D7.2 - Business Models and Financing Models Adapted to AquaSPICE Solutions

WP7 - Solution Uptake, Replication, Up-Scaling and Exploitation

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ABSTRACT	AquaSPICE aims to adopt different combinations of technologies and practices in industrial level, in order to facilitate further exploitation, upscaling of project results and possible replication to other industries, by providing strategic, business and organisations plans, together with concrete technological solutions. Work package 7 (WP) has been designed to facilitate this objective by providing solutions of further upscaling and exploitation of demonstrated solutions, which include a market analysis and a financial plan; identification of feasibility and applicability of demonstrated solutions and their market demand; and the development of exploitation plans and commercialisation of project's deliverables. Exploitation plans are also constructed as part of business models, which is the purpose of this deliverable. Deliverable 7.2 aims to build business plans and identify the potential commercial exploitation of AquaSPICE. A mapping of potential water and water treatment market demands with AquaSPICE technologies and industries determines possible upscaling opportunities for further expansion, and investment opportunities. A value distribution and cost-benefit analysis has also been conducted to examine the environmental, social and territorial impact of AquaSPICE in industrial partners, through the collection of primary data. Information visualised in the Business Model Canvas and cash-flow			

	analysis is of high importance because they are closely related to the main objective of this report. The potential of water reuse for industrial purposes has been identified and business models have been generated presenting business and commercial exploitation opportunities of AquaSPICE as a bundling service and WaterCPS only. The designed business models can be applied in diverse industries and serve as potential clients of AquaSPICE as they have been identified in this deliverable. Moreover, options for financing future exploitation plans have also been presented, to further enhance the exploitability potential.

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The cash flow analysis is based on theoretical estimates and not on real figures and it is performed for illustration purposes only.

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Table 1 ABBREVIATIONS/ACRONYMS

AOP	Advanced Oxidation Process	kg	Kilogram
AOX	Adsorbable Organic Halogen Compounds	km	Kilometre
AquaSPICE	Advancing Sustainability of Process Industries through Digital and Circular Water Use Innovations	KPRs	Key Project Results
BAC(F)	Biologically Activated Carbon (Filter)	L	Litre
BFW	Boiled Feed Water	m	Metre
BOD	Biochemical Oxygen Demand	m^2	Square Metre
CAGR	Compound Annual Growth Rate	m^3	Cubic Metre
CapEx	Capital Expenses	MABR	Membrane Aerated Bioreactor
CBA	Cost-Benefit Analysis	MBR	Membrane Bioreactor
CEPT	Chemically Enhanced Primary Treatment	mg	Milligram
CEFIC	European Chemical Industry Council	Min	Minimum
cm	Centimetre	mL	Millilitre
CO_2	Carbon Dioxide	mm	Millimetre
COAGL	Coagulation	NAFTA	North American Free Trade Agreement
COD	Chemical Oxygen Demand	NF	Nanofiltration
COP	Chemical oxo-precipitation	NH_4-N	Ammonium Nitrogen
CPS	Cyber Physical System	OpEx	Operational Expenses
CS	Case Study	P	Phosphorus
CTBD	Cooling Tower Blow Down	P&ID	Piping and Instrumentation Diagram
CTMU	Cooling Tower Make-Up	PFRO	Pulse Flow Reverse Osmosis
d	Day	pH	potential of hydrogen
DAF	Dissolved Air Flotation	PoA	Port of Antwerp
demin	Demineralized	ppm	Parts Per Million
DECARB	Decarbonised	POTWs	Publicly Owner Treatment Works
DCS	Distributed Control Systems	PPP	Public Private Partnership
diss	Dissolved	regen	Regeneration
DO	Dissolved Oxygen	RO	Reverse Osmosis
DOC	Dissolved Organic Carbon	RTM	Real-Time Monitoring
DSPW	Dilution Steam / Process Water	s	Second
e.g.	exempli gratia (for example)	SCAV	Scavenger
EDR	Electro Dialysis Reversal	SRF	Solid Recovered Fuel
ESG	Environmental, Social and Governance	TDS	Total Dissolved Solids
EU	European Union	TOC	Total Organic Carbon
FLOCC	Flocculation	TSS	Total Suspended Solids
FOG	Fat,Oil & Grease	UF	Ultrafiltration
FfP	Fit-for-Purpose	WAPEREUSE	Peroxidised Wastewater Reuse
g	Gramm	WCPs	Water Cyber Physical System
(B)GAC	(Biological) Granular Activated Carbon	WL	Water-link
h	Hour	WP	Work Package
i.e.	id est (that is)	WW	Wastewater
IEX	Ion Exchange	WWRP	Wastewater Reuse Plant
I(o)T	Internet of Things	WWTP	Wastewater Treatment Plant
ibid	ibīdem: “in the same place”	y	Year

1. Highlights

- The water treatment market has grown significantly the last decade and is expected to grow in the next one demonstrating high probability of success for a new venture.
- The business model for the new venture could be a software (WaterCPS) only cleantech startup.
- Then it could evolve into a full scale company following a “bundling service” business model, which could act as an option to expand after the first 5 years.
- Target customers for AquaSPICE are more likely to be large companies registered in the chemical and food and meat industry.
- The most appropriate source of finance seems to be equity crowdfunding and AquaSPICE venture could be located in Germany.

