are different uses, but only agricultural irrigation is regulated at European level. 4 water classes have been determined according to irrigation: A is the strictest quality for

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human safety and D the worst one, not adapted for uses related to human consumption due to pathogens presence (Table 30).

Table 29 Proposed reclaimed water quality classes. (Source: European Parliamentary Research Service)

Water quality class	Crop category	Irrigation method	Indicative treatment process*
A	Root crops consumed raw; food crops, where the edible part is in direct contact with reclaimed water; other food crops	All methods	Secondary, tertiary and advanced treatment
B	Food crops consumed raw, where the edible part is produced above ground and is not in direct contact with reclaimed water; processed food crops; non-food crops, including crops to feed milk- or meat-producing animals	All methods	Secondary and tertiary treatment
C		Drip irrigation only	
D	Industrial, energy, and seeded crops	All methods	

Table 30 Proposed reclaimed water quality requirements. (Source: European Parliamentary Research Service)

Water quality class	Quality requirements				
	E. coli, cfu/100 ml	Biological oxygen demand (BOD_5), mg/l	Total suspended solids (TSS), mg/l	Turbidity (NTU)	Other
A	≤10*	≤10	≤10	≤5	*Legionella spp.*: <1,000 cfu/l where there is risk of aerosolisation in greenhouses Intestinal nematodes (Helminth eggs): ≤1 egg/l for irrigation of pastures or forage
B	≤100	25 mg/l O_2**	35 mg/l**	-	
C	≤1 000			-	
D	≤10 000			-	

Different European countries had developed their own regulations on REUSE, and it became urgent to unify and harmonize these regulations in the framework of the European common market. The government grants permits based on legally binding standards and which cover treated wastewater from municipal WWTPs. Agricultural irrigation is now regulated by the 2020 Regulation, but other aspects/uses are regulated at national level.

As an example, the French regulation considers four different categories of water quality (A, B, C and D), which include the same microbiological and physical-chemical parameters with varying levels of tolerance and limits. In this approach, the intended uses are associated with one or more quality categories. Decrees should be published in the next few months to regulate the possibilities of experimenting with industrial REUSE.

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There are regulations in each European country but very few regulate REUSE from industrial wastewater and industrial water. In Greece and Italy, regulations exist.

Industrial wastewater is “any wastewater which is discharged from premises used for carrying on any trade or industry, other than domestic wastewater and run-off rainwater” (according to Directive 91/271/EEC).

The Regulation of 2020 sets out that “Without prejudice to other relevant Union law in the fields of the environment and of health, Member States may use reclaimed water for further uses such as: — industrial water reuse; and — amenity-related and environmental purposes”.

The Italian regulation applies the same water quality limits for all uses of reclaimed water aside from industrial uses. Limit values for industrial reuse are set by the parties concerned depending on the requirement of the industrial process. This approach does not consider the different risks associated with each particular use, and it is not consistent with the later approach recommended by the WHO (2006). [11]

The Council Directive 91/271/EEC of 21 May 1991 concerning urban waste-water treatment defines three levels of treatment:

- "Primary treatment" means treatment of urban wastewater by a physical and/or chemical process involving settlement of suspended solids, or other processes in which:
    - the BOD5 of the incoming wastewater is reduced by at least 20 % before discharge
    - the total suspended solids of the incoming wastewater are reduced by at least 50%
- "Secondary treatment" means treatment of urban wastewater by a process generally involving biological treatment with a secondary settlement or other process in which the requirements established in **Table 30**;
- "Appropriate treatment" (or tertiary treatment) means treatment of urban wastewater by any process and/or disposal system which after discharge allows the receiving waters to meet the relevant quality objectives and the relevant provisions of this and other Community Directives.

5.1.4.3. Conclusions and replication potential

There are 94 irrigated area covered under less than 200 m from WWTP or a water treatment industrial site at a European level:

a. **19 fields inside range of 100 m**
b. **94 fields have been detected under range of 200 m**

Briefly, the study of the synergy’s identification has been taken various factor into account to make it more sustainable and economically feasible.

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Moreover, the irrigated area identified (the receiver sector) can benefit from the treated water from the water treatment industrial sites (the emitter sector) that are located in a distance less than 200 m. The benefits are in terms of economical savings and ease of availability resources. This will indirectly reduce the consumption of the fresh ground water use in irrigation and other sector.

Specifically, for both sites CS3 and CS4, there were several agricultural areas found close by. From the two, the one that shows more promise is CS4 due to its strategic location. By being in an agricultural zone, such synergy becomes more convenient and probable also considering that Alberta has relationship with some of the local farmers. CS3 has some agricultural sites that could be good options, specially the first 3. and the last site in Figure 20 If the volumes available are significant enough, the investment needed for infrastructure will be cost effective. This initiative for both CS3 and CS4 is supported by the regulation if the treatment can attain the quality standards mentioned in Table 30. This makes it a promising synergy and further study is advised.

5.1.5. Flow 5: Lime

Objective of the flow valorisation

Lime is a resource used in the SUEZ’s incineration site in CS8 as a raw material in the flue gas scrubbing treatment performed. The flue gas treatment has as result a wastewater that is then treated in site to remove the pollutants that were recovered during said process. Lime plays a significant role in the industry for the removal of pollutants in this type of treatments. The project of finding an alternative supply for this material has a double purpose: finding a material that could substitute completely or partially the Lime input for the current flue gas treatment that could also be compatible with the future production of Sodium Bisulphite.

Limestone, also known as calcium carbonate (CaCO3), occurs naturally in various forms, such as marble or chalk.

According to the European Lime association, lime conventional production is generally made in two different processes. The first one is the calcination of limestone, which creates quicklime. This process is energy consuming because of the high temperature used and produces carbon dioxide. The second process produces hydrated or slaked lime by the hydration of quicklime. Moreover, lime production uses limited resources. Indeed, limestone is extracted from quarries or mines which creates pressure on the availability of the material. These production processes are energy-intensive and use non-renewable resources (although abundant), they cannot be deemed sustainable.

In addition, lime is widely used in the industry in many sectors: construction of houses and roads, glass, metallurgy, chemical industry, and plastic production. Therefore, implementing a synergy with an alternative resource seems coherent and consistent with a sustainability approach. [12]

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5.1.5.1. Sector's identification and technical screening

After consulting the matchmaking tool and SCALER's report D3.5 "Quantified potential of industrial symbiosis in Europe", a potential alternative or complement to the lime supply needed by SUEZ could come from the **Kraft pulping process used in the pulp and paper manufacture**.

In the paper industry, the kraft pulping process generates a lime mud waste (waste code: 03 03 09) from its chemical processes. This process generates organic solid wastes, sludge, which is composed of dregs, green liquor sludge and lime mud from the chemical recovery. This lime mud has the potential to be recovered and reintroduced in the industrial market. [13]

These components are often mixed, which means that a separation step would be needed to recover the lime. The composition of the mixture varies, as does the amount of sludge produced. Between 10 and 60 kg of sludge is produced per ton of pulp with an average of about 30 kg/t of pulp. [13]

To find the sites that are susceptible of producing that type of waste, the NACE code of those activities were identified. They can be found on Table 31 below.

Table 31 NACE code of lime potential alternative resources

NACE Code	Sector	Description
17.11	Manufacture of pulp	Kraft pulping process
17.12	Manufacture of paper and paperboard	Kraft pulping process

The reuse of this type of waste material was studied in the SCALER with IS applications in different sectors such as the steel scrap melting industry, agriculture, cement production and sewage sludge stabilization but not for the type of usage that CS8 would give it. However, there would be the need to explore with SUEZ if the resource could be compatible with their needs or if there is a treatment that could make the resource usable to replace the current lime supply or to complement a part of it to reduce SUEZ demand of a primary raw material.

As it was discussed before, the sludge composition is variable, so the implementation of this synergy is limited by the composition of the lime sludge and the treatment of the lime sludge that would make the resource compliant with sodium bisulphite production. Nevertheless, lime sludges could potentially be used directly in dry flue-gas treatment units due to its $CaCO_3$ composition. Wet scrubbers would likely need an additional treatment, a calcination process. [1]

If it is possible to the emitter site to treat the sludge or if another partner that could treat the effluent exist within an acceptable perimeter and at an acceptable cost. This could complexify the implementation of the IS.

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There is some literature available on the use of lime sludge a lime substitute but there are no reports of it being implemented in an industrial scale.

5.1.5.2. Regulatory aspects

From the supplier side (the pulp producing partner), the regulatory and administrative process to change the waste status of the sludge is a topic that needs to be reviewed during the study of the synergy.

Since SUEZ site handles waste as a main operation, it could be conceivable that the addition of another waste that will be used in their activities will not be a critical aspect.

Suez has an authorisation order for its activity. In this document, certain materials are authorised for flue gas cleaning. Lime is currently used as a raw material in this process but in the interests of a circular economy, it is possible to use lime from other industrial sectors.

To reuse lime from the pulp and paper industries, it must be determined whether or not SUEZ is allowed to use waste. If SUEZ has this authorisation, then SUEZ can recover and use lime from the paper industry.

If SUEZ is not allowed to use waste, then the paper industry will have to remove the lime from waste status or consider it as a by-product.

The EU end-of-waste criteria are based on article 6 of Directive 2008/98/EC of the European Parliament and of the Council on waste (see Section 2).

In order to characterize the by-product lime, the paper mill has to prove that the lime complies with the conditions determined at European level (see Section 2).

Each condition will have to be proven:

- For the first condition (use is certain), lime is used by SUEZ in the flue gas scrubbing treatment performed. The market exists and the use is certain. In the same way, a financial advantage will be drawn by the paper industry which will give more value to the lime.
- For the second one (used directly without any further processing), the paper industry treats the lime itself, the separate step mentioned in the Section 1.1.2.1 has to be done by the paper industry.
- For the third condition (integral part of a production process), the paper industry creates lime on the same site as its kraft paper.
- For the fourth condition, the lime has to be registered under REACH.

5.1.5.3. Mapping of nearby partners (for selected sectors) and Distance distribution

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Distribution of distance

To assess the viability of IS between SUEZ and one or several actors from the paper sector a map representing the corresponding sites in the vicinity is shown in Figure 22. These sites have a potential to establish an IS with SUEZ to provide them with a Lime sludge adapted to the scrubbing process and the Sodium Bisulphite production.

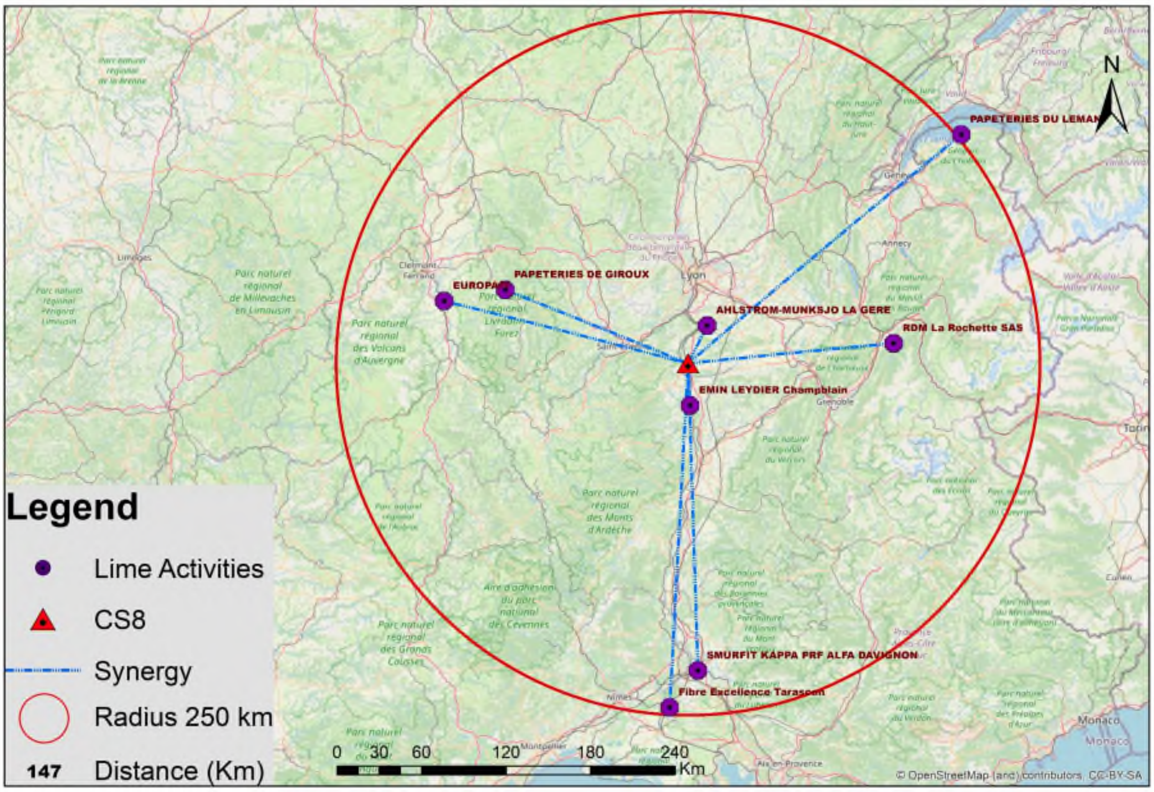

Figure 22 Map of potential sites generating a potential substitute for CS8 lime needs within a 250 km. (Source: Strane)

The radius shown in the map is 250 km to illustrate the location of the first sites whose lime sludge waste could be investigated. This considers a desired short circuit for waste valorisation. Given that the sludge constitutes a waste that is likely to require additional processing, the short circuit becomes more important as now it is very difficult to know if the emitter sites could be capable of performing the treatment themselves. This represents a group of 7 sites. These sites could be contacted in parallel to survey them on their capabilities concerning volumes produced and openness to change their current waste management activities.

It is assumed that lime sludge from production of pulp and paper industries is sent to landfill and the waste does not have any intrinsic value. However, the treatment needed and the regulatory and administrative would play in the pricing of the material. As the cost and the conditions, and even the need for said treatment, is unknown at

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this stage, the viability radius was calculated by considering a modified current price of the raw material with a depreciation to consider a second raw material as follows:

- **An approximate primary raw material price of 224.7 €/t (Source: Strane)**
- **A secondary raw material could have up to 30% of depreciation**
- **A conservative approach with a conservative approach of 10% depreciation**

Considering those parameters, the estimated figure is **134 €/t** and the radius that was determined is **770 km**.

Table 32 shows the cumulated of sites of interests as the research radius is increased. If there is the possibility of increasing the radius for the partners research which could increase the chances of an IS to be implemented. Even if for this study the viability radius already includes a good number of potential partners is important to remember that in this case, the valorisation is highly dependent on the capabilities of the emitting site. This could be explored in many ways and even in a case-by-case approach, that considers the characteristics of the sludge generated, and so the treatment needed, the capacities of the sites to perform or not that treatment, and the business arrangement that could be reached with the partner.

Table 32 Table of lime sludge as a lime substitute potential synergies (Source: Strane)

Distance (km)	Potential synergies
100	2
250	7
350	16
550	55
650	78
770	156
800	166

Figure 23 shows the distribution of opportunities on each radius tranches. The opportunities that are within the viability radius are represented between the vertical red lines. We can see that from 0 to 550 km, the number of opportunities remains fairly small compared to the cumulated of the viability radius. However, this number is tripled when we consider the tranche between 600 and 700 km radius. This is important because it gives us an idea that most opportunities will not be located is the short circuit which could complicate business models and transportation. Although transportation cost by truck could represent an obstacle for most of opportunities, it is still feasible, particularly if the right composition is found. That being said, there is still more than 50 opportunities within the first 550 km which is already a good number of opportunities.

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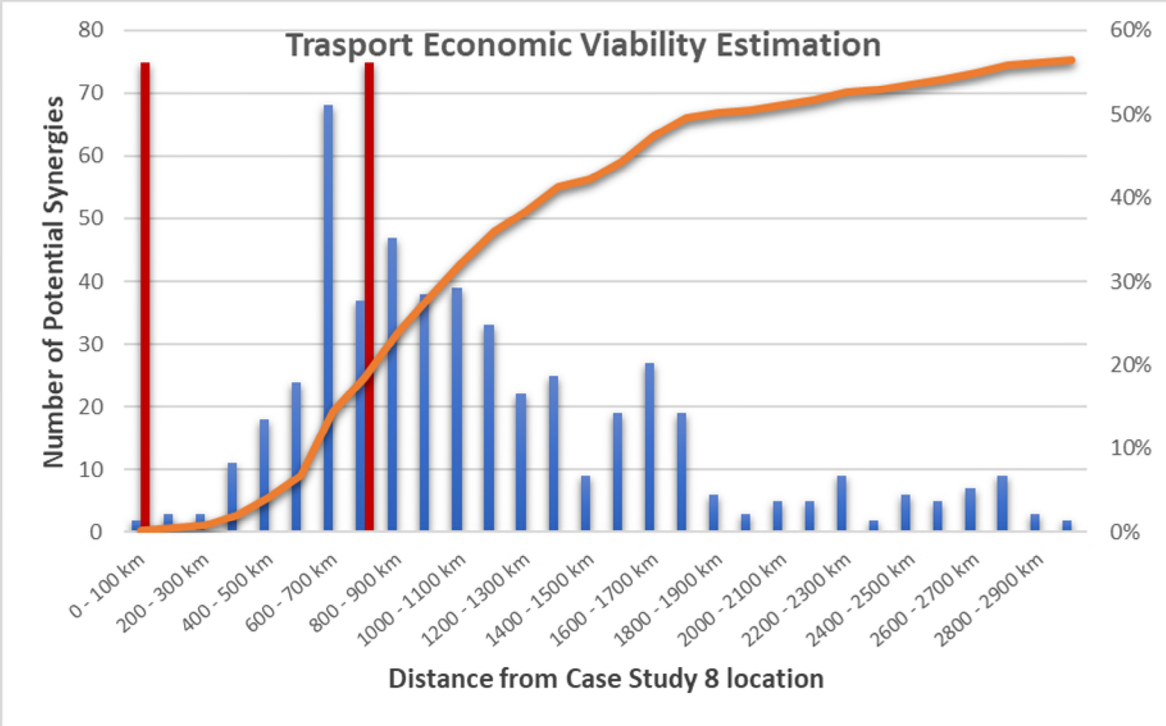

Figure 23 Transport viability estimation for Lime sludge as lime substitute potential IS. (Source: Strane)

As the economic viability of the transportation of the lime sludge is based on an estimate, it should be considered with a wide margin of tolerance. A better understanding on SUEZ's capabilities of assimilating a substitution material and the capabilities of the potential partners to supply a material that can satisfy SUEZ's needs will allow a more solid understanding on the viability of the synergy and the calculations of a definitive viability radius.

5.1.5.4. Replication potential

The potential for replication in Europe for a similar type of IS was modelled for in SCALER project report D5.3. Though, it is related to the use of lime in other sectors, the economic and environmental benefits in terms of savings from substituting a raw material with a recycled material are similar. Table 33 below shows the findings of the evaluation of the European impact of an IS involving the use of lime from the paper industry for flue gas treatment.

Table 33 Impact of the use of lime residues from the paper industry at European level. (Source: SCALER)

Synergy 36	
Waste stream price in Baseline scenario (€/Unit)	
Waste stream volume (Unit/y)	378 000
Substituted material equivalent price (€/Unit)	85,0
Final volume recovered (Unit/y)	378 000
Operational costs (€/y)	

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VA	32 130 000 €
VAT	6 895 098 €
Labour Share (€/y)	14 779 800 €
Direct jobs (€)	335
Indirect jobs (min)	168
Indirect jobs (max)	1013
Investment	
CAPEX	No CAPEX
Total investment in EU	No Investment
External impacts	
Climate change (kg. CO_2-eq)	-16775083
Human health (DALY)	-20,833349
Ecosystem quality (PDF.m2.y)	-9089753
Use of resources (MJ)	-245875920
€ Climate change	1 342 007 €
€ DALY	1 541 668 €
€ Ecosystem quality	12 725 654 €
€ Use of resources	983 504 €
Sum of external economic impacts (€)	16 592 832 €
Carbon tax evolution (€/y)	-671 003 320 €
Waste tax	
Waste tax Baseline scenario (€/y)	14 673 960 €
Waste tax Synergy (€/y)	0 €
Waste tax balance	-14 673 960 €
Viability distance (100% of the resource price)	486
Viability distance (10% of resource price)	49
Waste treatment costs Baseline scenario (€/y)	75 600 000 €
Waste treatment costs Synergy (€/y)	0 €
Waste treatment costs balance (€/y)	-75 600 000 €

In addition, the exact synergy for Sodium Bisulphite production is not very likely to be replicated due to the specificity of the technology that SUEZ is currently developing, however, there could be potential for a usage in the flue gas treatment itself, which is the current use for the lime in SUEZ's site and could be highly replicable. But is outside the ULTIMATE scope so it will not be further commented.

5.1.5.5. Conclusions

There is a valid interest in further exploring this synergy. There is a non-negligeable number of actors in the vicinity and there is both the interest of ensuring the supply for a raw material that is demanded and has a price that is on the rise. In addition, the material is very probable compatible with the current use is being giving, after minor treatment, even if this changes in the future.

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For further exploration of this synergy, the first subjects to be addressed are the following:

- **Have an average composition of Lime sludge from the paper industry sites closest to SUEZ' s incinerators to have a complete and specific technical feasibility assessment.**
- **Do an in-depth concept study and literature review on the use of lime sludge for flue gas treatment.**
- **Identify the treatments and actors that would be needed in order to treat the waste to fit SUEZ needs.**
- **The administrative and regulatory tasks needed concerning the use of waste in SUEZ, if any.**
- **A study on the investment needed.**
- **Assess compatibility in the rate production and seasonality of demand/supply.**
- **Assess material conditioning and transport.**

A Synergy involving a lime source coming from the pulp and paper industry for SUEZ's activities if interesting enough to pursue further consideration. There is a considerable number of sites that could be generating the waste. Enough so a good pair within a reasonable distance could be found given that options are available. The location of this SUEZ site is very helpful in this regard. As lime is a resource that continues to have a demand across different sectors and thus is a commodity, its price is not necessarily stable. A low-cost alternative resource available in the vicinity could facilitate the supply. This will also divert the material from the waste stream which is both sustainable and convenient for the site that produces it. Lastly, considering SUEZ activity and current legislation, there are administrative options that will allow this material to be reused respecting the regulation.

It is recommended to go further in this synergy exploration. The global synergy assessment is provided in the next table:

Table 34 Recapitulative table of Synergies related to a lime substitute coming from the paper industry for SUEZ's activities

Indicator	Qualitative assessment	Quantitative assessment
Technical ease to replicate	A few sites for replication and low technical requirements once the sludge composition is validated. Probable need for additional treatment.	2 more sites in SUEZ where the same technology could be applied for sodium bisulphite production. Other incineration with the same type of fume scrubbing could also benefit from this synergy.
Number of potential partners/receivers	Enough sites to launch a field survey.	**156 sites** within a viability radius of 770 km.
Environmental benefits	Eliminates or reduces the use of a mineral non-renewable raw material. Diverts waste from landfilling and incineration giving a material valorisation.	To quantify with a Life Cycle Analysis.
Value added	Savings in supply management for SUEZ.	Potential conservative savings:

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	Revenue from the sale of lime sludge for the paper industry. Potential savings in pollution taxes for the sludge emitter.	900 € per 10 tonnes of substituted lime. Potential conservative revenue: 1 340 € per 10 tonnes of substituted lime. Sludge disposal management cost not available.
Regulation	Possibility of the use of the sludge as waste without further procedures needs to be confirmed. If not, possibility to change the status of the sludge as by-product is promising and condition need to be proven with the corresponding authority.	Does not Apply
General Assessment	Promising Synergy, it is advised to continue the evaluation and implementation of it.	

Two other potential sources of lime that where not explored in this study but could also be addressed are:

- Lime sludge from sugar plants.
- Lime Kiln dust.

5.1.6. Flow 6: pH correctors

Objective of the flow valorisation

pH correctors are widely used in conventional and innovative water treatments. This are also a very widely commercialised substances as they have many other applications. The substances being considered as pH correctors for this study are Hydrochloric Acid (HCl), Sulphuric Acid (H_2SO_4), Sodium Hydroxide (NaOH).

For this flow type there are four CS involved: CS4 Nafplio, CS5 Lleida, CS7 Tain and CS8 Saint Maurice l'Exil. They are all in the receiving end of the symbiotic relationship as they would require having an alternative supply of pH correctors for different processes. For CS4, CS5 and CS8 these materials will act as pH correctors in different steps of their WWT and for the CS7 it will be potentially needed for the processing of the ammonia that is to be extracted from the brewery effluents.

The amount of raw materials saved is very hard to estimate as it depends highly on the effluent that is being treated, namely the volumes and the composition. The needs for the CS that use these types of substances are currently unknown due to the gap of data available. The same is true for the economic assessment of the synergies. Specific quantities will be known as the project advances and then, the environmental and economic assessment will be able to progress. There is one exception for this, which is CS5. At this point in time, the CS has an estimation of their treatment needs in full scale.

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For this type of flow, a short circuit and big volumes are very important as its market value is not very high. This will mainly have on its advantage the positive environmental impact of the use of a secondary raw material or by product and the economic advantages that the emitting site will have as savings in waste management or effluent treatment.

5.1.6.1. HCl

Hydrochloric acid (HCL), also called muriatic acid, is a strong acid that is very commonly used in different applications and different concentrations of an aqueous solution according to the use it is given. Some of those applications are pH neutralization, bleaching in different sectors, metals processing, the food industry and vinyl chloride production. [14]

HCl tends to be used instead of other pH correctors, such as H_2SO_4, due to its low cost.

As raw material is largely produced as a by-product of chlorination reactions as a gas that is then transformed into a concentrated liquid by an absorption column with a solution of HCl. This is then further processed. This means that some of the supply is greatly dependant on the manufacture of the primary products. [15]

5.1.6.1.1.Technical screening of application sectors identification

After consulting market studies, SCALER's report D3.5 "Quantified potential of industrial symbiosis in Europe", SCALER's Synergies Outlook document, and the University of Cambridge IS database, a potential alternative or complement to the HCl supply needed CS 4, 5 and 8 could come from the sectors listed on Table 35.

Table 35 HCl potential alternative source sectors and their NACE codes.

NACE Code	Sector	Description
24.42	Aluminium Production	Primary aluminium production
24.10	Processing of steel	Pickling Steel
20.12	Manufacture of dyes and pigments	Titanium dioxide producer
20.13	Manufacture of other basic chemicals	Basic Chemicals, Wet scrubbers
20.16	Manufacture of plastics in primary forms	Ethylene dichloride/vinyl chloride monomer (EDC/VCM)

Except for Ethylene dichloride/vinyl chloride monomer, all HCl sources are not ones that commonly produce it as a co-product but as an effluent. If this acid is to be obtained from the monomer production, the volumes will likely be very small as it is already being looped into production for the most part. It can however be tried if there is a producer sufficiently nearby that has residual HCl that is currently being disposed of, to either supply or help reduce the need to supply from another source.

Most of the activities listed in Table 35 have a HCl effluent containing HCL that needs treatment to remove impurities, generate or require an extraction treatment to obtain HCl. Some of them, such as HCl used for treating steel are currently being recycled and reintroduced into that industry's production, there is then the precedent of this effluent being treated for reuse as raw material.

This effluent is called spend pickling liquor and is the spend acid bath used to remove oxide from metal surfaces. Once this bath has been used several times, the acid concentration has decreased and is no longer usable. This type of liquid effluent can be neutralized and treated for disposal or for reuse. The HCl present can be recovered (or regenerated) using different methods. [16] [17] This can be provided by different technology providers. This is becoming a more common practice since it can allow to save money in raw materials and effluent treatments as well as producing revenue from other materials recovered.

Challenges of this type of recovery are:

- Its production is mostly captive by the same industry that produces it.
- Acid regeneration technologies produce a concentration of around 20% of HCl, this is not likely to be sufficient for all the pH correction needs of different water treatments.

The most convenient arrangement for this particular IS, could be with a partner that does not find use for all of its regenerated HCl or could see an additional benefit in selling it. This is however not highly likely.

HCl, as other acids, can be recovered from flue gas wet scrubbing wastewater. This flue gas can come from different inorganic chemical industries. This type of IS was reported in SCALER project but was targeted for power plants application.

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A record of an industrial application of this type of synergy was found in a study in Finland where the HCl recovered from the chemical industry was used in a power plant, and the recovery required low technical requirements to be implemented. The adaptation to each CS's applications would need to be analysed in a more in-dept manner for the water treatment application which would involve a technical study to verify the technical feasibility. Given that this is likely to require an investment, the correct partners would have to be found where the interest will probably be the opportunity to recover big volumes. This could be likely applicable for CS5 or CS8.

All that was mentioned before does not account for the impurities and the complexity of treating the effluent to make it pure enough, this complexifies the technical feasibility assessment and the IS. [18]

The IS rout most promising would probably be the HCl recovery from the effluents of some chemical industries followed by residual HCl from Ethylene dichloride/vinyl production. To generalise the partner search, all sectors shown in Table 35 were considered in the mapping for this IS.

5.1.6.1.2.Mapping of nearby partners and Application to case study

CS4 Nafplio

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To assess the viability of this IS in CS4, a mapping of potential partners and a calculation on an economical viability radius based has been dobe. These are shown in Figure 24 and Figure 25. Based on that information, Table 36 shows the potential parterns in the vicinity of CS4 location and thus, the number of opportunities for establishing the IS.

Due to the relatively low price of the resource, the transport viability radius is not very large. It was calculated in function of :

- **An approximate raw material price of 29 €/t**
- **A secondary raw material could have up to 30% of depreciation**
- **A conservative approach with a conservative approach of 10% depreciation**

This results in a secondary raw material of 17.4 €/t and a viability radius of less than 100 km, which means, there is an opportunity for profitability within the first 100 km that the acid is transported aproximately.

Figure 24 Map of potential sites generating a potential substitute HCl for CS4. (Source: Strane)

The map above shows the first ten industrial sites. None of the industrial sites shown in Figure 25 can be considered as potential partners for an IS creation due to their distance from Alberta's production plant. There are three sites that come close to the transport viability radius, but the quantity is still very reduced, aditionally, they are all metal related sites, which is not the most promising sector for his HCl SI. This all means that a IS does not looks promising for Nafplio CS.

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Table 36 Table of HCl potential synergies for CS4. (Source: Strane)

Distance (km)	Potential synergies
10	0
50	0
100	0
250	4

In addition, the location of the CS4 and the Alberta plant and the geographic and topographic characteristics of the surroundings make it difficult to find multiple viable transportation options.

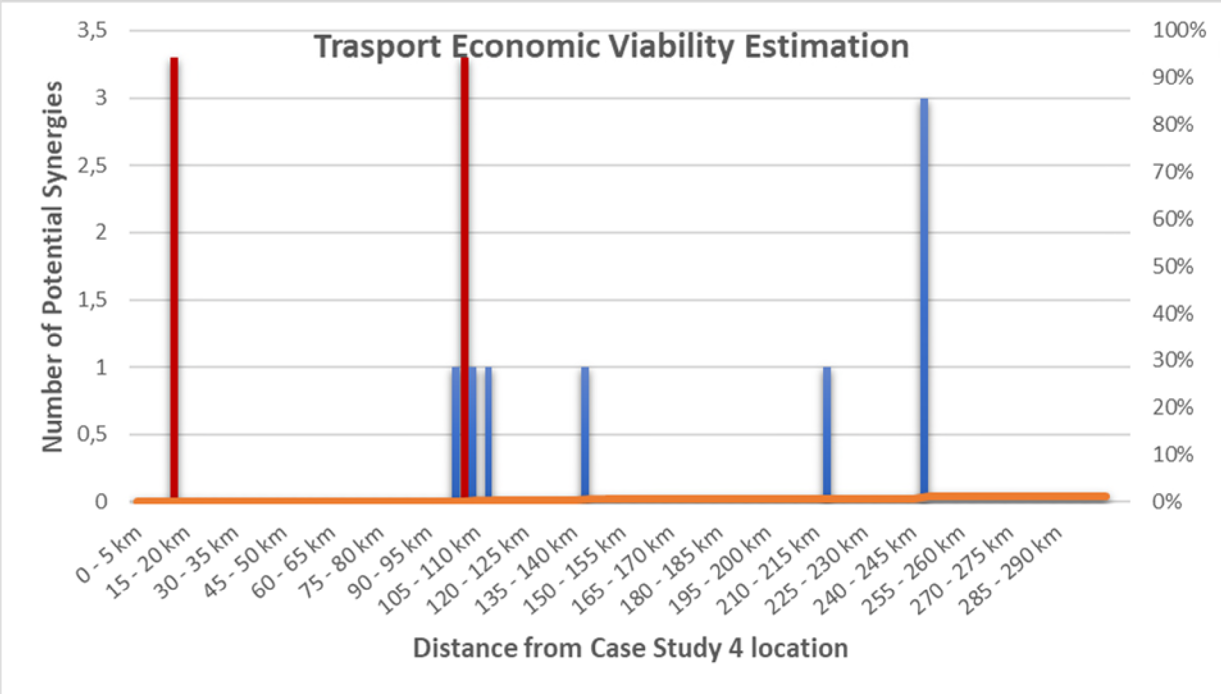

Figure 25 Transport viability estimation for HCl for CS4. (Source: Strane)

Figure 25 shows the number of IS opportunities by tranche of distance from CS location. Is accentuates the lack of opportunities within the transport viability radius that is represented in between the red vertical lines.

Conclusions

The global synergy assessment is provided in the next table:

Table 37 Recapitulative table of Synergies related to a secondary HCl coming from the steel industry for CS4 WW treatment.

Indicator	Qualitative assessment	Quantitative assessment
Technical ease to replicate	The technology to obtain a secondary HCl from steel making is proven, however it is likely not	Does not apply

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	compatible with the HCl needed for this application.	
Number of potential partners/receivers	Not enough sites to make a survey study..	No sites found within viability radius
Environmental benefits	Eliminates or reduces the use of a raw material. Aids in the treatment of the acid effluents of the steel industry.	To quantify with a Life Cycle Analysis.
Value added	Savings in supply management for Alberta and GtG. Revenue from sales of acid for the emitter. Potential savings in pollution taxes for the emitter.	Potential conservative savings:170 € per 10 tonnes of substituted acid. Potential conservative revenue: 174 € per 10 tonnes of substituted acid. Acid effluent treatment cost not available.
Regulation	Possibility to change the status of the acid as by-product although not promising since the acid is not a direct consequence of the main production.	Does not Apply
General Assessment	Synergy not promising.	

After all that was considered above, this synergy is not considered a promising one and an in-depth study or a field survey is not likely to have positive results which makes it an unadvised investment.

CS5 Lleida, Spain

To assess the viability of this IS in CS5 the same process that was implemented for CS4 was implemented for the Lleida location : a mapping of potential partners and the same calculated viability radius applies here. The map of industrial sites is shown in Figure 26 and the opportinities per radius tranche is shown in Figure 27. Based on that information, Table 38 shows the potential parterns in the vicinity of CS5 location and thus, the number of opportunities for establishing the IS.