2. Executive summary

This report aims to identify and assess the value distribution of AquaSPICE technologies across early adopters (AquaSPICE Case studies) by examining the environmental, social and territorial impact of the project across various case studies, as well as by analyzing monetary and non-monetary externalities through primary data collection. A mapping of potential water and water treatment market demands with AquaSPICE technologies and industries will determine possible upscaling opportunities for further expansion, and investment opportunities. The potential of water reuse for industrial purposes will be identified and business models will be generated which will present business and commercial exploitation of WaterCPS, in diverse industries concerning AquaSPICE.

D7.2 is related to D7.4, D7.5 & D7.1 produced by STRANE which have identified AquaSPICE’s Key Exploitable Results (KERs) in each Case Study and as a whole. D7.2 aims to identify the market size and market needs at global and European level, to assess market potentials related to wastewater treatment processes and technologies and to make a cost-analysis for each CS for water saving. Moreover, D7.2 focuses on replication and potential business model of WaterCPS, focusing on specific industries replication such as the chemicals-petrochemicals, food and meat processing and oil refineries.

First an analysis about the global and European water treatment market is conducted and shows significant growth in the last five years and high growth potential. The size of water treatment market was in 2021 was $281.75b and is expected to grow at $489.07b in 2029. This represents a 73.58% increase. The European water treatment market is expected to growth as well in the next five years with a cumulative growth rate at around 3%. The North American market however is the largest.

This study also investigates what may be the most appropriate business model for AquaSPICE drawing on case study specific results. They show that several technology combinations might be profitable when upscaling and that a key competitive advantage is the “WaterCPS” technology. This can be launched as a standalone venture in the form of a cleantech startup. However, our analysis suggests that there is a considerable incremental value derived from a customized combination of related technologies. Therefore, we suggest that the evolution of a software only cleantech startup into an “on demand” customization and installation of a combination of technologies following a “bundling service” business model is a rather valuable option to expand.

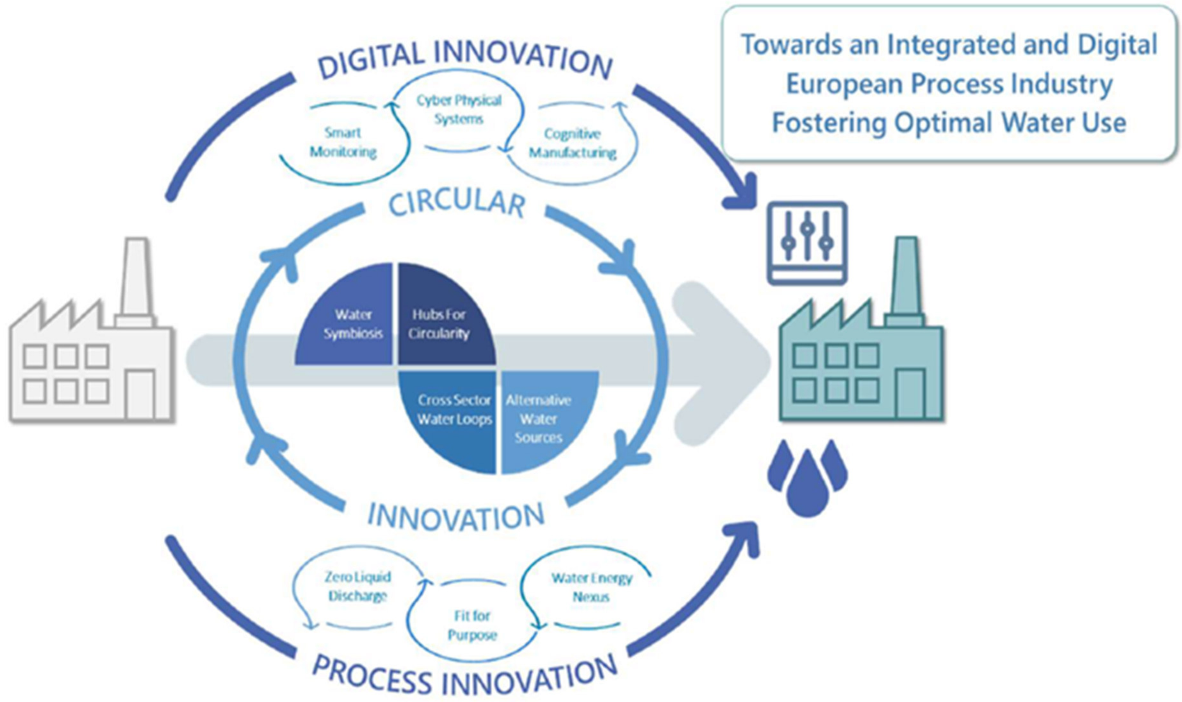
Finally, it concludes by investigating what type of industries/companies may be more likely to buy services from the AquaSPICE venture. The analysis suggests that large companies registered in the meat and food, and chemical industry group are more likely to use services from AquaSPICE. Moreover, an appropriate source of finance seems to be equity crowdfunding and AquaSPICE startup could be located in Germany.

3. Introduction

Advancing Sustainability of Process Industries through Digital and Circular Water Use Innovations (AquaSPICE) aims at materializing circular use of water use within particular industrial processes in the European market, with the ultimate purpose of fostering awareness in resource-efficiency and delivering concrete solutions for industrial applications. This process has been enhanced by:

1) fostering the industrial deployment of innovative water treatment and reuse technologies;
2) establishing closed-loops practices regarding water, energy and substances;
3) establishing a novel system of digital innovation based on water-specific *Cyber-Physical-System (WaterCPS)*, which synthesises digital twinning, real-time monitoring and optimisation processes for water efficiency in industrial processes within the current value chain.
4) providing an effective organisational, regulatory and business framework.

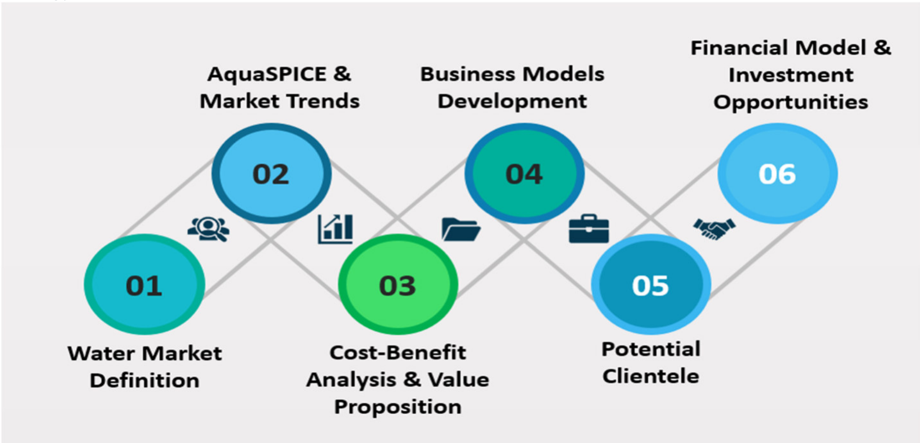
Figure 1. Innovation and Water Use



Through a systemic approach in water management, AquaSPICE aims to adopt different combinations of technologies and practices in industrial level, in order to facilitate further exploitation, upscaling of project results and possible replication to other industries, by providing strategic, business and organisations plans, together with concrete technological solutions. Work package 7 (WP) has been designed to facilitate this objective by providing solutions of further upscaling and exploitation of demonstrated solutions, through:

- Conducting a market and financial analysis;
- Propose upscaling plans;
- Identify the feasibility and applicability of various technologies;
- Develop business models;
- Design exploitation plans;
- Provide interoperability and standardization recommendations.

Figure 2. Methodology Outline



The overall aim of Deliverable 7.2 is to propose a business plan for the exploitation of technologies or technology combinations implemented in AquaSPICE and potential upscaling opportunities. The primary objective is to identify whether a market exists for these technologies and what the value of the market might be. This (No 1 in Figure 2) is the first tangible objective in this study, that is developed further in Chapter 5. For a business plan to be viable, a sizeable and growing market is a pre-requisite. The material in Chapter 5 complements the content of Deliverable 7.1, by focusing on the assessment of the water and water treatment markets, in order to assess whether a new venture can be successful.

The next step in our analysis focuses on the exact technologies implemented in AquaSPICE and whether they address the needs of the water and water treatment market (No 2 in Figure 2). The material developed in Chapter 6, draws heavily on the first 6 work packages for the definition of technologies, as well as their link with water treatment processes. The objective of Chapter 6 is to assess whether these technologies can address market needs from an economic perspective. Within the context of a business plan development, this is necessary in order to identify the value that a new venture might propose.

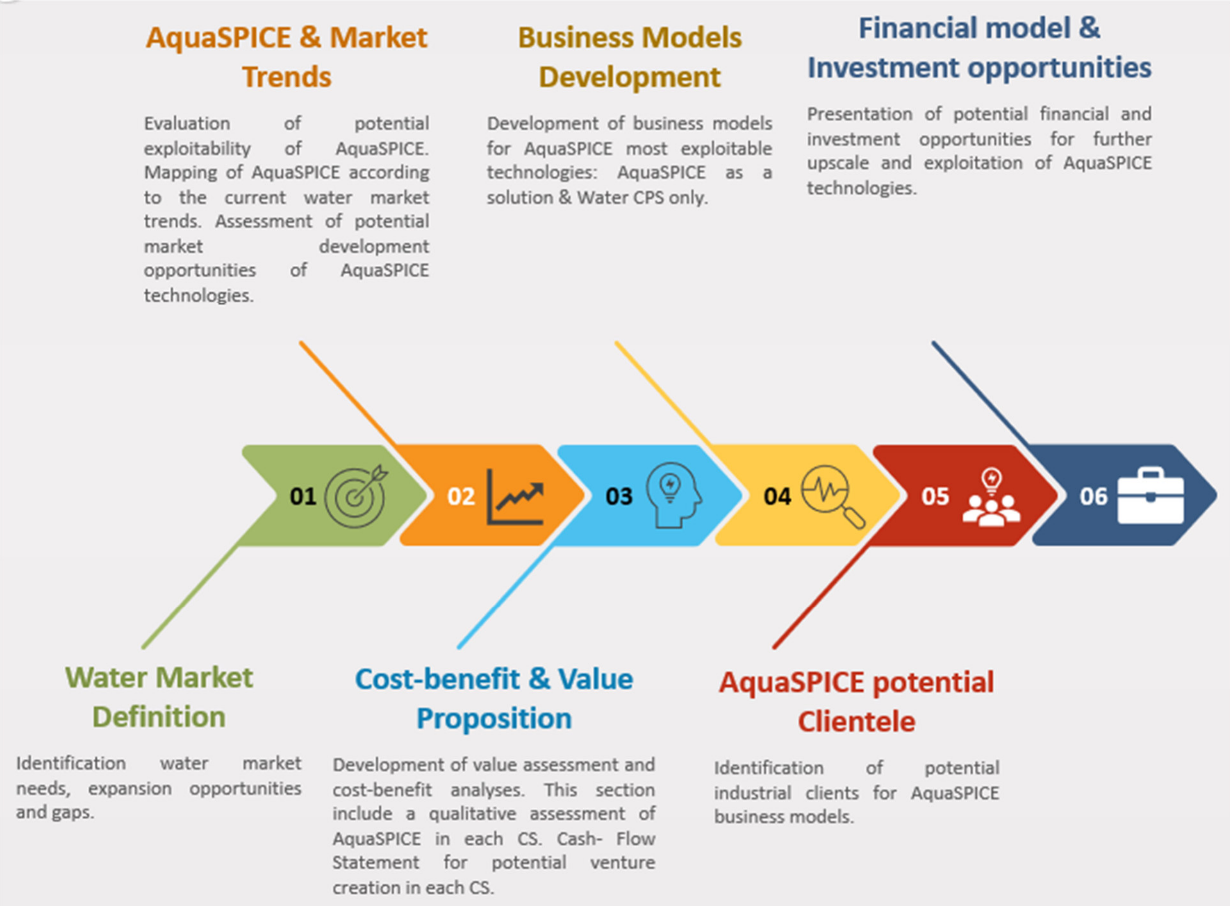
This particular concept, i.e., the value proposition of technologies (or technology combinations) implemented in AquaSPICE, is investigated further in Chapters 7 to 9 (No 3 in Figure 2). In particular, the content of these chapters focuses on whether these technologies might be viable from a financial point of view (Chapter 9) and what the costs and benefits (Chapters 7 and 8) might be. This is done on an aggregated level (Chapters 7 and 8), as well as on a case-by-case basis (Chapter 9). The rationale of our approach is to, first, identify direct and indirect costs and benefits and, second, to investigate their impact on a specific example, i.e., pilots. If this appears to be viable within the context of a pilot, then it might be exploitable on a larger scale. If not, a further exploitation might be financially non-feasible.