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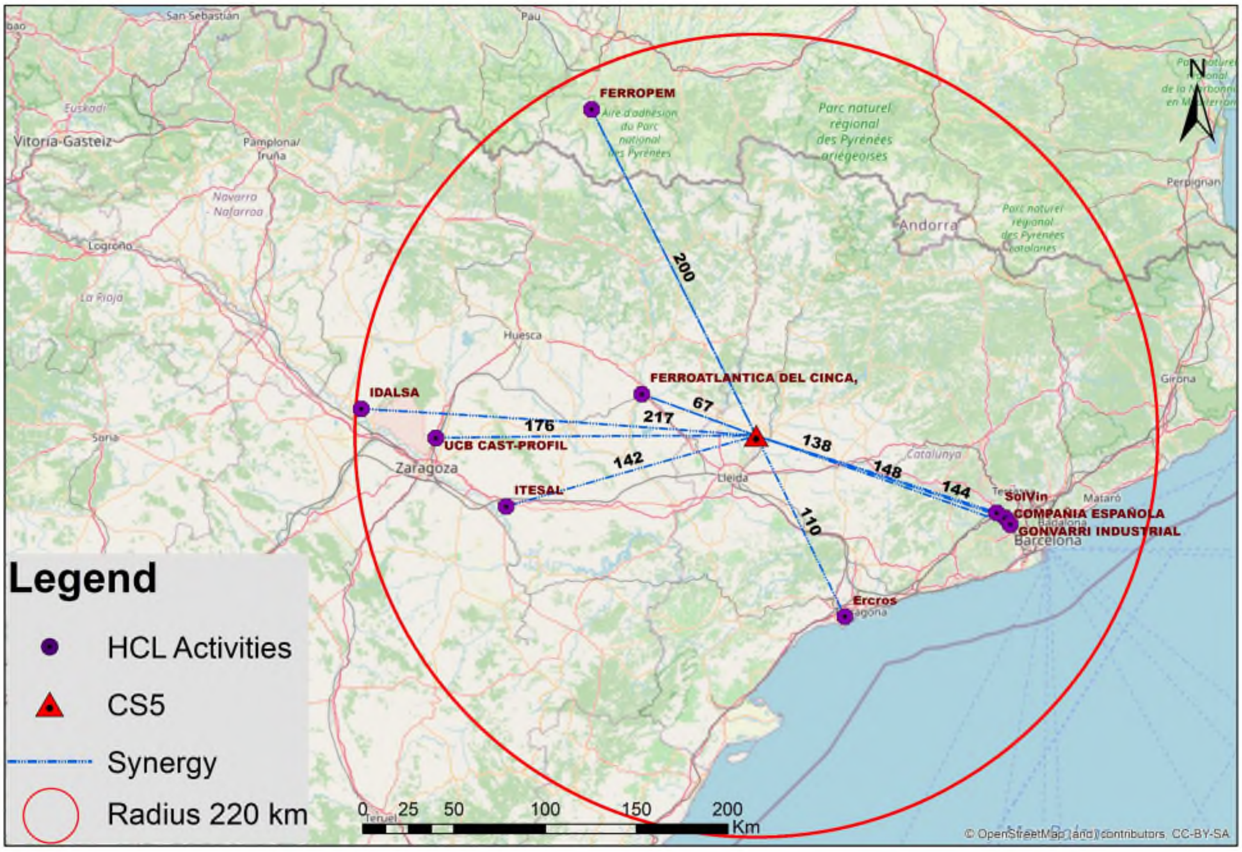

Figure 26 Map of potential sites generating a potential substitute HCL for CS5 (Source: Strane)

The map above shows the first ten industrial sites from the sectors mentioned in Table 35. Only one of the industrial sites shown in Figure 27 can be considered as potential partners for a IS creation due to its distance from Mahou brewery. There is another site that comes close to the transport viability radius, which makes for two potential sites to partner in an IS, one from the metalurgy sector and one from the chemical sector. As Table 38 shows, the amout of potential synergies does not seem promising.

Table 38 Table of HCl potential synergies for CS5. (Source: Strane)

Distance	Potential synergies
10	0
50	0
100	1
150	6
200	7

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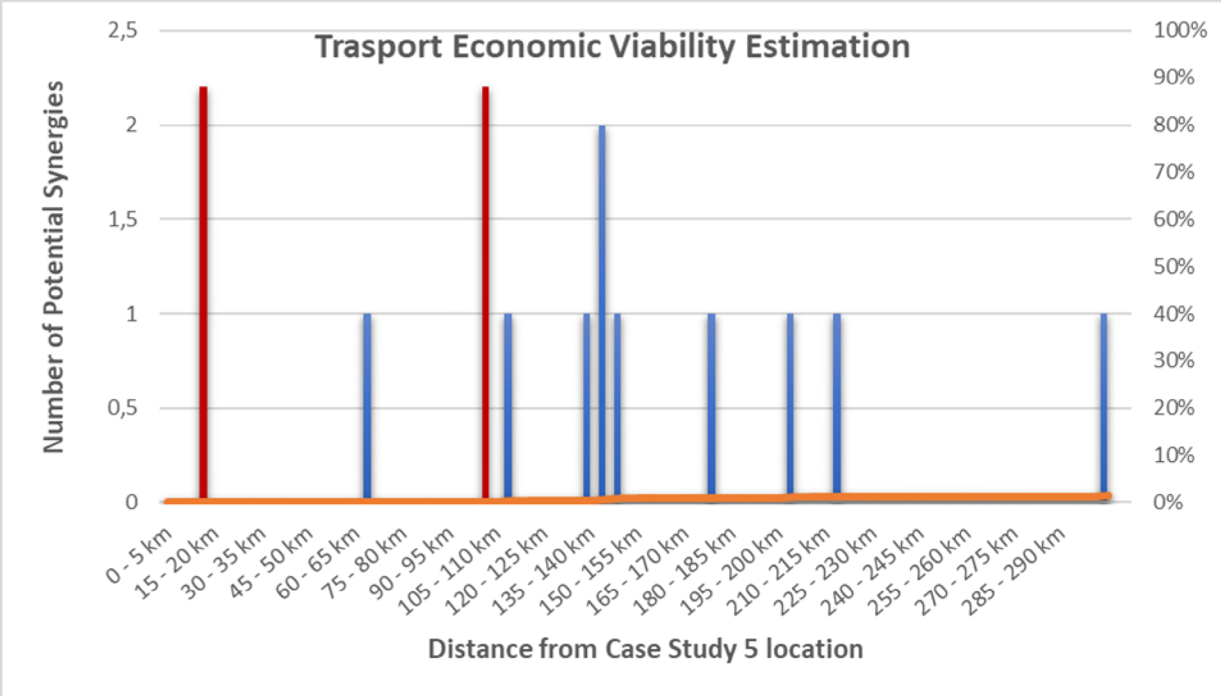

Figure 27 Transport viability estimation for HCl for CS5. (Source: Strane)

Figure 27 shows the number of IS opportunities by tranche of distance from CS location. The site found within the transport viability radius that is represented in between the red vertical lines and is a metallurgy site.

Conclusions

The global synergy assessment is provided in the next table:

Table 39 Recapitulative table of Synergies related to a secondary HCl coming from the steel industry and slaughterhouses for Aqualia's WW treatment

Indicator	Qualitative assessment	Quantitative assessment
Technical ease to replicate	The technology to obtain a secondary HCl from steel making is proven, however it is likely not compatible with the HCl needed for this application. The technology to obtain secondary HCl from Ethylene and chemical production are viable.	Does not apply
Number of potential partners/receivers	Not enough sites to make a survey study.	No sites found within viability radius
Environmental benefits	Eliminates or reduces the use of a raw material. Aids in the treatment of the acid effluents of the involved industries.	To quantify with a Life Cycle Analysis.

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Value added	Savings in supply management for Alberta and GtG. Revenue from sales of acid for the emitter. Potential savings in pollution taxes for the emitter.	Potential conservative savings:170 € per 10 tonnes of substituted acid. Potential conservative revenue: 174 € per 10 tonnes of substituted acid. Acid effluent treatment cost not available.
Regulation	Possibility to change the status of the acid as by-product although not promising since the acid is not a direct consequence of the main production.	Does not Apply
General Assessment	Synergy not promising.	

After all that was considered above, this synergy is not considered a promising one and an in-depth study or a field survey is not likely to have positive results which makes it an unadvised investment.

CS8 Saint Maurice l'Exil, France

To assess the viability of this IS in CS8 the same process that was implemented for CS4 and CS5 was implemented in SUEZ location : a mapping of potential partners and the same calculated viability radius applies here as it is assumed that the price of the resource and the transportation is fairly similar for the three locations. The map of industrial sites is shown in Figure 28 and the opportinities per radius tranche is shown in Figure 29. Based on that information, Table 40 shows the potential parterns in the vicinity of CS8 location and thus, the number of opportunities for establishing the IS.

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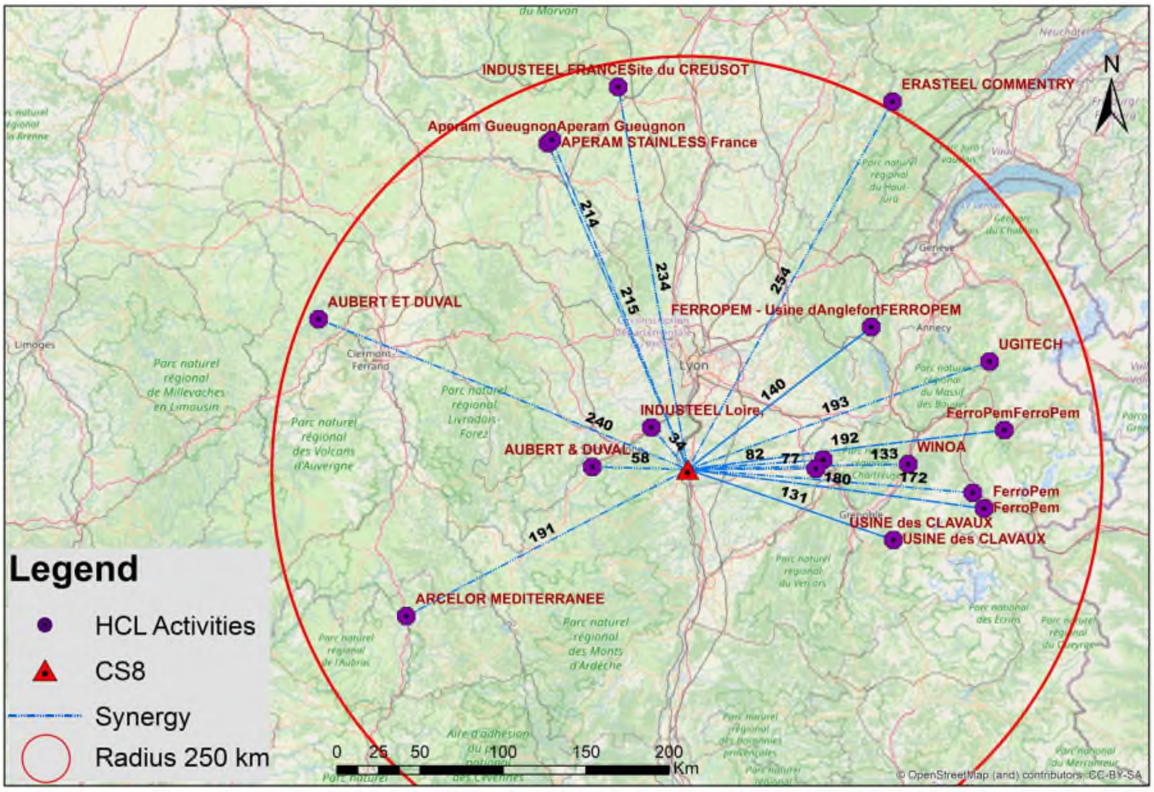

Figure 28 Map of potential sites generating a potential substitute HCL for CS8. (Source: Strane)

The map above shows the first seventeen industrial sites from the sectors mentioned in Table 35. In this case, we can see that this area is more dense in the type of industrial activity of interest. Four of the industrial sites shown in Figure 28 can be considered as potential partners for an IS creation since distance from SUEZ plant falls within the viability radius, as can be seen in Figure 29. As for CS5 there is representation from both steel processing industry and chemical industry. Howerver, the amout of potential synergies does not seem promising.

Table 40 Table of HCl potential synergies for CS8. (Source: Strane)

Distance	Potential synergies
10	0
50	1
100	4
150	7
200	13

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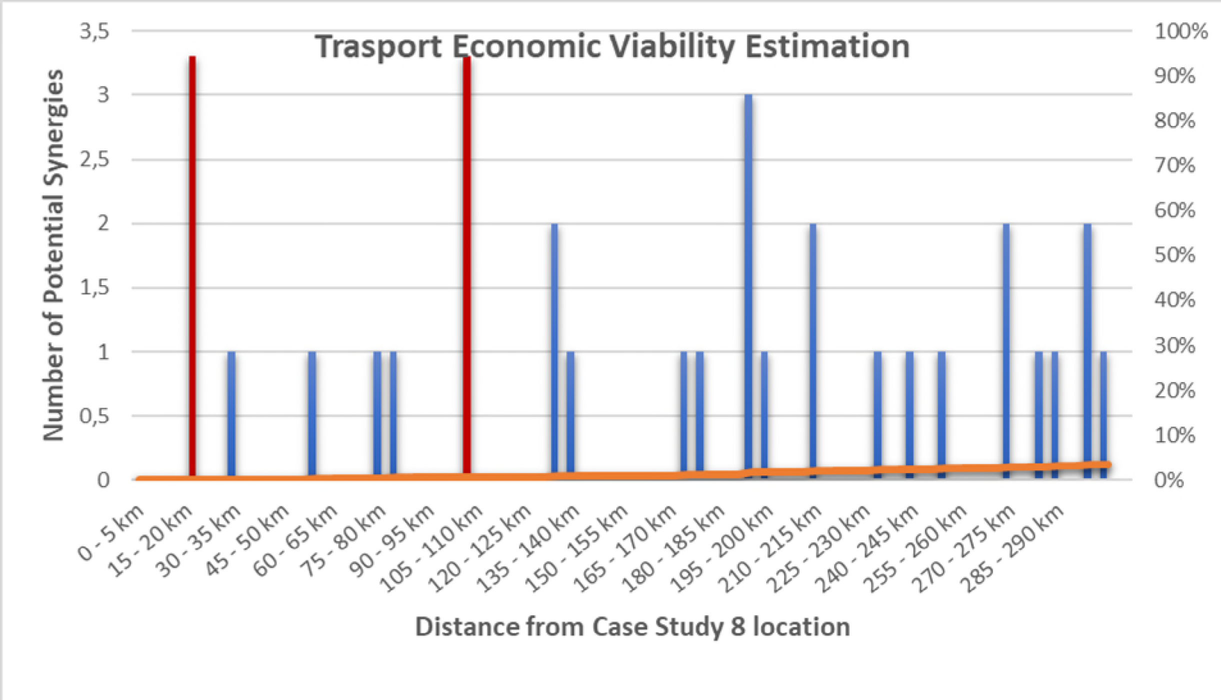

Figure 29 Transport viability estimation for HCl for CS8. (Source: Strane)

Figure 29 shows the four sites within the viability radius and none other close enough to be considered. It can be seen in the graphic that some are within a short distance. Nevertheless, four is still a small number for an IS research to be considered promising.

Conclusions

The global synergy assessment is provided in the next table:

Table 41 Recapitulative table of Synergies related to a secondary HCl coming from the steel and chemical industry for SUEZ's WW treatment

Indicator	Qualitative assessment	Quantitative assessment
Technical ease to replicate	The technology to obtain a secondary HCl from steel making is proven, however it is likely not compatible with the HCl needed for this application. The technology to obtain HCl from fumes in the chemical industry is viable.	Does not apply
Number of potential partners/receivers	Not enough sites to make a survey study.	**4 sites** found within a viability radius of 100 km.
Environmental benefits	Eliminates or reduces the use of a raw material. Aids in the treatment of the acid effluents of the chemical industry scrubbing effluents.	To quantify with a Life Cycle Analysis.

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Value added	Savings in supply management for SUEZ. Revenue from sales of acid for the emitter. Potential savings in pollution taxes for the emitter.	Potential conservative savings:170 € per 10 tonnes of substituted acid. Potential conservative revenue: 174 € per 10 tonnes of substituted acid. Acid effluent treatment cost not available.
Regulation	Possibility to change the status of the acid as by-product although not promising since the acid is not a direct consequence of the main industrial activity.	Does not Apply
General Assessment	Synergy not promising.	

After all that was considered above, this synergy is not considered a promising one and an in-depth study or a field survey is not likely to have positive results which makes it an unadvised investment.

5.1.6.1.3.Conclusions

A big challenge for the establishment of this IS is that this would not be a direct synergy. The resource would need a treatment to be valorised as a pH corrector. There is also the potential of the need for a regulatory revision and possibly additional administrative process to be followed. This will depend a lot on the actors and the type of business, technical and logistics model that is chosen. The most convenient and efficient would be researched in case of pursuing the IS.

Another major challenge for HCl coming from an industrial effluent to have a valorisation is the low price of the HCl in the market. This is partly because most HCl in the market is already a by-product. The main driver in this type of synergy will be the environmental impact that could be reduced by removing a substance that is in principle a waste in some industries. This low price makes for a fairly small viability radius which then makes for a small number of sites that could be considered for an IS. Finally, this is the main reason why an IS that uses recycled HCl for water treatment is not considered promising for any of the CS studied.

5.1.6.2. Sulfuric acid H2SO4

Objective of the flow valorisation

Sulfuric acid is used as a pH corrector in the WWT of CS5 in Lleida, Spain and CS7 in Tain, United Kingdom.

H_2SO_4 is produced by contact process in which one SO_2 is oxidized to SO_3 at high temperature with vanadium catalyst. SO3 then is dissolved in concentrated sulfuric acid forming oleum. Then, the reaction with water produces concentrated sulfuric acid. [19]

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Despite the technological improvements, its environmental impact is important too. Chemical industry is pollutant and energy consuming, which shows the importance of implementing a circular process by finding alternative resources. It is also significatively more expensive than the HCl alternative used for the same purpose which further increases the interest of finding an alternative resource to replace or substitute current supply of H_2SO_4.

5.1.6.2.1.Technical screening of application sectors identification

After consulting market studies, SCALER's report D3.5 "Quantified potential of industrial symbiosis in Europe", SCALER's Synergies Outlook document, a potential alternative or complement to the HCl supply needed CS5, and CS7 could come from the sectors listed on Table 42.

Table 42 H_2SO_4 potential alternative source sectors and their NACE codes.

Code	Sector	Description
10.11	Processing and preserving of meat	Slaughterhouses
10.12	Preserving and processing of poultry meat	Slaughterhouses
24.44	Copper production	Primary Copper Production
24.45	Other non-ferrous metal production	
24.43	Lead, zinc, and tin production	Lead and Tin production

Sulphuric acid could be recovered as a by-product of lead and tin process production in non-ferrous metals industries and provide other industries. This sulphuric acid is not one that come directly from the process but is a recovery of SO_2 that is usually released as an emission of lead and tin production. The valorisation of this sulphur by a wet sulphuric acid process would make this IS possible. [1]

This IS was reported by the SCALER Project and it's economic and environmental impact where modelled. The results showed potential on the recovery of the sulphuric acid from the lead and tin production industry and that there could be a significant value in there. Not only there is a monetary value, in revenue creation and pollution taxes avoidance, that could be exploited but also environmental and social values coming from reduction on carbon emissions, improvement of human health and job creation.

It is important to note that the application of this synergy is quite different, which means is not directly applicable to ULTIMATE project. Nevertheless, it is an important clue on the potential source of secondary raw material.

The same type of process of sulphur recovery in sulphiric acid is possible in the primary cooper smelting process. The potential impacts of this synergy where also modelled in the SCALER project. The applicability would depend on the capabilities of the partner to produce a sulphuric acid of a quality that could be used in each CS.

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H_2SO_4 content coming from Slaughterhouses is a less known potential source. For the moment, the information on it is very limited and this IS would be the one that would require more research before pursuing it. At this point, this synergy would need to be considered as theoretical. Sulphuric acid can be found in the effluents coming from slaughterhouses. [20] However, reports on the recovery could not be found.

5.1.6.2.2.Mapping of nearby partners and Application to case study

CS5 Lleida, Spain

The map made of sites in the vicinity of CS5 that are susceptible of producing sulphuric acid that could be recovered is shown in Figure 30. This map shows the ten closest sites from the brewery, which are inside of a 150 km radius. This is shown like this to privilege a short circuit in the transport of the resource. This would reduce environmental impacts and increase the profitability of the IS. However, as it can be seen in Table 43, there are more oportunities within the viability radius of **257 km**.

That viability radius was calculated based on a modified market price of the acid following the next parameters:

- **An approximate raw material price of 75 €/t**
- **A secondary raw material could have up to 30% of depreciation**
- **A conservative approach with a conservative approach of 10% depreciation**
- **A secondary raw material price of 45 €/t**

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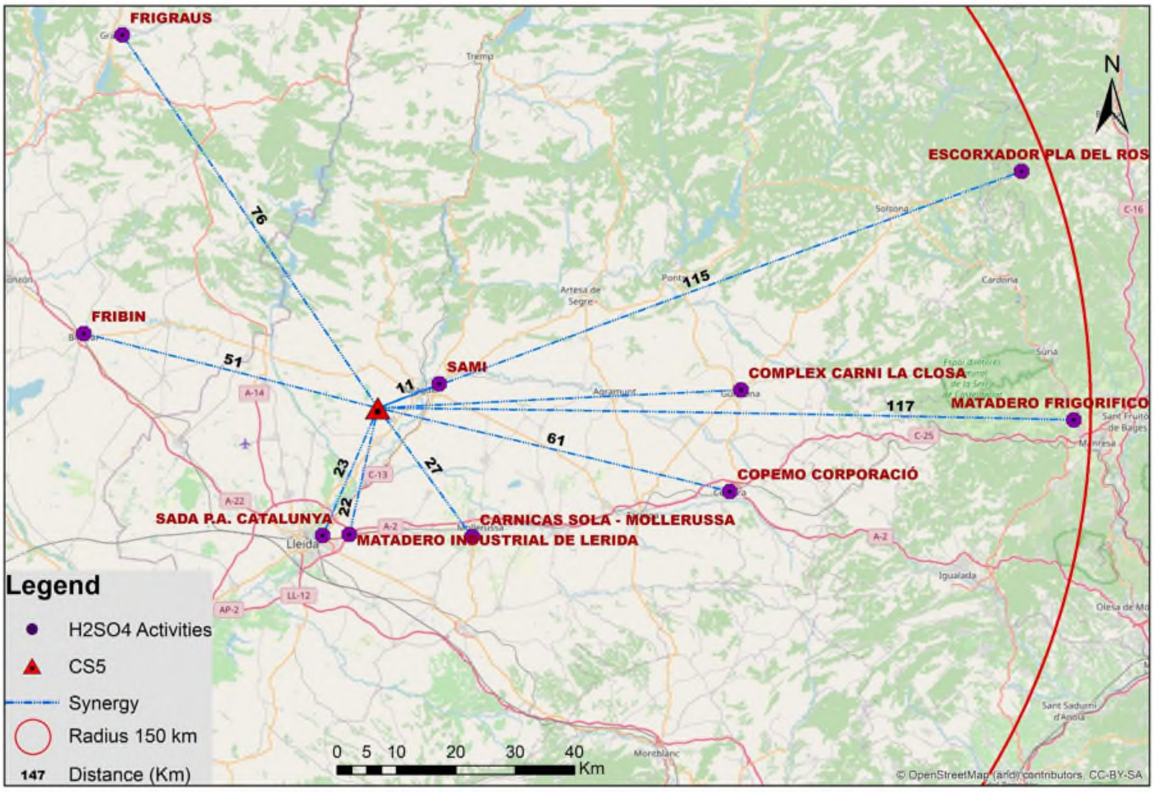

Figure 30 Map of sites generating a potential substitute H_2SO_4 for CS5. (Source: Strane)

Table 43 Table of H_2SO_4 potential synergies for CS5. (Source: Strane)

Distance (km)	Potential synergies
50	4
100	8
150	14
200	30
250	44
300	52

Usually, the flow of SO2 produced is released into the air. It therefore has no economic value. The pricing of the material could also depend on the process of recovery of sulphur, production of the sulphuric acid and purification of the substance. At this stage is not possible to consider with certainty the cost of the extraction and the purification of the acid but it will need to come to a lower price as the acid production for this IS is convenient. All the sites found within the viability radius are slaughterhouses. This is also the less direct synergy.

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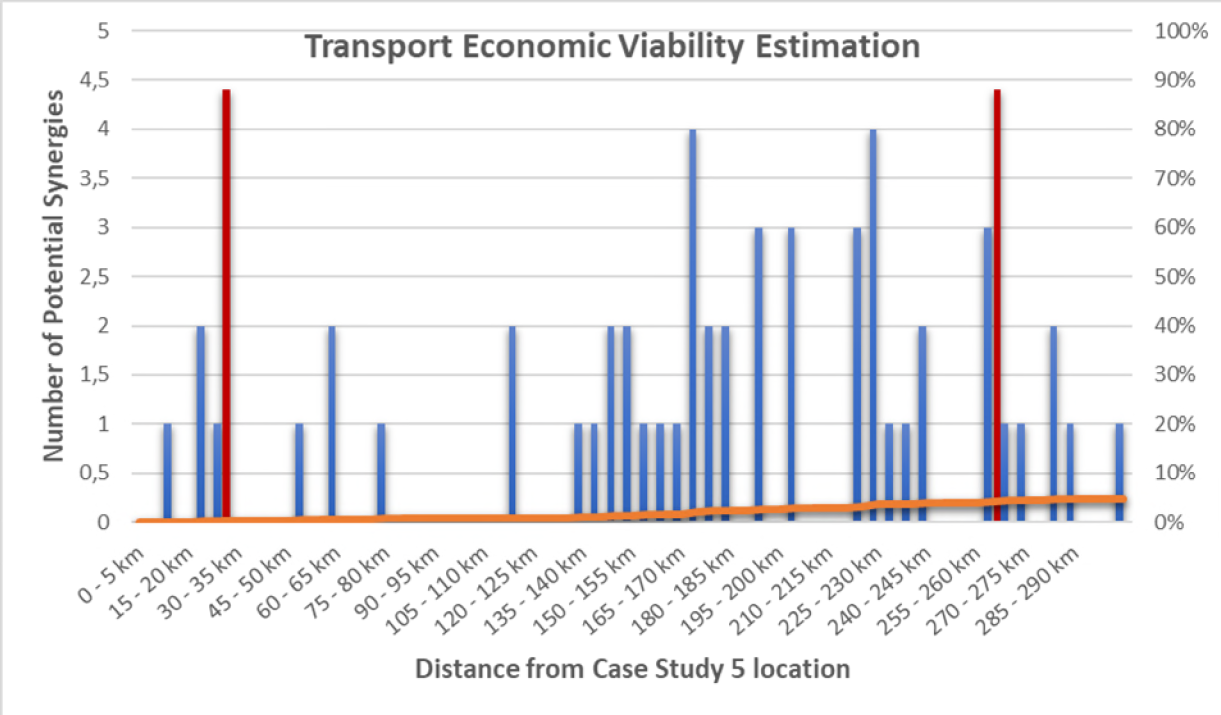

Figure 31 Transport viability estimation for H2SO4 for CS5. (Source: Strane)

Figure 31 shows the number of IS opportunities by tranche of distance from CS location. It shows that most opportunities start from the 150 km distance. This gives an idea on the most likely average transportation cost for the synergy as most potential partners are found in the second half of the viability radius.

Conclusions

Given the high quantities of the pH corrector that are needed for Aqualia's treatment and the fact that the HCl alternative is not promising, this synergy could be explored from the technical side to confirm feasibility as there is a good number of potential synergies within the viability radius. This could be done with a chosen partner in the proximity or by involving a third party to do the study. However, given that no evidence of potential technical progress to recover the acid from slaughterhouses effluent, there is not enough evidence supporting an investment in this study.

The global synergy assessment is provided in the next table:

Table 44 Recapitulative table of Synergies related to a secondary sulphuric acid coming from slaughterhouses and cooper smelting process for Aqualia's WW treatment

Indicator	Qualitative assessment	Quantitative assessment
Technical ease to replicate	The technology to obtain secondary sulphuric acid from slaughterhouses is non-existent. The technology to obtain secondary sulphuric acid fril cooper smelting process is viable.	Does not apply

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Number of potential partners/receivers	Enough sites to make a survey study.	**44 slaughterhouses** found within viability radius of 257 km No cooper smelting sites found within the viability radius.
Environmental benefits	Eliminates or reduces the use of a raw material. Aids in the treatment of the acid effluents of the slaughterhouses and the cooper smelting process.	To quantify with a Life Cycle Analysis.
Value added	Savings in supply management for Aqualia. Revenue from sales of acid for the emitter. Potential savings in pollution taxes for the emitter.	Potential conservative savings:375 € per 10 tonnes of substituted acid. Potential conservative revenue: 750 € per 10 tonnes of substituted acid. Acid effluent treatment cost not available.
Regulation	Possibility to change the status of the acid as by-product although not promising since the acid is not a direct consequence of the main production.	Does not Apply
General Assessment	Synergy not promising.	

CS7 Tain, UK

To assess the viability of this IS in CS7 the same process that was implemented for CS5 was implemented in Grenmorangie's location. The map of industrial sites is shown in Figure 32 and the opportinities per radius tranche is shown in Figure 33. Table 45 shows the number of potential parterns in the vicinity of CS7 location and thus, the number of opportunities for establishing the IS.

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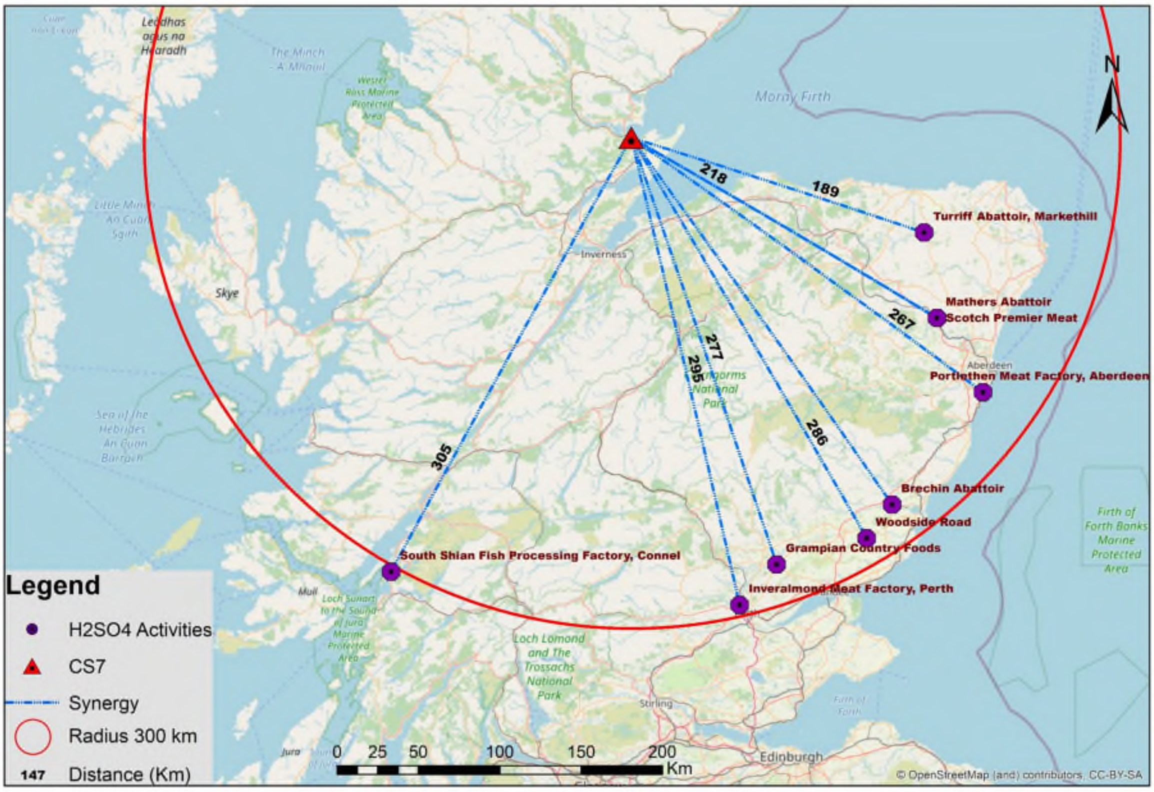

Figure 32 Map of sites generating a potential substitute H2SO4 for CS7. (Source: Strane)

The map shows the first seven industrial sites that are closest to the distillery, however only three enter within the viability radius, wich is the same as for CS5: **257 km**. This number is low, and those sites are found close to the viability area limits which makes an IS implementation even more unlikely.

Table 45 Table of H_2SO_4 potential synergies for CS5. (Source: Strane)

Distance (km)	Potential synergies
50	0
100	0
150	0
200	1
250	3
300	8

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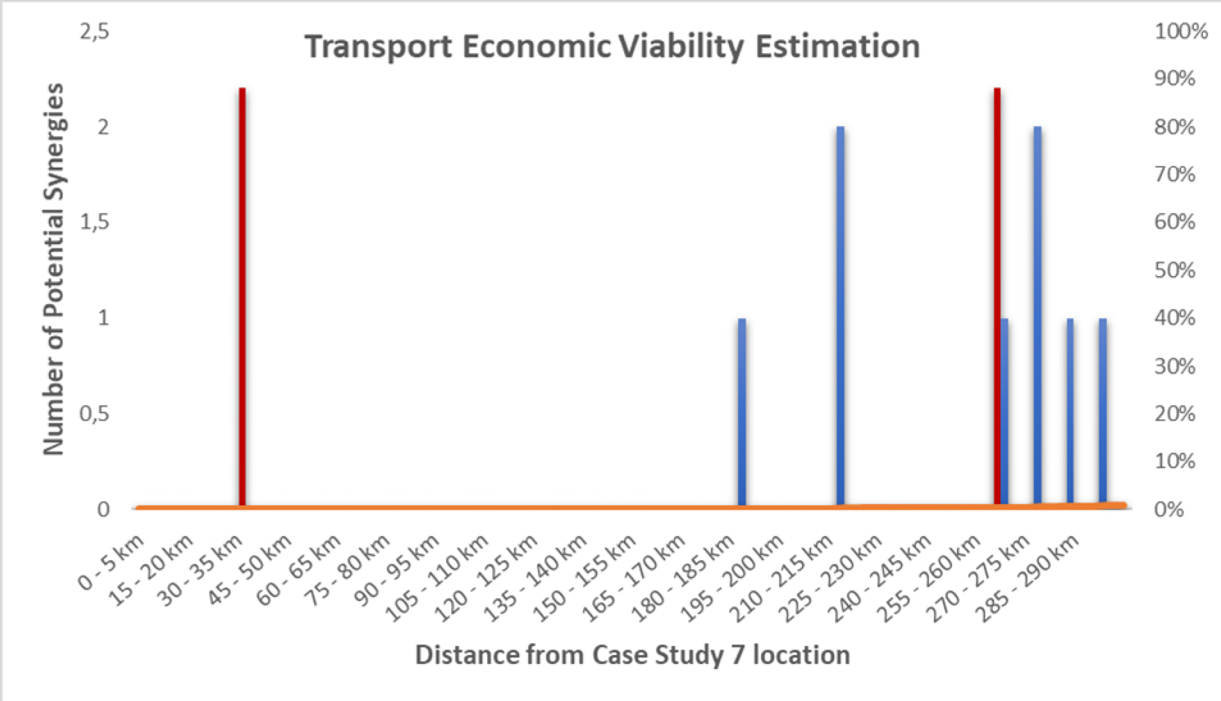

Figure 33 Transport viability estimation for H2SO4 for CS7. (Source: Strane)

Figure 33 shows the number of IS opportunities by trance of distance from CS location. Is accentuates the lack of opportunities within the transport viability radius that is represented in between the red vertical lines. Comparing Figure 31 and Figure 33, the synergy opportunities profile looks very different. The probability of finding a synergy is not similar to that of CS5.

Conclusions

The global synergy assessment is provided in the next table:

Table 46 Recapitulative table of Synergies related to a secondary sulphuric acid coming from slaughterhouse for CS7 distillery's WW treatment

Indicator	Qualitative assessment	Quantitative assessment
Technical ease to replicate	The technology to obtain secondary sulphuric acid from slaughterhouses is non-existent.	Does not apply
Number of potential partners/receivers	Not enough sites to start a survey.	No sites found within viability radius
Environmental benefits	Eliminates or reduces the use of a raw material. Aids in the treatment of the acid effluents of the slaughterhouses.	To quantify with a Life Cycle Analysis.
Value added	Savings in supply management for the distillery WWTP. Revenue from sales of acid for the emitter. Potential savings in pollution taxes for the emitter.	Potential conservative savings:375 € per 10 tonnes of substituted acid. Potential conservative revenue: 750 € per 10 tonnes of substituted acid.

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		Acid effluent treatment cost not available.
Regulation	Possibility to change the status of the acid as by-product although not promising since the acid is not a direct consequence of the main production.	Does not Apply
General Assessment	Synergy not promising.	

After all that was considered above, this synergy is not considered a promising one and an in-depth study or a field survey is not likely to have positive results which makes it an unadvised investment.

5.1.6.2.3. Conclusions

The lower price of a secondary sulphuric acid could make it competitive with respect to primary HCl as a pH corrector given that the price of HCl in the market is significantly lower. Even with this depreciation, sulphuric acid has still a value that allows for more potential for the establishment of an IS that recovers it from waste effluents. If technical feasibility is confirmed, this could be a reliable and convenient source of an acid pH corrector for CS5. But this is not promising due to the reduced knowledge in the slaughterhouse's effluents.