Drawing on these results, we further develop business models (Chapter 10) for the technologies or the technology combinations that are identified as exploitable (No 4 in Figure 2). For this, we identify the technologies on our results (Chapter 9) and on Deliverable 7.4 (KER's). We consider, from the value proposition of AquaSPICE as a whole, WaterCPS to be the main exploitable technology. This conclusion also drove us from the market research conducted and future market growth potential. We develop a business model for this as a starting point. Then we elaborate on its growth opportunities by implementing our results from Chapter 9. This leads us to a discussion of growth opportunities that include various levels of services and/or technologies or technology combinations. Finally, we conclude the work in D7.2 by identifying what the potential clientele of the new venture might look like (No 5 in the illustration below), in Chapter 11, and what the potential financing schemes might be (No 6 in Figure 2), in Chapter 12. The material in these chapters will be essential for Deliverable 7.3, which focuses on value distribution and potential stakeholder issues.

4. Methodology

The illustration below outlines the methodology followed in Deliverable 7.2. The structure of D7.2 starts with the assessment of the market value and proceeds with the evaluation of the value proposition of the exploitable technologies from a qualitative, as well as from a quantitative point of view. Then, based on that, several business models are developed, taking into consideration the potential clientele and financing schemes.

Figure 3. Methodological Steps



4.1. Water Market definition

In this, first step (No 1 in Figure 3), we conduct a macro-economic analysis focusing on what is the market value of the water and water treatment market and what the growth opportunities might be. This is an essential step prior to launching any new venture, in order to ensure that a target group (clientele) can be identified. We are using a well-established metric for estimating the market value:

$$\boldsymbol{Market\ value} \ = \sum_{i=0}^{n} \boldsymbol{Number\ of\ users} * \boldsymbol{price\ per\ unit}$$

And its growth opportunities (compound annual growth rate: CAGR)

$$\mathbf{CAGR} \ = (\left[\frac{\boldsymbol{Value\ at\ the\ end\ of\ the\ period}}{\boldsymbol{value\ at\ the\ beginning\ of\ the\ period}}\right] * \ \mathbf{1}^{\frac{\mathbf{1}}{\boldsymbol{time}}}) - 1,$$

4.2. AquaSPICE & Market Trends

The following step (No 2 in Figure 3) identifies the available waste water treatment technologies used for industrial water management, their market size and market expansion potential in a five years period using a market trend analysis. This is complementary to the information introduced in Deliverable 7.1. In Chapters 5 and 6 here, we focus on the markets and industries identified in 7.1 and we estimate their potential value and value trends. This process aims to highlight the potential exploitability of AquaSPICE technologies within the current market framework and to analyse recorded market behaviour and generate valuable insights for strategizing and forecasting AquaSPICE business plans. The ultimate goal is to identify the target clientele (point 4.5 below and in Chapter 10). The process includes:

a. Matching market needs with AquaSPICE technologies, to identify upscaling and commercial opportunities;
b. Identifying future market expansion and growth potential of AquaSPICE