In summary, this is an IS that would be interesting to explore more but there is not enough information that supports an investment. According to the study is clear that an IS for CS7 does not have a potential that makes it a good option going into further exploration.

Despite that, if this synergy is to be pursued, the following subjects need to be addressed firstly:

- **Do an in-depth concept study and literature review on the use of H_2SO_4 from slaughterhouses.**
- **A terrain survey to identify the closest actors that could be interested in pursuing an IS with Aqualia.**
- **A characterisation on the effluents coming from the interested sites including composition, production rate and seasonality of demand/supply.**
- **Identify the treatments and actors that would be needed and do a study on the investment needed from the partners.**
- **The administrative and regulatory tasks needed concerning the use of such effluent in wastewater treatment.**

5.1.6.3. Caustic soda NaOH

Sodium hydroxide, also known as Caustic Soda, is a versatile alkali. It is used in the industry in chemical production, as well as in the manufacture of pulp and paper, alumina, soap and detergents, textile treatments, water treatment and others. [21]

In the ULTIMATE project, it is used as a pH corrector input in CS 4 in Napfplio, Greece, CS 5 in Lleida, Spain, and CS 7 in Tain, United Kingdom. It is considered that

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the NaOH used for this CS is similar to a 25% concentration, considering it as a standard commercial concentration.

NaOH is usually produced by Chlor-alkali process (1.1 tonne caustic for 1 tonne chlorine), using either mercury cell technique (by the electrolysis of a sodium chloride brine in mercury), diaphragm cell technique or membrane cell technique. Each of these processes uses NaCl contained in brine as a flow input. Additionally, Chlorine gas is created as a co-product. [21] [22]

The mercury cell technique is the source of hazardous wastes. In Fact, mercury is a dangerous pollutant which can accumulate in the process facilities. This can also cause potential damage to the environment due to mercury deposits. Additionally, some diaphragm cells used are asbestos based which also represent an environmental risk and a source for pollution. [21] [22] The pollutant characteristic of the NaOH production makes pertinent the research for an alternative supply.

Membrane cells work with a more concentrated brine and produce a more concentrated caustic liquor with less impurities. In Europe, there has been an effort to move from mercury plants to a membrane technology. [21]

In past years, supply in Western Europe depended on the imports from Eastern Europe as the chlorine demand lowered in the former, while increased in the latter. An exploitation of the NaOH present in some industrial effluents could help ensure a local supply.

5.1.6.3.1.Technical screening of application sectors identification.

The following sectors have been identified as an alternative source of NaOH (non-exhaustive list):

- **Paper industry and more specifically treatment of cellulose process used in the manufacture of pulp, wadding and webs of cellulose fibres.**
- **Preparation and dying in textile fibres manufacturing.**

Different textile treatments with NaOH have as a result a liquid effluent high in NaOH content [23]. NaOH is used in concentrates solutions of caustic soda in the following processes:

- **mercerising process (170 – 350 g NaOH/kg)**
- **scouring process (40g/kg)**
- **bleaching (15g/kg)**

Due to the high content and the potential value in recovery this element, several experimental studies have been made in order to develop a technology to recover it [24] [25].

The alkaline or neutral spent pulping liquor from the paper industry can contain high concentrations of carbonate, it is possible to recycle it to regenerate the sodium hydroxide. The organic matter from the wood pulp in this liquor can be burned. The

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resulting smelt can be dissolved in water and turned into green liquor, containing sodium carbonate that can be causticizing with hydroxide and turned into sodium hydroxide. [26]

There is not report of industrial scale application. This would mean a previous research with the potential partners and, if possible, contact with researchers and technology developers that have reported their studies with this material, to verify if their effluents could be eligible for NaOH recovery and if it is possible to apply the technology necessary to their production.

It is important to note that the NaOH composition and physical state recovered will likely be a solution and not in solid form as it is common in the market.

Table 47 H_2SO_4 potential alternative source sectors and their NACE codes.

Code	Sector	Description
17.11	Manufacture of pulp	Treatment of Cellulose
17.12	Manufacture of paper and paperboard	Manufacture of cellulose wadding and webs of cellulose fibres
13.10	Preparation and spinning of textile fibres. This class includes preparatory operations on textile fibres.	Preparation and dyeing of textiles
13.30	Finishing of textiles	Dyeing of textiles

The potential sources of a usable NaOH are experimental. The price and demand for this resource can work as a driver to the development of this type of synergy.

5.1.6.3.2.Mapping of nearby partners and Application to case study

The same basic process of viability assessment considered for the previous two types of pH correctors was applied also to the IS for a NaOH supply for CS 5 and CS7. Given that this time, the raw material has a higher price in the market, and the calculated viability radius is significantly bigger than it was for the acids as it gets to **990 km** for a secondary NaOH cost of **173 €/t**. It was calculated considering the following:

- **An approximate primary raw material price of 350 USD/t (Source: Echemi)**
- **A secondary raw material could have up to 30% of depreciation**
- **A conservative approach with a conservative approach of 10% depreciation**

CS5 Lleida, Spain

Figure 34 shows in a map the first 12 sites that can be a source of a NaOH effluent. They are all part of the paper and pulp sector. All of them benefit from the proximity to CS5 so a short transportation circuit could be in place. Also, it is already known that for the treatment of Mahou effluents a considerable quantity of this chemical will be needed, which increases the probabilities for a viable synergy.

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Since the indicative viable radius is considerably bigger of what is shown in the map (**900 km**), it is worth exploring further away to see how many opportunities for an IS partnership can be found by expanding the research radius.

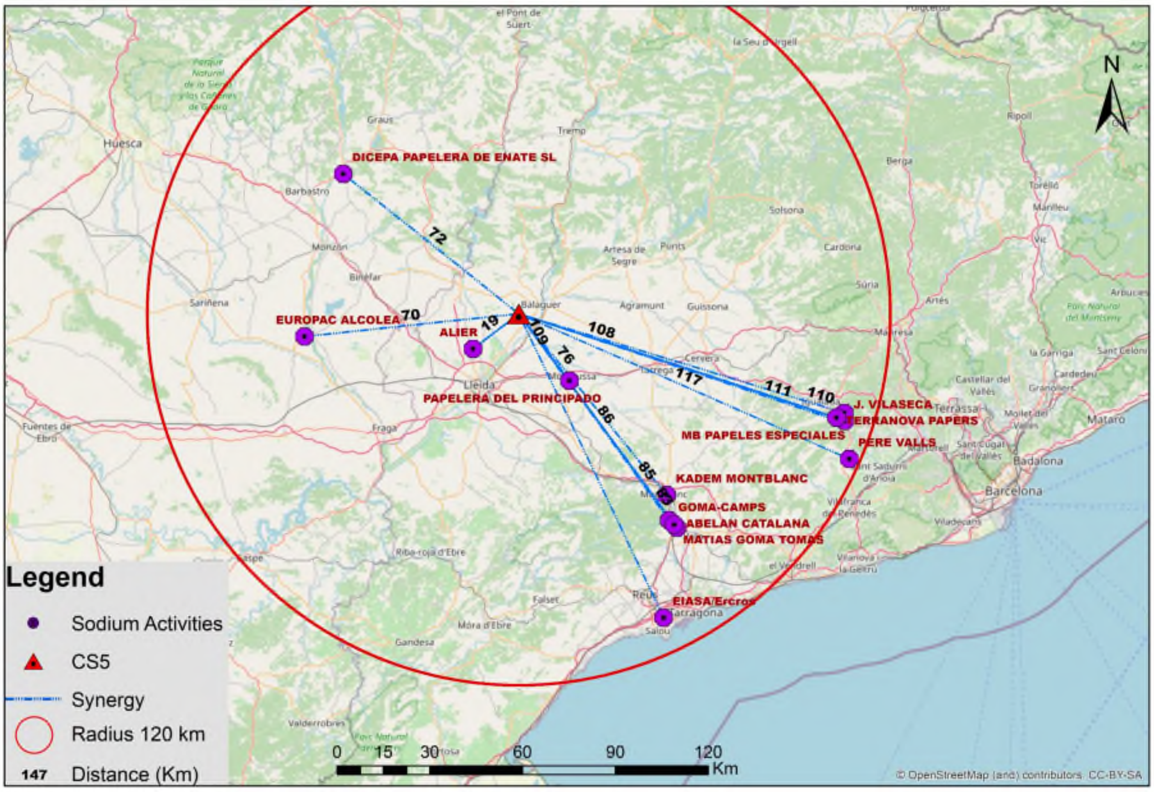

Figure 34 Map of sites generating a potential substitute NaOH for CS5. (Source: Strane)

Table 48 shows that by increasing less than 100 km, opportunities for an IS partnership increase considerably even more than double. The more the distance can be increased until reaching the viability zone limits, the opportunities increase more than 10 times from those shown in the short circuit of Figure 34. It also offers the possibility to explore other type of effluents to find the one that best adapts to CS5 needs or requires less or more accessible treatment. Most and closest sites found for CS are paper and pulp production sites, which means this is the application that would be pursued in case of a continuation in a NaOH synergy project.

Table 48 Table of NaOH potential synergies for CS5. (Source: Strane)

Distance	Potential synergies
50	2
120	15
300	41
500	83
700	107
800	115

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1000	142

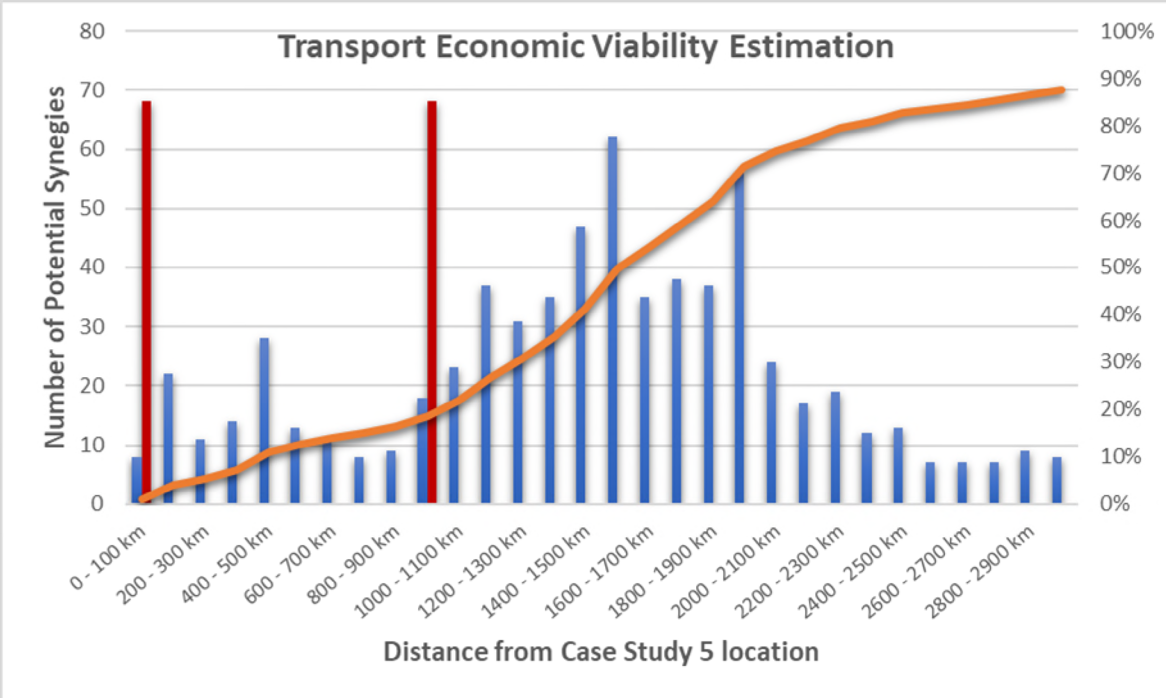

Figure 35 Transport viability estimation for NAOH for CS5. (Source: Strane)

The opportunity distribution of Figure 35 actually shows that the opportunities are distributed in a fairly homogenic manner with closest sites being a little more numerous, which is a positive sign. In a short circuit of 300 km there are already a little over 30 opportunities for synergy. This opens the possibility of making the synergy more profitable and convenient for both parties as it makes truck transportation viable and cheaper.

Conclusion

Looking only into the number of opportunities found within the viability radius of the CS, the general conclusion would be that there is enough to consider that there is a high chance to find a partner. However, being a very experimental type of synergy, this is a concern that needs to be addressed and consulted with CS5 and followed by a concept study.

The economic and environmental advantage is clear. Given the high quantities of material, there could be considerable savings in the supply management chain and in terms of use of primary raw materials. Adding to that, by helping recuperate NaOH from concentrated effluents, there will be a lesser impact of liquid effluents treatment and a cleaner effluent to be rejected into nature. A review on the use of this effluent and treatment needed will be necessary from a regulatory point of view. An extraction of this material would have to result in a type of by-product for it to be commercialized and thus used by Aqualia in Spain or any other actor in any other site according to local regulation.

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The global synergy assessment is provided in the next table:

Table 49 Recapitulative table of Synergies related to a secondary sodium hydroxide coming from the paper industry for CS5 Aqualia's WW treatment

Indicator	Qualitative assessment	Quantitative assessment
Technical ease to replicate	The technology to obtain secondary sodium hydroxide is experimental according to the literature.	Does not apply
Number of potential partners/receivers	Enough sites to start a survey.	**141 sites** found within viability radius of 900 km
Environmental benefits	Eliminates or reduces the use of a raw material. Aids in the treatment of the NaOH heavy liquid effluents.	To quantify with a Life Cycle Analysis.
Value added	Savings in supply management for the brewery WWTP. Revenue from sales of NaOH for the paper production site. Potential savings in pollution taxes for the emitter.	Potential conservative savings: 20 762 € per year considering 50 weeks of 6 business days. Potential conservative revenue: 28 545 € per year considering 50 weeks of 6 business days. NaOH effluent treatment cost not available.
Regulation	Possibility to change the status of NaOH as by-product although not promising since that material is not a direct consequence of the main production. The regulatory review would be much more complex	Does not Apply
General Assessment	Promising Synergy.	

CS7 Tain, United Kingdom

As it is presented in the map of Figure 36 emitting sites are not numerous nor close enough to consider that there is a high probability of finding a synergy that would be pertinent and more advantageous than a conventional supply of NaOH.

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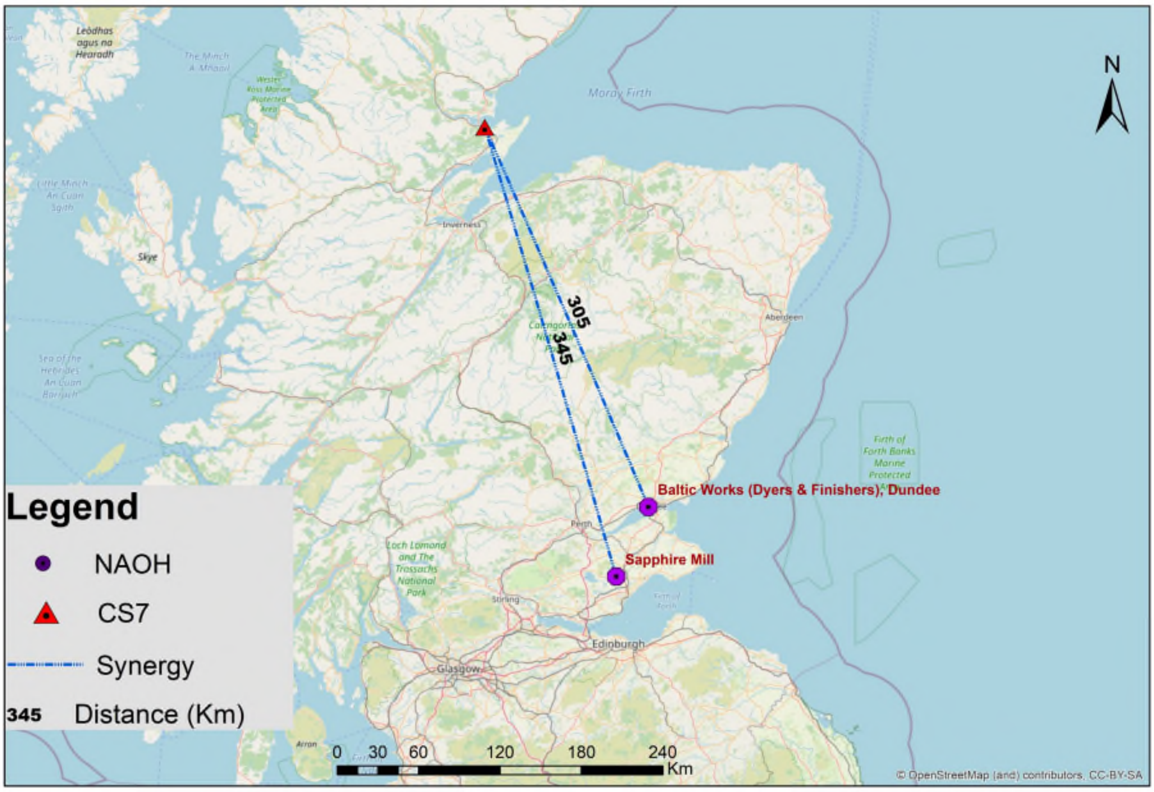

Figure 36 Map of sites generating a potential substitute NaOH for CS7. (Source: Strane)

As can be seen in Table 50 reaching the limit of the viability area, more sites start to appear, however, it is still limited considering that they are far away from the demanding site and potential transport complications because of the geographic characteristics of the area.

Table 50 Table of NaOH potential synergies for CS7. (Source: Strane)

Distance (km)	Potential synergies
250	0
400	2
600	3
700	5
800	12

This synergy will not be further analysed since the bulk of opportunities are found close to the limits of the transport viability radius.

5.1.6.3.3. Conclusion

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As it was the case for the sulphuric acid study, there were considerably more potential partners found in the viability radius of Lleida than Tain. This is probably because CS5 is emplaced in a denser industrial area and CS7 in a more agricultural area. Given that this could be considered a valuable resource, it could be interesting to further continue with the exploration of this synergy for CS5 which will have a big and probably costly demand from an economic and an environmental point of view which will make an investment more logical than for CS7. However, this exploration will continue to be mostly theoretical in the near future as this particular technology is not well explored and it's in an early stage with no industrial scale application.

To continue the exploration, the following steps would be the most pertinent ones:

- **An in-depth concept study and literature review on the extraction of NaOH from the pulp and paper industry sector, including contact with the authors of the pertinent studies and patents consulted, when possible.**
- **A field survey to identify the sites that produce the spent liquor necessary for this IS and to identify interested partners.**
- **Concept study can involve a preliminary study on investment needed and a price point for the material.**
- **Administrative and reglementary review.**
- **Assess compatibility in the rate production and seasonality of demand/supply.**

5.1.6.4. Conclusions

The potential replicability of synergies involving pH correctors for water treatment could be an important driver for its further study in the exploitation WP5 or other tasks in ULTIMATE project. If these synergies are further explored and their feasibility and pertinence are proven, then a twinning process can be carried out in a future exploitation task to explore the European potential. However, as stablished before, there is potentially a complexity in the extraction of the materials of interest. For this, early knowledge on needs and the potential degree of tolerance on impurities and concentration per application is needed.

The price for the acids is already low and variable. The profitability of this synergy for the supplying partner will highly depend on the volumes emitted by them and the post treatment that will be needed in order to establish this IS. On the other hand, environmental thorough assessments can be done to further push the interest for a development for concept studies or application.

Given that there is a good number of emitting sites with a diversity in activity and thus in effluent types, there is a good possibility that some valorisation opportunities can be found for NaOH.

5.1.7. Flow 7: Coagulants for water treatment

Objective of the flow valorisation

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Finding an alternative supply for coagulants concern CS2 led by KWR, CS3 led by UNIVPM, ARETUSA and CS4 led by GTG.

Water treatments have different configurations and combinations of steps for the water treatment depending on the composition and characteristics of the effluent being treated. There are common basic steps that are commonly used in most water treatments. In the coagulation-flocculation step, coagulants are used in wastewater treatment to destabilize suspended colloidal particles and other suspended matter that are present in water. This process is the agglomeration of colloidal particles in water by adding coagulants. The objective of this is to separate those particles from the water. This material is then recovered as flocs by a sedimentation process where the flocs settle to the bottom of the containing tank by gravity. Some of the most commonly used alum and ferric slats as coagulants are aluminium sulphate, aluminium chloride, ferric chloride, polyaluminium chloride.

Water treatment is essential for universal access of potable water to the population and so is the removal of matter in the water. Therefore, the use of coagulants is unavoidable. This causes a large raw coagulants consumption.

Ferric chloride is used as a coagulant in CS2 at the current WWTP that operates treating the water of the greenhouses of a cooperative. An alternative source for a ferric based coagulant was not found during the search.

CS4 has not identified the type of coagulant that will be used in their mobile WWT in Alberta. Therefore, a general alternative resource will be proposed.

CS3 is studying the potential use of alternative coagulants to test and eventually apply in the Aretusa reclamation plant. Those alternative coagulants were chosen in a CE and IS logic and are a by-product of industries present in the same region as ARETUSA and Solvay plant. Those are bentonite and organoclay.

5.1.7.1. Bentonite and Organiclay

Both Bentonite and organoclay are generated by the same process, the organoclay being a by-product of the Bentonite production, so the same sites are concerned for both materials. This also means that the research for bentonite will be the residuals of production that could be available in the industrial sites.

Bentonite is a fine clay that is naturally produced by deposited volcanic ash that is mined and extracted by quarrying. It is then purified and processed according to the use it will be given. Bentonite is usually used as drilling mud, cat litter production, cosmetics, binding agent in animal feed, and a foundry-sand bond. [27]

Organoclay is a sludge produced by the Laviosa factory during a purification process of Bentonite. Bentonite is initially dispersed in water at a defined concentration. Subsequently this dispersion is centrifuged to eliminate the grit. The part containing montmorillonite continues in the plant. Wet grit and other impurities are discarded in the form of sludge.

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Moreover, bentonite is not available anymore near CS3 Rosignano site. This presents an opportunity to find an alternative resource and to implement a synergy.

5.1.7.1.1. Technical screening of application sectors identification

As mentioned before, the sites that will be concerned for both bentonite and organoclay are the same ones, so a geolocated research for them must be done. By following the same process as for the other materials, the NACE codes corresponding to exploit the information for said database. The producers of these materials would enter activities corresponding to the codes mentioned in the table down below.

Table 51 Bentonite and Organoclay potential alternative source sectors and their NACE codes.

NACE Code	Sector	Description
08.12	Operation of gravel and sand pits; mining of clays and kaolin	Bentonite Extraction
09.90	Support activities for other mining and quarrying	Bentonite processing

As it can be seen, these code categories encompass a spectrum of activities that was not possible to reduce. This information does not allow for a fine enough research and thus the results would contain too much noise and irrelevant information that would make for a very inefficient process. For this reason, the NACE database was not used for this particular research. Another source of geolocated information was needed. The European Bentonite Association, member of the European Industrial Minerals Association has a database for bentonite producers which was used to obtain the locations of European producers with an interest in the Greek and Italian sites.

The technical review of this material as a potential substitute for coagulant and adsorption agent is one of the research subjects of CS3 UNIVPM.

5.1.7.1.2. Mapping of nearby Partners and Application to Case Study

CS3 Rosignano

Figure 37 shows in a map the first 3 sites that can be a source of residual bentonite and organoclay. The one closer is an actor already identified by CS3 and it's working with them. The main purpose of this research for this location is to provide CS3 with alternatives on its organoclay supply and to find residual bentonite, as it is not available in the site the CS is working with. They are not found in the same region as the ARESTUSA plant, but they are within a viable distance considering the estimated value of the resource it could substitute.

The transport viability radius used for bentonite and organoclay resources was estimates by calculating an indicative price for an aluminium based coagulant. The same one that was used in **Flow 2 Aluminium Sludge** which is **700 km**. Since the indicative viable radius is considerably bigger, Figure 38 shows how many

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opportunities for an IS partnership can be found by expanding the research radius in the case this IS is deemed technically feasible by CS3 experiments. They will not be likely be considered as CS3 looks for a solution within its region.

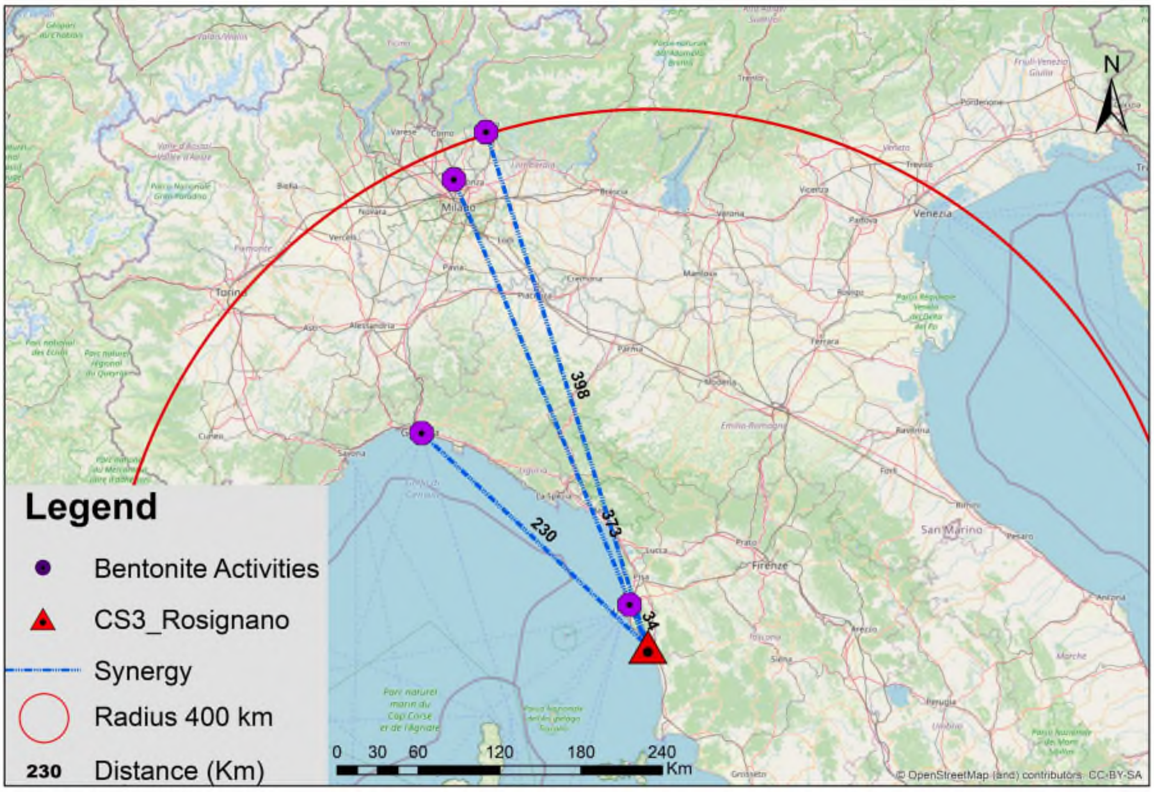

Figure 37 Map of sites potentially generating residual bentonite and organoclay for CS3. (Source: Strane)

Since this mineral material is a more specific resource than most of the other flows that have been examined, the production sites are considerably less numerous. However, a terrain survey could bring to surface more sites. This can be seen in the graphic below that show the distribution of sites producing bentonite by radius tranche from Rosignano.

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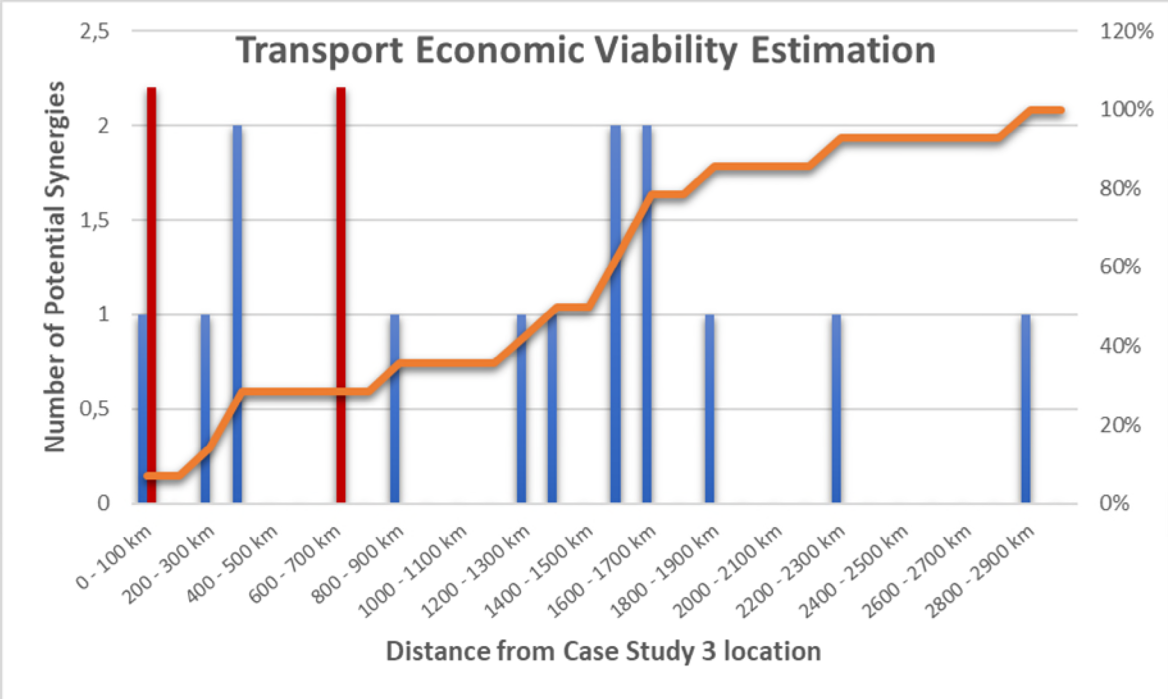

Figure 38 Transport viability estimation for bentonite and organoclay for CS3. (Source: Strane)

Conclusion

This IS research is different since the main purpose was to find potential partners within a reasonably close distance from ARETUSA plant where the pilot experiments with alternative coagulants will be carried out. Since UNIVPM is already working with one of the sites, the other two Italian sites could serve as backups for later stages in the project or as replication potential.

Steps to follow for this IS application will be commercial and administrative activities, once the experiments confirm technical feasibility:

- Develop a business arrangement or model that allow ARETUSA WTP to have a viable supply of alternative coagulant.
- Explore administrative, reglementary, logistic and transportation activities.

CS4 Nafplio

Figure 39 shows in a map the first 2 sites that can be a source of residual bentonite and organoclay. There is not one that could be found whithin the continental territory of Greece, nearby the Alterta production site, even when there is one within the viability radius.

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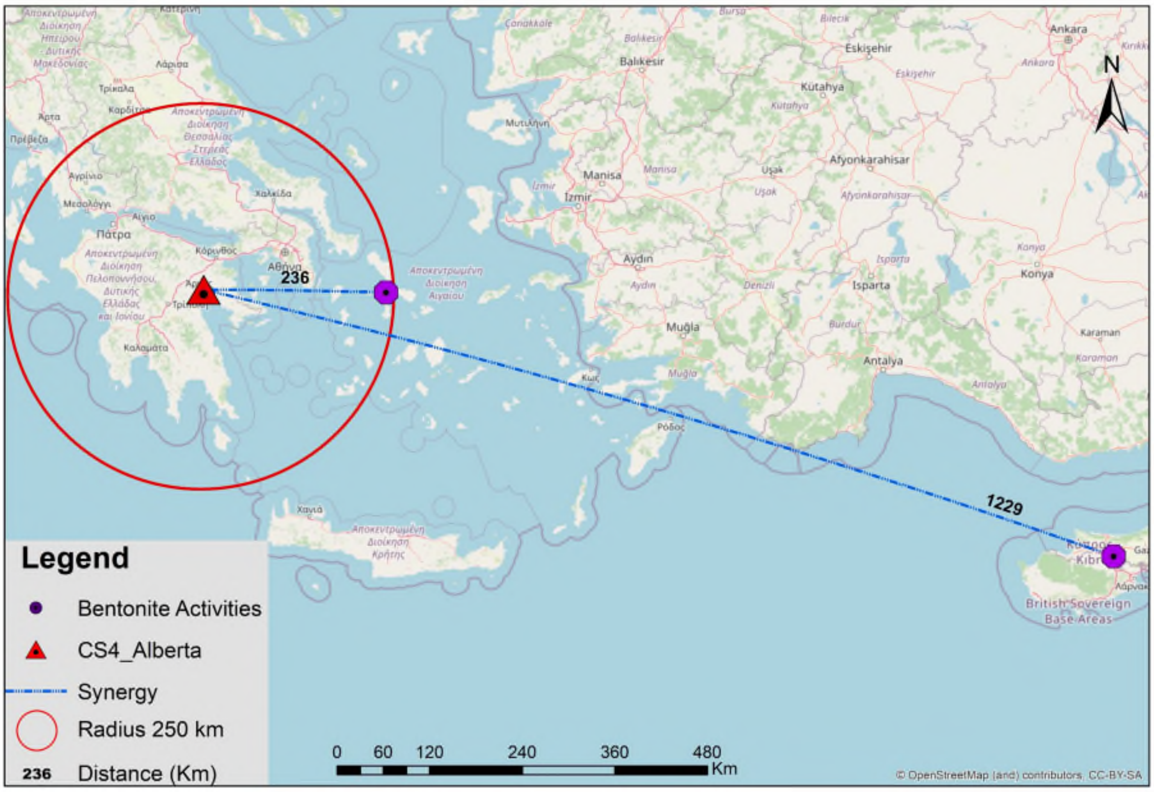

Figure 39 Map of sites potentially generating residual bentonite and organoclay for CS4. (Source: Strane)

Figure 40 shows that, even if the radius is considerable, the sites identified are reduced in quantity.

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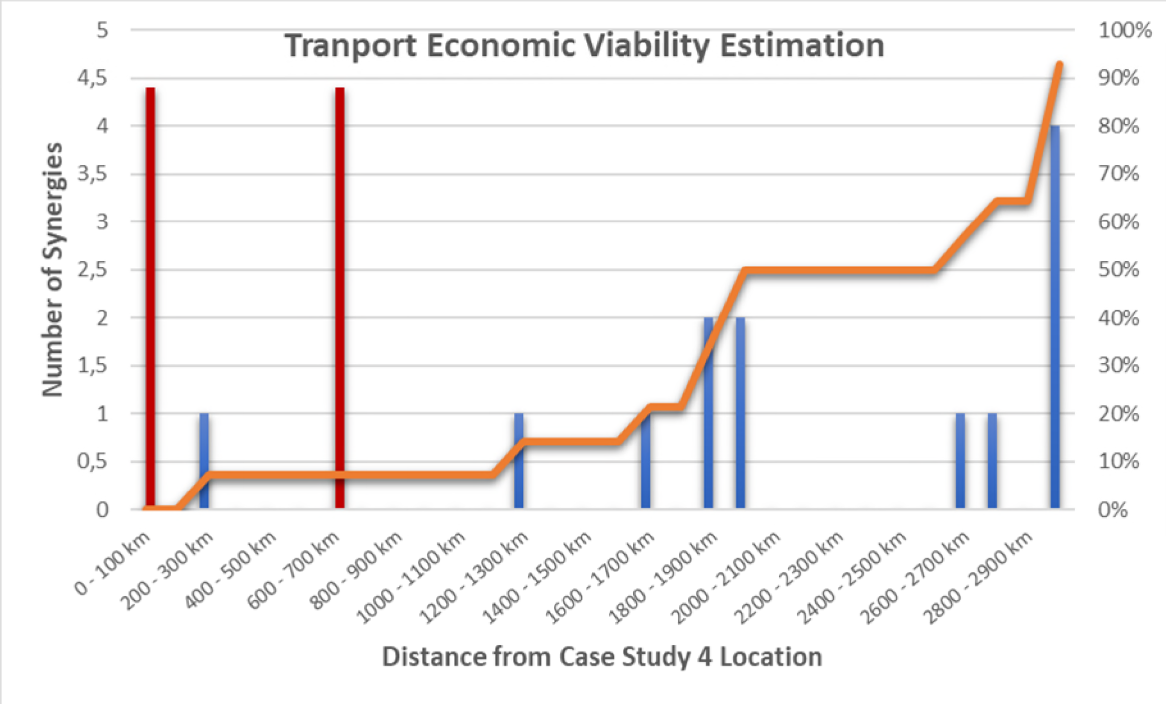

Figure 40 Transport viability estimation for bentonite and organoclay for CS4. (Source: Strane)

Conclusions

For CS4 bentonite could be an interesting alternative to not chlorine-based coagulant. Nevertheless, the partners research show that is very improbable to find a productor with whom a partnership is viable. Given the very small number of sites found, the logistic issues related to the transport of the resource, not possible by truck, in this region and the small volumes of the effluents treated by CS4 process, this synergy is not likely to have success. It is not recommended for further study.