4.3. Cost-benefit Analysis & Value Proposition

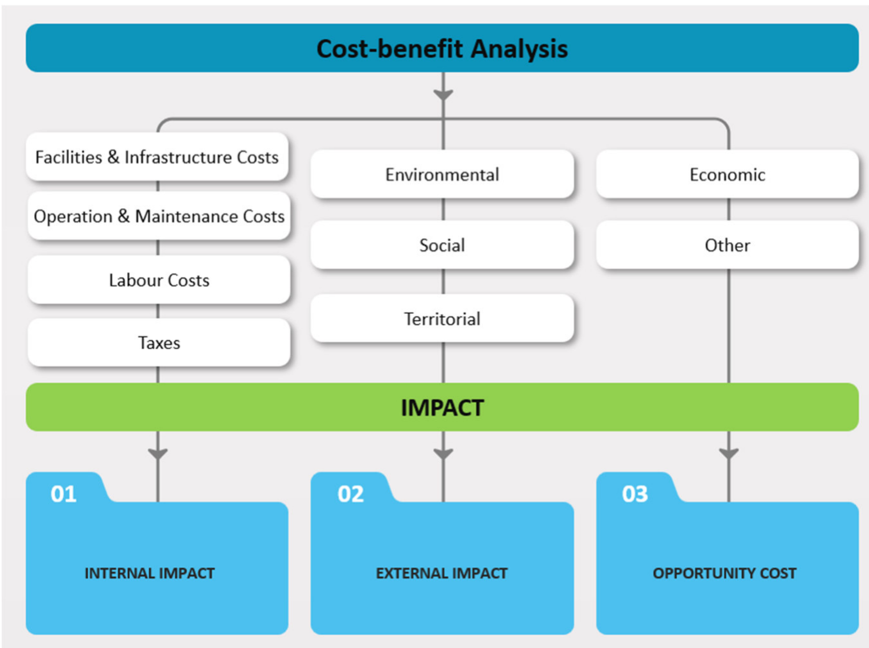
This section (No 3 in Figure 3) introduces the basis for the qualitative assessment of the value proposition of the AquaSPICE technologies and technology combinations (Chapters 7 and 8). In particular following the collection of primary data with a questionnaire (Appendix), the content in this section identifies what are the tangible and intangible costs and benefits at different levels of AquaSPICE technology implementation. There are costs and benefits specific to the technologies or case studies, as well as aggregated benefits related to water treatment. This is placed into the generic context of value proposition, that is next identified in a per-case scenario in the following chapters (Chapter 9).

In this stage a cost-benefit analysis per Case Study will be conducted based on the following:

4.3.1. Qualitative Assessment of value proposition of Case Studies

- A qualitative assessment of the AquaSPICE value per CS. In order to achieve that, the authors follow a two-fold approach. First, a qualitative assessment followed the approach created by Molinos and Senate (2011) on Cost-Benefits analysis. The main information collected from CS has been presented on Table 8 (Section 6 pp. 49-50), and is summarized below:

Figure 4. Cost Benefit Analysis Outline



Second, in order to be able to synthesize the information collected by Case-Studies, the authors follow the approach developed by Alexander Osterwalder, the Business Model Canvas, which is used as a strategic management tool to visualize and assess a business idea/concept. The initial version is modified to reflect other important information that was relevant for further exploitation of AquaSPICE and value proposition. Information is be collected directly from CS's.

Table 2. Business Model Canvas Illustration

<table>
<tr><td rowspan="2">Key Activities</td><td rowspan="2">Key Resources</td><td rowspan="2">Distribution Channels</td><td colspan="3"><u>Stakeholders/Key Partners</u></td></tr>
<tr><td>Central Stakeholders</td><td>Peripheral Stakeholders</td><td>External Stakeholders</td></tr>
<tr><td colspan="3">Customer Relationships</td><td colspan="3">Customer Segments</td></tr>
<tr><td colspan="3">Cost Structure</td><td colspan="3">Revenue Streams</td></tr>
<tr><td colspan="6">Value Propositions</td></tr>
<tr><td colspan="2"><u>Economic</u></td><td><u>Environmental</u></td><td colspan="3"><u>Social/Territorial</u></td></tr>
<tr><td colspan="2">Private financial mechanisms</td><td>Private non-financial mechanisms</td><td colspan="2">Public financial mechanisms</td><td>Public non-financial mechanisms</td></tr>
</table>

4.3.2. Monetization of cost-benefits for each Case Study

Following the qualitative assessment of the value proposition of AquaSPICE and the identification of various exploitable results, the following step is to assess whether they can be viable from a financial point of view. We proceed the analysis focusing on the early adopters and we try to identify whether there is a financial argument in the pilots that could eventually be developed into a full scale venture. At this level, the primary objective is to identify, first the cost, second, the profitability and then the profitability per unit of capital spent; all based on an incremental cash flow analysis. [1]

4.3.2.1 COST

The basic metric that is used to compare the different technology combinations is the (T)otal (L)evelized (C)ost (TLC), defined as:

$$TLC = \frac{\sum_i^n \frac{(All\ costs_i)}{(1 + discount\ rate)^i}}{\sum_i^n \frac{water\ units_i}{(1 + discount\ rate)^i}}$$

This metric aims to evaluate the net present cost over its lifetime. It would be estimated per unit (m^3) of water intake or water intake reduction, which will be the base for developing a pricing approach in the exploitation stage. The estimation of the cost is based on the discounted cashflows, as well as on the discounted units saved. This is a less biased comparison between the costs that occur early and longer term benefits. The discounting is performed using the after-AquaSPICE implementation cost of capital as an indirect way to account for the reputational gains and other non-monetized externalities.