If CS4 would like to apply the findings of CS3 to its project, three other main issues to address with this application if CS3 experiments are successful, are:

- Compatibility with a mobile and reduced in scale treatment.
- Compatibility with CS4 research schedule.
- An interview with closest site to confirm interest in a partnership.

5.1.7.1.3.Conclusions

Given that the database of the European Bentonite Association encompasses 90% of Bentonite production, there is little probability that significant or viable partners could be added to the list for a survey. Because of the nature of the industry this IS does not have a high probability of being achieved as there is no volume in the opportunities. For CS3, given that this is already part of their ULTIMATE activities, if technical feasibility is confirmed in ARETUSA's WTP equipment, the sites found in these tasks could function as backup in case search for partners needs to be restarted.

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Since the technical feasibility assessment is precisely one of the main missions of CS3, the work of this CS in the project has and will follow a part of IS creation process already, so this IS is to be explored.

The subject of applicability of an alternative coagulant to the process of CS4 is interesting but experimental and nor directly transferred from CS3 activities. That and the very scarce potential partners in the vicinity make the exploration of this IS not advisable.

5.1.7.2. Other coagulants

In **Section 5.1.2**, aluminium sludge as a potential secondary raw material for coagulant was analysed. They could work as a partial substitute for coagulant needs in the coagulation/flocculation step and in the conditioning and dewatering of the sludge produced by the WWTP. A partner research will not be done for this, as CS2 has a treatment that is already stablished with a ferric-based coagulant, for CS3, they have their own production of aluminium sludge and are looking for an outlet, and finally, CS4 is looking for a chlorine free option, which discards the option of this type of material.

5.1.7.3. Conclusions

Coagulant recovery and recycling are very desirable WT industry goals. It offers many potential benefits in reduction of coagulant chemicals demand and avoidance of waste generation and subsequent treatment. However, the nature of this type of enterprise, its current experimental nature, and the lack of demonstration at an industrial level are current roadblocks. There need to be research that can prove that recycled coagulants can be viable substitutes. This means, demonstrating that the treatment quality produced with the recycled coagulants is equivalent of that obtained with the primary commercial coagulants.

Some of these activities will be performed for the bentonite and organoclay for the CS3 and the application of the results for other CS could be assessed in the future by looking at the most similar treatments and effluents to that of the ARETUSA plant. For the present of the project, CS3 IS is the only one that shows promise.

5.1.8. Flow 8: Water Disinfection Agents

5.1.8.1. Residual Hydrogen Peroxyde

Objective of the flow valorisation

As was mentioned in **Section 3** of this report, it is part of CS3 project to test the pertinence and effectivity of industrial by-products in WW treatments. One of those by-products which is commonly used in the disinfection stage of some WWT is residual Hydrogen Peroxide. This would mean that if the technical feasibility was proven, then this type of IS could have good opportunity for replication in other European sites, including CS2.

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5.1.8.1.1.Sector's identification and technical screening

After a preliminary study, it was found that sites that could produce this type of residual Hydrogen Peroxide were very scarce in the areas there were looked for. A significant number of sites in the vicinity of CS2 and CS3 were not found. There is not enough volume of possibilities to justify a field study. These results are Shown in for Figure 41 for CS2 and Figure 42 for CS3 (The only location found was the Solvay site, already identified by CS3), as well as Table 52 and Table 53.

Figure 41 Map of sites potentially generating residual hydrogen peroxide for CS2. (Source: Strane)

Table 52 Table of hydrogen peroxide potential synergies for CS2. (Source: Strane)

Distance (km)	Potential synergies
50	1
150	3
250	3
500	5

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Figure 42 Map of sites potentially generating residual bentonite and organoclay for CS3. (Source: Strane)

Table 53 Table of hydrogen peroxide potential synergies for CS3. (Source: Strane)

Distance (km)	Potential synergies
50	1
100	1
500	1

Furthermore, after UNIVPM analysis of residual Hydrogen Peroxide that was being considered as disinfecting agent, it was concluded that the concentration of this subproduct was not enough to be used for the UWWT. This is the reason why this flow will no longer be considered nor further assessed in Task 5.1.

5.1.9. Flow 9: Filtration and Adsorption Agent

5.1.9.1. Hydrochar

Due to lack of data available on the subject, this flow will not be analysed in task 5.1.

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5.1.10. Flow 10: Polyphenols

Due to lack of data available at the time of realisation of this study, this flow will not be analysed in task 5.1.

5.2. Final shortlist of synergies

5.2.1. Prioritisation process

The analysis performed of the 9 flows lead to a screening assessment of 20 synergies. Those 20 are cited on Table 54, Table 55 and Table 56. Each flow could be involved in more than one synergy.

In order to compare synergies with each other, a prioritisation process was applied. It was based on relevant criteria for IS creation to determine which ones are promising enough to be considered for further research. The assessment criteria selected were the following ones:

- **Number of CS concerned.**
- **Amount of material involved.**
- **Market value of the resource.**
- **Treatment needed: technical difficulty, maturity of the technology or process involved**
- **Number of potential receivers within a viable radius.**
- **Potential for replication in Europe.**
- **Environmental Benefits.**
- **Regulatory issues or aspects**

The objective is to categorise the synergies according to the following classification:

1. <u>**Promising synergy**</u>
    - **This synergy has a good potential to generate a revenue, savings on waste management costs, or savings on raw material procurements.**
    - **Technology to recover and transform the resource exists or is in development.**
    - **Significant number of partnership opportunities were found within a viable distance.**
2. <u>**Synergy not promising**</u>
    - **There is not sufficient prove that the material can be extracted and reused conveniently.**
    - **The number of potential partnerships found in the vicinity is limited.**
3. <u>**Promising synergy concept**</u>
    - **The material is abundant, valuable or the synergy has an important replicability potential.**
    - **The technical and/or economic feasibility need to be further studied.**
4. <u>**Inconclusive**</u>

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- **Not enough data available at this stage of the project to do an assessment.**
- **Is advisable to reassess later in the project because the material is abundant, valuable or the synergy has an important replicability potential.**

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Table 54 Prioritisation process synthetic table

	Flow	CS	Type of Synergy	Selected Receiving/Producing Sector	Quantities Involved	Market Value of the primary raw material	Pre or Post Treatment	Viability Radius	Maturity of Technology or Process	Barriers	Preliminary Replication Potential	Environmental Benefits
Promising Synergy	**Sodium Bisulphite**	CS8 Saint Maurice l'Exil	CS8 produces Sodium Bisulphite as a by-product from its flue gas scrubbing and sells it as a secondary raw material. Direct Synergy.	Paper Industry WWTP Others: Leather Tanning, Flue gas treatment	3000 t/y	300 -320 USD/t for a technical grade Sodium Metabisulphite salt. Source: Echemi May 2021	None Only internal process of SUEZ	356 km 45 sites within viability radius	Industrial Pilot in ULTIMATE TRL :6 at the end of the project	• **Technical Feasibility being confirmed by ULTIMATE project.** • **Regulatory aspects to be explored in detail because of potential barriers in 2 criteria**	Low	• **Eliminates the need to treat SUEZ's WW for Sulphur content** • **Use of a secondary raw material**
Promising Synergy	**Aluminium Sludge**	CS3 Rosignano	CS3 water treatments produce an aluminium sludge that can be valorised by backed clay construction material producers as well as desulphuring agent in WWTP. Material post treatment before reuse by a third party or direct synergy.	Manufacture of tiles and bricks in backed clay Others: Land based application, gas purification, decontamination of water and soil	For a common water potabilization plant treating between 30 000 and 40 000 m³/day, there would be a production of 750 – 1000 tones/year of sludge. (Source: Strane's Industrial partner)	16 USD/t for clay for construction Source: Statista May 2021	Post-treatment: Drying, then with binding elements and new clay.	56 km 1 site within viability radius	Experimental in laboratory scale. TRL: 6	• **Scaling up of the technology needs to be proven in an industrial pilot.** • **Regulatory and administrative activities need to be considered. The resource is currently being considered a waste material, so end of waste status likely applies.** • **Regulatory and certification activities corresponding to the insertion in the market of construction materials manufactured with the new materials.**	Medium	• **Applies circularity to the sludge waste management.** **Reduction on primary raw materials demand in a very resource demanding and impactful sector.** **Reduction of waste management activities and diverting material from landfill.**
Promising Synergy	**Aluminium Sludge**	CS3 Rosignano	CS3 water treatments produce an aluminium sludge that can be valorised by other WWTP as aid for coagulation or conditioning and dewatering of sludge. Material post treatment before reuse by a third party or direct synergy.	Industrial or urban WWTP Others: Land based application, gas purification, decontamination of water and soil	For a common water potabilization plant treating between 30 000 and 40 000 m³/day, there would be a production of 750 – 1000 tones/year of sludge. (Source: Strane's Industrial partner)	200 - 280 USD/MT for aluminium based coagulant Source: Echemi May 2021	Post-treatment: Aluminium fraction recovery by chemical processing and mixing with new coagulant	700 km 184 sites within viability radius	Experimental in laboratory and WWTP. TRL: 6	• **Scaling up of the technology needs to be proven in an industrial pilot.** • **Regulatory and administrative activities need to be considered. The resource is currently being considered a waste material, so end of waste status likely applies.** • **Regulatory activities corresponding to the use of a former waste to treat water.**	High	• **Closes the loop on coagulation process of WT.** **Applies circularity to the sludge waste management.** **Reduction on primary raw materials demand.** **Reduction of waste management activities and diverting material from landfill.**
Not analysed due to lack of data but Promising Synergy	**Ammonia**	CS7 Tain	CS7 produces an ammonia solution or precipitate from its effluents to commercialise.	Agriculture	180 kg/day of NH4-N.		None	To be defined	Industrial Pilot in ULTIMATE. TRL 7 at the end of the project	• **Experimental phase during ULTIMATE project. Not the type of ammonia to produce, nor technology that will be used are selected.** • **Technology is very specific to the demonstration including the building on a very particular Aquabio treatment that is customized to the distillery.**	Low	• **Closes the loop on nutrient recovery of WWT.** **Eliminates current nutrient excess going to surface water.** **Reduction on primary raw materials demand by offering a sustainable fertilizer option.** **Valorisation of a material instead of eliminating it.**
Promising synergy	**Lime**	CS8 Sain't Maurice l'Exil	The paper industry generates a lime sludge that could be implemented as a partial or total substitute for lime milk used to treat flue gas and sodium bisulphite production for CS8. Required pre-treatment by a third party or direct synergy.	Paper Industry Others: Sugar Production, Lime klin dust	700-800 m3/year of 23% lime milk	224.7 €/t Source: Strane	Pre-treatment: Impurity Removal and calcination	770 km 156 sites within viability radius	Experimental TRL: 5	• **Potential compatibility issues between the composition of the lime sludge and the sodium bisulphite production.** • **Regulatory and administrative activities to be considered in use of a waste. Likely to be minimal or inexistence as SUEZ already handles waste.** • Potential investment needed.	Medium	• Reduction of waste management activities and diverting material from landfill. Reduction on primary raw materials demand.

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Table 55 Prioritisation process synthetic table

	Flow	CS	Type of Synergy	Selected Receiving/Producing Sector	Quantities Involved	Market Value of the primary raw material	Pre or Post Treatment	Viability Radius	Maturity of Technology or Process	Barriers	Preliminary Replication Potential	Environmental Benefits
Promising synergy	Water for Irrigation	CS3 Rosignano	CS is the resource generator. Direct Synergy	Agriculture	To be defined during ULTIMATE project	Dependant on location	None	10 km 3 agricultural sites within viability radius	Industrial Pilot construction TRL: 7	• Scaling up of the technology needs to be proven in an industrial pilot. • Regulatory and administrative activities need to be considered.	High	• Reduction of water pressure resource.
Promising synergy	Water for Irrigation	CS4 Nafplio	CS is the resource generator. Direct Synergy	Agriculture	To be defined during ULTIMATE project	Dependant on location	None	10 km	Industrial Pilot construction TRL: 7	• Scaling up of the technology needs to be proven in an industrial pilot. • Regulatory and administrative activities need to be considered	High	• Reduction of water pressure resource.
Promising synergy	Sodium Hydroxide	CS5 Lleida	The paper and pulp industry produces an effluent from which Sodium hydroxide can be extracted and used in CS5 as pH corrector. Depending on the WWTP of the industrial site, could be a direct synergy.	Paper Industry Textile Industry	1 kg/m3 of treated water which will amount to about 550 kg/day	350 USD/ton Source: Echemi May 2021	Pre-treatment: Extraction from effluents and purification.	900 km 141 sites found within viability radius	Experimental TRL: 5	• Investment needed. • Not industrial applications found.	Medium	• Recovering of material instead of effluent treatment • Use of a secondary raw material
Promising synergy	Bentonite/Organoclay	CS3 Rosignano	Sites producing bentonite as main activity generate residual bentonite and organoclay that could be used by WWTP of CS3 as an alternative coagulant and adsorber. Direct synergy.	Bentonite Production Industry	To be defined during ULTIMATE project	200 - 280 USD/MT Source: Echemi	To be defined	700 km 3 sites within viability radius	Experimental. Industrial Pilot. TRL: 7	• Specific mineral material that doesn't have numerous production sites close to the CS. • Technical application not yet confirmed.	Low	Bentonite • Avoiding waste of valuable residual matter. Organoclay • Valorisation of waste instead of treatment. • Reduction in demand of a non-sustainable raw material.
Promising synergy	Polyphenols	CS4 Nafplio	The effluents produced by the CS4 Alberta's fruit and vegetable processing WW contain phenols that can be used by the superfoods, cosmetics, and pharmaceutical industry.	Superfoods Cosmetics Pharmaceutics	To be defined during ULTIMATE project	Up to 150-374 €/kg	None	To be defined	Industrial Pilot in ULTIMATE TRL: 7	• Technical Feasibility being confirmed by ULTIMATE project. • Regulatory aspects to be explored in detail.	High	• Recovering of material instead of effluent treatment. • Use of a secondary raw material
Promising synergy	Polyphenols	CS6 Karmiel	The effluents produced by the OMWW CS6 contain phenols that can be used by the superfoods, cosmetics, and pharmaceutical industry.	Superfoods Cosmetics Pharmaceutics	To be defined during ULTIMATE project	Up to 150-374 €/kg	None	To be defined	Industrial Pilot in ULTIMATE TRL: 7	• Technical Feasibility being confirmed by ULTIMATE project. • Regulatory aspects to be explored in detail.	High	• Recovering of material instead of effluent treatment. • Use of a secondary raw material
Inconclusive	Sodium Hydroxide	CS7 Tain	The paper and pulp industry produces an effluent from which Sodium hydroxide can be extracted and used in CS7. Depending on the WWTP of the industrial site, could be a direct synergy.	Paper Industry Textile Industry	To be defined during ULTIMATE project	350 USD/ton Source: Echemi May 2021	Pre-treatment: Extraction from effluents and purification.	900 km 43 sites found within viability radius	Experimental TRL: 5	• Investment needed. • Low price of the resource. • Low number of potential partners found.	Medium	• Recovering of material instead of effluent treatment Use of a secondary raw material.
Synergy not promising	Hydrochloric Acid	CS4 Nafplio	Basic chemical industries and/or steel production can generate a HCl solution that can be recovered and used by CS4 as a pH corrector in water treatment. Extraction by the partner and purification treatment needed in house or by a third party. Direct synergy or three partner synergy.	Basic Chemical Industry Steel production and treatment Other: Aluminium production, Titanium dioxide production, Ethylene production	To be defined during ULTIMATE project	29 €/MT Source: Echemi May 2021	Pre-treatment: Extraction from effluents and purification.	100 Km No sites found within viability radius	Industrial scale TRL: 7-8	• Investment needed. • Low price of the resource. • No potential partners found. • Captive production for steel production. • Concentration of the effluent not compatible with the use in WWTP	Low	• Recovering of material instead of effluent treatment and reduction of material for that treatment. • Use of a secondary raw material.