[1] This approach is preferred over a before-and-after comparison because it requires a lower set of assumptions. The pilots are not completed at this stage and the recovery of specific efficiency gains required for a detailed simulation of full scale operations are difficult to recover for the "after" scenario. However, focusing on incremental cash flows enables the use of the AquaSPICE target values defined in WP6 as reasonable proxies for the monetization of the costs and benefits.

4.3.2.2 PROFIT

The basic metric is used to assess the profitability of the potential combinations is the (N)et (P)resent (V)alue (NPV) per m^3 (intake or intake reduction):

$$NPV = \sum_{i}^{n} \frac{Cash\ Flows_i}{(1 + discount\ rate)^i}$$

This metric aims at assigning a monetary value on the valuation proposition at a case study level. It will also be computed per unit (m^3) in order to be applicable to companies of different scale. This will also act as a reference and a verification strategy, for the pricing of the AquaSPICE digital technologies.

We employ a generic definition of $Cash\ Flows = (Revenue - Costs - Depreciations)x(1 - tax) + [Depreciations + Working\ Capital]$

4.3.2.3 PROFITABLITY INDEX.

The NPV above is a very useful metric to identify the value of each solution in present value terms, but it has a scale and cannot be directly comparable in order to assess mutually exclusive technology combinations. For this purpose, we descale it by computing it per unit of cost:

$$NPV_{/unit} = \frac{NPV}{\sum_i^n \frac{water\ units}{(1 + discount\ rate)^i}}$$

This metric exhibits the notable benefit of being scale free and it will be the basis for the cross-technology comparison. It expresses the potential profit per $ spent.

4.3.2.4 Notable limitations and disclaimer

The discounted cash flows approach that is employed here is forward looking in nature and this matches well the forward looking character of the analysis here. However, it introduces also a lot of uncertainty in the potential outcomes that might also be inflated by the fact that we do not have full access to the necessary data. For this purpose, we explicitly identify the limitations of this approach and how we address them.

<u>Disclaimer</u>

Due to the proprietary nature of the data needed, as well as the significant delays in the completion of the pilot trials, there is a lot of data that is not available. For this purpose,

For the assessment of the benefits we reserve to the theoretical figures presented in the description of action and in Deliverables 1 to 6, or

For the assessment of the costs we employ the theoretical cost curves depending on the volume of water treatment. We will use the empirical Marginal Abatement Cost curves in Plumlee et al. (2014) that take the following form;

$$€million/_{MGD} = a\ x\ Quantity^b$$

Where MGD is million gallons per day, with a conversion rate to cubic meters of 3.785. a and b are empirical constants. This approach will be followed for the estimation of the "capital required", named as CAPEX, and for the "Operations and Maintenance" (O&M), named OPEX. These figures are reference prices for 2014 and will be adjusted with a compound inflation rate of 3%.

Addressing Limitations

We employ the following two ways to assess the sensitivity of the overall assessment to some crucial inputs.

A. We estimate the Internal Rate of Return (IRR) considering the cost of capital and the re-investment rate of each company separately. The IRR serves as an estimate for the maximum cost of capital tolerance and thus, it accounts for cost of capital or investment intensity variations over time. This metric is a direct assessment of the overall "room for error" of the project.
   a. We are aware that some of the assumptions we make, albeit realistic, might not reflect 100% the real figures. A high IRR would suggest that even if they are far from reality, there is still a strong probability for the project to be profitable.
   b. The discounted cash flows method is highly sensitive to the discount rate used. We follow the assumption that the overall riskiness of the project is comparable with the riskiness of the company overall. This might be somehow unrealistic because AquaSPICE is the same, while each company is different. To account for variations in overall riskiness cross-sectionally we get an estimate of the maximum cost of capital that would keep AquaSPICE profitable.
   c. Besides riskiness, inflation has been a major issue in the implementation of AquaSPICE solutions in the case studies. To account for uncertainty coming from inflationary pressures, we consider the sensitive of profitability to how inflation might affect the discount rate, by assessing its maximum values.

B. We also perform a sensitivity analysis on all the metrics above, in order to consider variations in the inputs of the assessment. Unfortunately, this becomes imperative due to the lack of full information.
   a. In particular, we estimate changes in the TLC, NPV and NPV/TLC that might result from variations in the inputs.
   b. We opt for scenarios, rather than "ceteris paribus" comparisons. The idea is that AquaSPICE is a "holistic" (different combinations of technologies) approach that might yield benefits at a company level. In addition, it is supposed to be integrated into, at least some of, the processes of the company and thus, we derive costs and benefits from water savings. Consequently, arguing that only one figure might change, keeping everything else the same might be a rather unrealistic assumption.
   c. Instead, we design "holistic" scenarios, where all the variables change simultaneously. We consider a basic scenario as well as other parallel objectives, such as:
      i. an assessment of the suitability in different company sizes
      ii. an assessment of the suitability in areas with different water prices
      iii. an assessment of the suitability across different efficiency levels
      iv. an adjustment to regional factors

C. The primary objective of the analysis above is to assess the financial viability of the technology combinations at pilot level, in order to identify whether any of them has an exploitation potential (purely from a financial perspective). However, due to the availability of data, this might not be fully realistic at pilot level. For this purpose we also conduct a breakeven point analysis trying to identify the minimum conditions that would render the technologies profitable.
   a. We only consider the technology combinations that appear to be profitable in the pilots
   b. We take into consideration the margin for error (IRR) and the profitability index
   c. We consider the breakeven points with respect to the inputs that might affect the estimates of NPV, TLC and NPV/TLC the most.

4.4. Development of business model

In this section (No 4 in Figure 3) we focus on the development of business models for the technologies or technology combinations that are identified in the previous section as financially viable.

A. As a first step, we evaluate the outputs of the analysis above, regarding the qualitative and the monetary assessment of the value proposition of AquaSPICE and we identify various business models that might be appropriate to match the benefits derived in the early adopters' cases. The initial options selected according to the findings in the CS's are:
    - Software company: "WaterCPS only"
    - Consultancy: "Fee for Services"
    - Full scale: "Installation"
    - On demand: "Bundling"

B. In the second step, we assess the profitability of each business model using cash flows analysis. We use the cash flows from the early adopters' cases and we match them with market values. Then we estimate the NPV of the venture, assuming a full business cycle of 6 years, including R&D.

   We also perform a sensitivity analysis on all the metrics above, in order to consider variations in the inputs of the assessment. This becomes imperative due to the lack of full information.
    a. In particular we estimate changes in the NPV
    b. We design "holistic" scenarios, where all the variables change simultaneously. We consider a basic scenario with 40% probability and two extreme scenarios, i.e., "good" and "bad", with 30% probability each.
    c. The overall NPV is then computed as the weighted average of the scenarios. This is the metric based on which all business models will be compared.

4.5. AquaSPICE Potential Clientele

This section aims to identify potential clients of the new venture that will take the form of the proposed business models for AquaSPICE. To do this, it builds on the findings of 7.1 and complements it by reviewing existing literature from published studies related to water management. Extending on this, we identify industry groups in which AquaSPICE service may be more likely to sell its services successfully. They are the ones with the largest use of water treatment technologies and potential value (discussed also in point 4.2 and in Chapters 5 and 6).

4.6. Sources of finance and location

Finally, this report aims to shed light on potential sources of finance for the AquaSPICE venture. Initially it reviews all potential sources for a startup relying on existing published articles. Then it proposes which one may be more appropriate. It takes into account local bias methodology.

5. Water Treatment Market

5.1. Water Treatment Market

In the last decade, several parameters such as urbanization, increased environmental concerns, population growth, and a reduced economic contribution of services have led to an increased need for further developing water markets, in a level which will permit cross-sectorial water transfers with the minimum transaction costs (Brewer et al, 2007). Water markets generally approach marginal-cost pricing in a calculation of the marginal benefits of water use and the marginal costs of supplying water (Johansson, 2005). The potential of water market to encourage further conservation and reallocation increases in areas where it can be observed scarcity of water supply (Rosegnant & Binswanger, 1994). Indeed, with the population growth and increased needs, fresh water supply is estimated to be 4,380m^3 per person per year, unevenly distributed between countries and regions. An estimation of water availability, projects that by 2025, more than 3 billion people will be living in water-stressed countries (Johansson, 2005; Postel, 1999) and by 2050, in regions like Middle East and North Africa, the average available amount of fresh water will account for less than 650m^3 per person (Johansson, 2005).

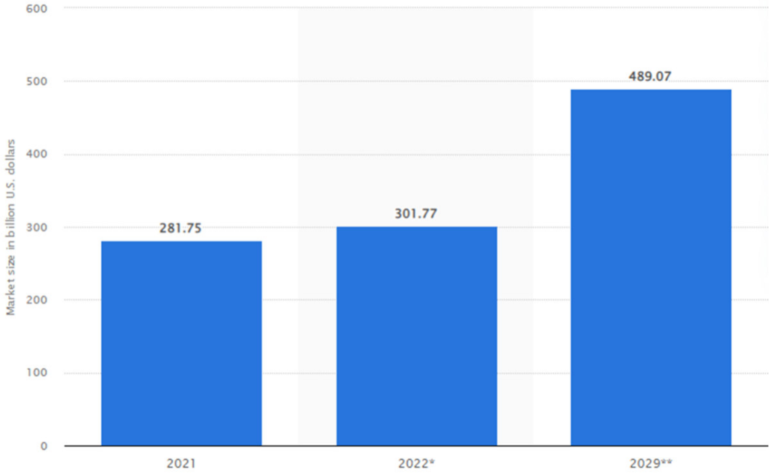
Future water scarcity - due to high use of water - increased industrial and urban needs and future climate uncertainty does not only cause environmental damage but can lead to economic losses throughout Europe and can have an impact at the EU economy and particular member states. Climate change and its effects on water scarcity is expected to influence several sectors of the European economy. The European Commission's Joint Research Centre has estimated annual loses of about €9 billion/year for the EU and the UK, with the highest losses to have been recorded in the Southern Mediterranean states such as Spain (€1.5 billion/year), Italy (€1.4 billion/year) and France (€1.2 billion/year) (2020). Most of those losses are concentrated in agriculture (39-60%) and the energy sector (22-48%), but it also affects other sectors such as transportation, and it is expected to lead to further economic deterioration when climate change temperature reaches 3°C (ibid). Economic losses are projected to reach €17.3 billion/year and it will particularly affect the Mediterranean and the Atlantic region (ibid). While another report has indicated that economic losses can touch upon €65 billion/year by 2100 and 4°C in the absence of climate action and no adaptation (Naumann et al, 2021).