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Table 56 Prioritisation process synthetic table

	Flow	CS	Type of Synergy	Selected Receiving/Producing Sector	Quantities Involved	Market Value of the primary raw material	Pre or Post Treatment	Viability Radius	Maturity of Technology or Process	Barriers	Preliminary Replication Potential	Environmental Benefits
Synergy not promising	**Hydrochloric Acid**	CS5 Lleida	Basic chemical industries, steel production and/or ethylene dichloride/vinyl production can generate a HCl solution that can be recovered and used by CS4 as a pH corrector in water treatment. Extraction by the partner and purification treatment needed in house or by a third party. Direct synergy or three partner synergy.	Basic Chemical Industry Ethylene dichloride/vinyl production Steel production and treatment Other: Aluminium and Titanium dioxide production	0.5 kg/m3 of treated water which will amount to about 275 kg/day	29 €/MT Source: Echemi May 2021	Pre-treatment: Extraction from effluents and purification.	100 Km 1 site found within viability radius	Industrial Scale TRL: 8-9	• **Investment needed.** • **Low price of the resource.** • **Low number of potential partners found.** • **Captive production for Ethylene and steel production and steel production** • **Concentration of the effluent not compatible with the use in WWTP**	Low	• **Recovering of material instead of effluent treatment** • **Use of a secondary raw material**
Synergy not promising	**Hydrochloric Acid**	CS8 Sain't Maurice l'Exil	Basic chemical industries, steel production and/or ethylene dichloride/vinyl production can generate a HCl solution that can be recovered and used by CS4 as a ph corrector in water treatment. Extraction by the partner and purification treatment needed in house or by a third party. Direct synergy or three partner synergy.	Basic Chemical Industry Ethylene dichloride/vinyl production Steel production and treatment Other: Aluminium and, Titanium dioxide production	1800-2000 t/an	29 €/MT Source: Echemi May 2021	Pre-treatment: Extraction from effluents and purification.	100 km 4 sites found within viability radius	Industrial application TRL: 8-9	• **Investment needed.** • **Low price of the resource.** • **Low number of potential partners found.** • **Captive production for Ethylene and steel production and steel production.** • **Concentration of the effluent not compatible with the use in WWTP**	Low	• **Recovering of material instead of effluent treatment** • **Use of a secondary raw material**
Synergy not promising	**Sulphuric Acid**	C5 Lleida	Slaughterhouses can generate a H2SO4 solution that can be recovered and used by CS4 as a pH corrector in water treatment. Extraction by the partner and purification treatment needed in house or by a third party. Direct synergy or three partner synergy.	Slaughterhouses Other: lead and tin production	0.5 kg/m3 of treated water which will amount to about 275 kg/day	75 €/MT Source: Echemi May 2021	Pre-treatment: Extraction from effluents and purification.	256 km 44 sites found within viability radius	Theoretical TRL: 1	• **Sulphuric acid used has a low concentration, likely insufficient for the application. Other sources could be more promising from the technical point of view.**	Low	• **Recovering of material instead of effluent treatment.** • **Use of a secondary raw material.**
Synergy not promising	**Sulphuric Acid**	CS7 Tain	Slaughterhouses can generate a H2SO4 solution that can be recovered and used by CS4 as a pH corrector in water treatment. Extraction by the partner and purification treatment needed in house or by a third party. Direct synergy or three partner synergy.	Slaughterhouse Other: lead and tin production	To be defined during ULTIMATE project	75 €/MT Source: Echemi May 2021	Pre-treatment: Extraction from effluents and purification.	256 km No sites found within viability radius	Theoretical TRL: 1	• **Sulphuric acid used has a low concentration, likely insufficient for the application.** • **The possibility of recovery is not proven.**	Low	• **Recovering of material instead of effluent treatment** • **Use of a secondary raw material**
Synergy not promising	**Hydrogen Peroxide**	CS2 Netherlands	Sites producing hydrogen peroxide as main activity can generate residual hydrogen peroxide that could be used by WWTP of CS2 as an alternative. Direct synergy.	Hydrogen Peroxide Industry	To be defined during ULTIMATE project	167.5 USD/MT Source: Echemi May 21	None.	470 km 5 sites found within viability radius	Experimental. Industrial Pilot. TRL: 6	• **Technical feasibility was not confirmed due to low concentration of the residual hydrogen peroxide.** • Very few sites found within the viability radius.	Low	• **Avoiding waste of valuable residual matter.** • **Reduction in the demand of primary raw materials.**
Synergy not promising	**Hydrogen Peroxide**	CS3 Rosignano	Sites producing hydrogen peroxide as main activity can generate residual hydrogen peroxide that could be used by WWTP of CS3 as an alternative. Direct synergy.	Hydrogen Peroxide Industry	To be defined during ULTIMATE project	167.5 USD/MT Source: Echemi May 21	None.	470 km 1 site found within viability radius	Experimental. Industrial Pilot. TRL: 6	• **Technical feasibility was not confirmed due to low concentration of the residual hydrogen peroxide.** • **Only one site found in the viability radius.**	Low	• **Avoiding waste of valuable residual matter.** • **Reduction in the demand of primary raw materials.**

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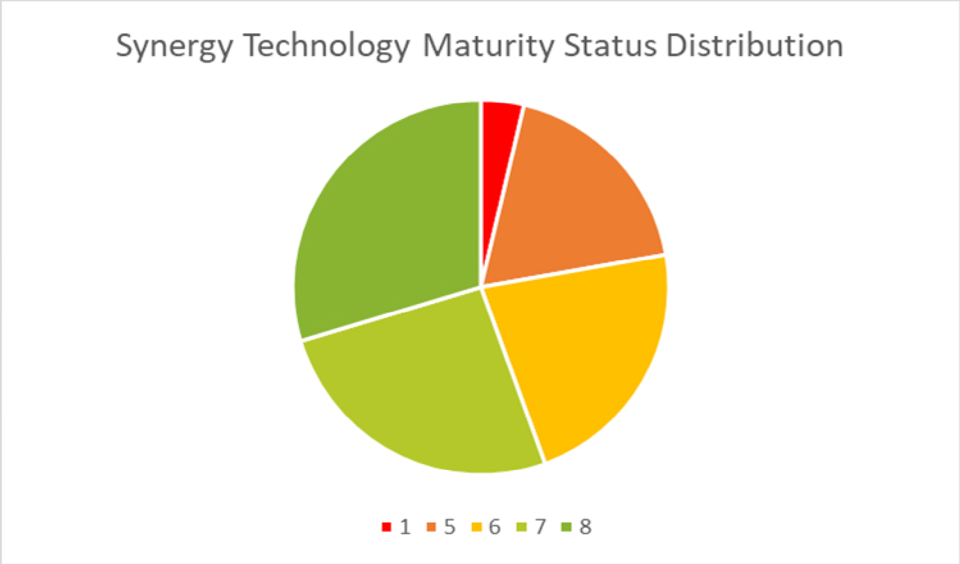

Figure 43 Technology maturity status of researched synergies.

The tables above show a synthesis of all the information and quantitative (if available)/qualitative analysis performed during synergy identification. They also show a general landscape on what the synergy represents for the case study, why it is interesting and whether the technology involved is mature enough or not to pursue action. Figure 43 shows that a quarter of the synergies explored have already been proven at an industrial scale, which simplifies its application to ULTIMATE's CS and enable to focus on the replication potential. Around half of the synergies will be tested as pilots in ULTIMATE, whether as demonstration of concept pilot or in full industrial scale. The technical feasibility will be confirmed or not during the project. The synergies that are considered as theoretical correspond to a sulphuric acid effluent. They are automatically ruled out because the maturity is still not high enough. The rest of them can be considered when the other criteria are favourable.

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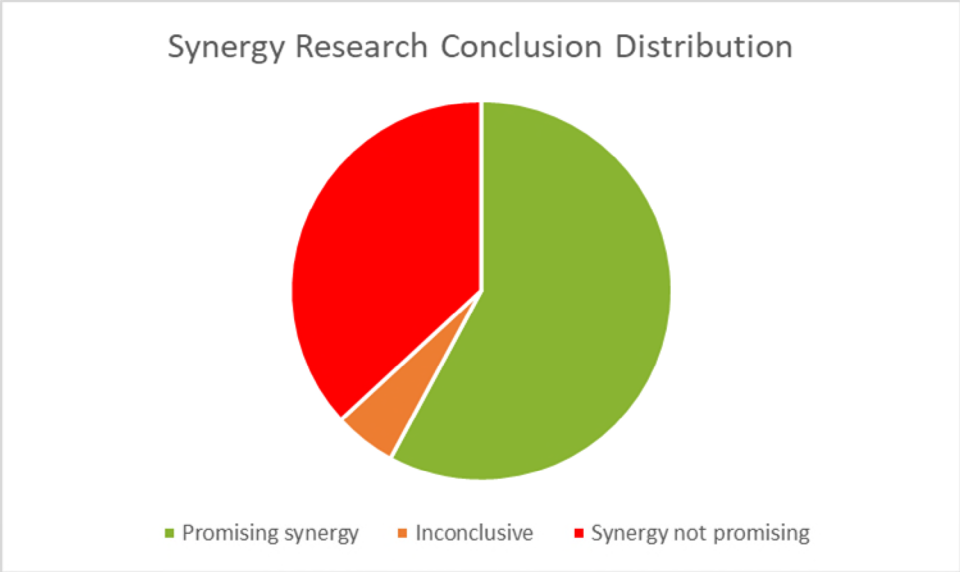

Figure 44 Synergy Research Conclusion Distribution.

From the 17 synergies assessed, almost half are not promising (37%), and further study is not advised. A little over half are considered promising (58) and 5% was either not analysed or inconclusive, this corresponds to a synergy. This distribution is represented in the graphic on Figure 44.

The synthetic tables show the number of opportunities found for each synergy. As explained before, the number of opportunities depends on the resource price and the CS location. The CS location was a key factor. The CS located in rural areas are significantly less dense in industrial activity, which translated in a low number of opportunities.

In total, 9 synergies could be implemented with the shortlisted resources.

This analysis and conclusions allowed to form a final shortlist of the synergies with their associated potential. This sample is promising and present a high probability of being implemented. This is the main result of ULTIMATE's 5.1 task and is shown in the next section.

5.2.2. Final shortlist and associated impact

The prioritisation process resulted in a shortlist of 11 synergies that have a potential to be pursued and/or further analysed. This averages to 1 synergy per CS. However, the exploration resulted in several CS implicated in more than one synergy and others are not implicated. In consequence, some CS have no further action to pursue in the immediate future with respect to synergy exploration.

Table 57 and Table 58 down below present the final shortlist containing:

- **The synergy**

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- **The implicated actors**
- **The associated impacts**
- **The follow-up actions.**

The associated impact constitutes a qualitative estimation on of economic and environmental benefits of synergies. It is a first rough estimation on analysing what does the synergy mean for each CS and its synergy partners. To fully address the impact, an in-depth study in close partnership with CS leaders, technology developers and industrial stakeholders is needed. To make a full environmental impact of the synergies explored, a complete Life Cycle Analysis, including end of life stage, should be performed.

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Table 57 Elements 1 to 5 of ULTIMATE's IS shortlist

CS	CS role	Synergy	Impact	Recommended action
CS3 Rosignano	Producer	Aluminium Sludge produced by CS3 WTP and WWTP to be received by clay bricks and tiles producers	• **Revenue of approximately 10 €/MT for CS3** • **Reduction in solid waste disposal for CS3. Current disposal cost amounts close to 100 €/t of sludge. For a WTP processing around 35 000 m3/day savings could amount to 87 500 €/year.** • **Savings of approximately 30% in raw material cost for receiver. For the same type of plant and an average production of sludge of 875 t/year, a revenue of 8 750 €/year (for construction use).**	Concept Study focused on reduction of waste management cost and partner search.
CS3 Rosignano	Producer	Aluminium Sludge produced by CS3 WTP and WWTP to be received by other WWTP	• **Revenue of approximately 124 €/t for CS3** • **Reduction in solid waste disposal for CS3. Current disposal cost amounts close to 100 €/t of sludge. For a WTP. For a WTP processing around 35 000 m3/day savings could amount to 87 500 €/year.** • **Savings of approximately 30% in raw material cost for receiver. For the same type of plant and an average production of sludge of 875 t/year, a revenue of 107 625 €/year (for WWT use).** • **Material flow recycled.**	Concept Study focused on partner search.
CS3 Rosignano	Producer	Water for Irrigation produced from CS3 UWWTP for agricultural land in the proximity	• **Savings on freshwater of 10m3/day for UTLIMATE pilot**	Ongoing Synergy study: Technical feasibility Next step: Partner search and logistics set up
CS3 Rosignano	Receiver	Bentonite/Organoclay generated by bentonite producers and received by CS3 to be used as a coagulant and adsorber.	• **Savings in raw coagulator cost for CS3.** • **Reduction in solid waste disposal for the emitter (for the organoclay)**	Ongoing Synergy study: Technical feasibility Next step: Marker study and partner search survey
CS4 Nafplio	Producer	Water for Irrigation from CS4 produced by Alberta's agro-food site WWTP for agricultural land in the proximity.	• **Savings on freshwater of 10m3/day for UTLIMATE pilot**	Synergy Study

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Table 58 Elements 6 to 11 of ULTIMATE's IS shortlist

CS	CS role	Synergy	Impact	Recommended action
CS4 Nafplio	Producer	The effluents produced by the CS4 Alberta's fruit and vegetable processing WW contain phenols that can be used by the superfoods, cosmetics, and pharmaceutical industry.	• **Revenue of approximately 150-374 €/kg for CS4** • **Improvement of WWT efficiency** • **Savings of approximately 20% in phenols supply for the receiving sector**	Ongoing Synergy study: Technical feasibility Next step: Marker study and partner search survey
CS5 Lleida	Receiver	The paper and pulp industry produces an effluent from which Sodium hydroxide that could beused in CS5 as pH corrector.	• **Savings of approximately 20% in lime cost for CS8. Could amount to 13 000 €/year.** • **Revenue of approximately 173 €/MT for the producer**	Concept Study focused on technical feasibility
CS6 Karmiel	Producer	The effluents produced by the OMWW CS6 contain phenols that can be used by the superfoods, cosmetics, and pharmaceutical industry.	• **Revenue of approximately €/kg for CS6** • **Improvement of WWT efficiency** • **Savings of approximately 20% in phenols supply for the receiving sector.**	Ongoing Synergy study: Technical feasibility Next step: Market study and partner search survey
CS7 Tain	Producer	Grenmorangie distillery can extract ammonia products from its effluents to be introduced on fertilizer production or directly into agriculture.	• **Revenue from the sell of ammonia to farmers.** • **Eliminating the high ammonia content from effluents diverted into nature.**	Ongoing Synergy study: Technical feasibility Next step: Market study and partner search survey
CS8 Sain't Maurice l'Exil	Producer	CS8 produces Sodium Bisulphite which can be received by paper and pulp producers. Direct Synergy.	• **Revenue of approximately 62 €/MT depending on the purity for CS8, 186 000 €/year.** • **Reduction of sulphur in the WW.** • **Savings in carbon tax to be calculated.** • **Savings of approximately 30% in raw material cost for CS8**	Ongoing Synergy study: Technical feasibility Next step: Marker study and partner search survey
CS8 Sain't Maurice l'Exil	Receiver	The paper industry generates a lime sludge to be used by CS8 in flue gas treatment and sodium bisulphite production.	• **Savings of approximately 900 € per 10 tonnes of substituted lime. Potential conservative revenue: 1 340 € per 10 tonnes of substituted lime.** • **Reduction in solid waste disposal cost for the emitter**	Synergy Study focus on technical feasibility verification and partner research

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Of a total of 9 Case Studies in ULTMATE project, only 6 have actions to pursue from the pool of synergies studied during task 5.1. This is not final for the whole process but specific to this task as there will be other synergies for the consortium to pursue. From the 10 different categories of materials resources explored, 8 were found relevant for further study. Key factors for the selection (synergies and CS) were the technical potential, maturity, the associated impact, and the existence of potential partners within an acceptable distance.

Most synergies involve a CS in the producing end of the synergy which means the preliminary work and regulatory aspects of the synergies will largely be on ULTIMATE's partners and stakeholder's side.

IS involving CS8 are the most promising due to technical and economic aspects and the fact that relevant actors are found in the vicinity.

IS options involving CS 3 are the most numerous as this CS is heavily focused on material recovery and reuse.

The associated impact is in general a reduction of demand in primary raw materials and a reduction in the need to treat solid waste and liquid effluents. These synergies could also divert important volumes of waste from landfill. Waste management expenses, including pollution taxation, can be avoided.

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6. Conclusion

6.1. Conclusion on the synergy identification phase

This study's objective was to generate two main results:

1. **Generate a shortlist of synergies that could be pursued during the project lifetime and after.**
2. **Generate a baseline knowledge on industrial flows on ULTIMATE CS to support exploitation activities.**

For the first one, the methodology for IS research conceived during the European SCALER project was used. Due to the nature of ULTIMATE and the current stage of the project, adaptations to this methodology were done. For Task 5.1, it consisted of:

1. **Analysis of CS activities and Input / Output flows and identification of relevant opportunities.**
2. **Research of some material synergies to explore and assess.**
3. **Synergy screening: preliminary technical review, potential partners opportunities research and transportation viability assessment, and revision on some regulatory aspects.**

The results were represented in **Section 5.2** of this document along with the prioritization criteria for this early stage and the final Shortlist.

The use of Strane Matchmaking tool and other industrial internal databases was crucial in the finding of synergy opportunities to explore. Due to the applications of the industrial sectors of ULTIMATE, these tools were expanded from the data available.

Repeated material and valuable resources flows were analysed in order to maximize impact. Nevertheless, those were not necessarily the most successful due to the availability of the technologies available to recover materials and their price point. It was found that the most promising synergies where the ones with a higher raw material price. This has probably been an important driver allowing for more abundant information and technology on them. It was also found that certain CS are more eligible for the IS exploration and application progress due to its type of activity and location in industrial zones.

6.2. Recommendation

More than half of the synergies explored in **Section 5** resulted in successful findings, which means value and potential for synergy implementation exist, and need dedicated deeper studies: a full research methodology for 8 and concept studies for 3. The synergies that were marked as inconclusive or not analysed need to be re-addressed later in the project when more information is available.

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A global quantitative approach to this analysis is recommended, as the results will work as a driver for synergy creation. Both from the economical and the environmental point of view.

A good number of IS opportunities are not yet available at an industrial scale but are a clue into what opportunities could be available in the near future. This is why projects like ULTIMATE are so important for the implementation of an EC logic in the European context.

The conception on bilateral and non-conventional business models and IS arrangements could be very useful and facilitate the application of the IS. For example, given that the paper industry is at the same time susceptible of requiring SUEZ's Sodium Bisulphite and producing a lime sludge for the CS8 there is the potential for a partnership. With the support of Strane, Suez and a site from the paper industry could work on establishing a symbiotic relationship with several paper production installations nearby to implement the material transfer of a lime substitute and sodium bisulphite. This is key as the flexibility to build new arrangement and business models could be crucial in the decision of implementing an operating the synergy. CS, technology developers and Strane can work all together to build new operational material streams synergies implementation.

6.3. Perspectives

Strane can expand on the study of the promising synergies. It can be done in close collaboration with CS leaders and/or technology owners to assess all the technical and economic aspects. This work would lead to strong technical and business cases by applying the whole synergy implementation process.

Once the conclusions of the preliminary study are verified, business models and a synergy logistics can be developed in the most profitable and convenient way. Strane has the capabilities to support CS leaders and technology providers until the full implementation of the synergy.

There are several examples of synergies that seem promising from the experimental research, however there is no reports or not enough of scaling up of technologies. This shows the non-exploited potential of circularity in water treatment. This is particularly true for the case of mineral coagulants. The scaling up of such project would need a further study and probably complementary financing schemes. There is also work to do in the business model and logistics of this so it could represent an attractive enterprise.

The study of the replicability potential of all synergies that are explored is crucial for the SCALING up of ULTIMATE IS potential.

In ULTIMATE, there is an important potential in terms of material recovery that needs to be exploited as the project advances. At present, there is a very important roadblock in terms of lack of quantitative and qualitative data. This has not allowed to

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make in-dept, but this analyse works as a base for the exploitation in terms of synergy creation. But this barrier will naturally disappear as the project progresses.

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