Building a water resource management system is more prominent that ever before, due to several changes in the technological, environmental and industrial landscape. Increase urbanisation and consumerism, accompanied by climate change and sustainability needs, together with the urgency for cleaner production processes, have affected the water resource management and have demanded for immediate actions both in building efficient water management mechanisms but also for water treatment advancements in the industrial sectors. General pressures have been generated worldwide on improving resilience and sustainability to water treatment systems, as a way to also overcome and adapt to future climate change challenges in the industrial sector.

5.2. Global Water and wastewater market size

Recent studies foreseen an advancement on water treatment market, over the next ten years' period. According to Fortune Business Insights (2022), the global water and wastewater treatment market was US$281.75 Bn in 2021 and it was projected to grown to US$489.07 Bn in 2029, and a Compound Annual Growth Rate of 7.1% during 7-years period from 2022-2029. The largest market share recorded on the services and maintenance provision for water and wastewater market treatment, due to increase needs for upgrading aging infrastructure and existing sewage treatment plants in developed economies (Emergen Research, 2022). Incorporation of new technologies has also driven industry's growth (ibid).

Figure 5: Water and wastewater treatment market size worldwide in 2021, with a forecast to 2029 (in billion U.S. dollars)



Source: Statista ©2023

Similarly, the Water Treatment System Market Estimated Size in 2022 was US$ 66 Bn, while it is projected to reach up to US$ 111.9 Bn by 2031. This expansion signifies an increase of almost US$ 45.9 Bn, about 41% of the initial value. Whereas, the Compound annual growth rate is predicted to decrease by 2.4% by 2031 (ibid). The overall GASP for the period 2016-2022 was amounted to 8.4%, while for the period 2022-2031, a general prediction foresees a Water Treatment System Market Value-Based CAGR of 6% (ibid). The above information is summarised on the table below:

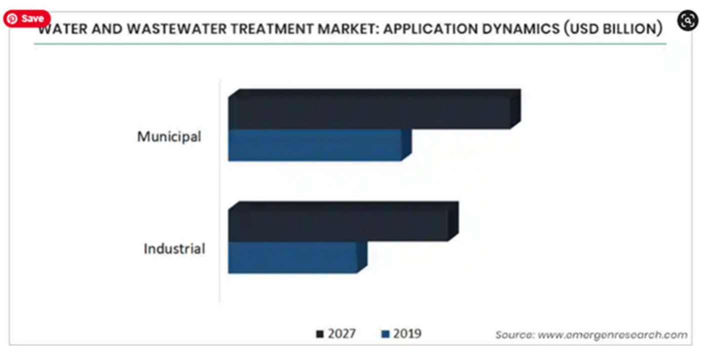
Table 3: Water Treatment System Market in US$ (Source: Future Market Insights Global and Consulting Pvt. Ltd.)

US$66 Bn	•Water Treatment System Market Estimated Size in 2022
US$111.9 Bn	•Water Treatment System Market Projected Size in 2031
8.4%	•Water Treatment System Market Historical CAGR (2016-2022)
6.0%	•Water Treatment System Market Value-Based CAGR (2022-2031)

The largest share in water and wastewater market segmentation was recorded at 57.4% in 2019, by municipal use. Increasing needs for water and wastewater treatment are more likely to follow the following years, due to growing population and urbanization (Emergen Research, 2020). Scarcity problems in different regions and cities worldwide is also driven augmented water usage, which requires advanced wastewater treatment technologies.

Industrial wastewater treatment market share is expected to be the fasted-growing in the upcoming five years period as it shown in the graph below; Primarily due to regulatory pressure. (ibid).

Figure 6: Water and Wastewater Treatment Market: Application DynamicsDigital Water Management & Market Share



5.3. European Water Market Size

Water scarcity concerns 11% of the EU territory and is projected to reach 30% by 2030, a figure three times higher. The problem is more pronounced in Southern-Europe, coastal areas and Central, Eastern and Northern-Western areas. Water quality will also be affected due to severe weather conditions and climate change but also water system can also be affected such as irrigation systems, flood defence systems, potable water and wastewater systems (Water Europe, 2016). There is an increased need for acting proactively in the European Union and boost its competitiveness in the global water market but also to create the essential preventive mechanisms for water scarcity in Europe (ibid).

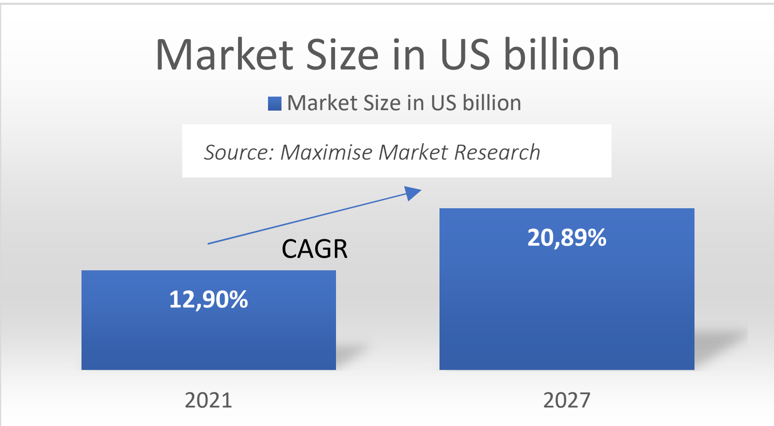
Also, environmental concerns regarding water disposal and energy saving, boosts growth potential for the wastewater treatment markets (Market Data Forecast, 2023). Water treatment is one of the biggest priorities for Germany, France and Italy, that are mainly linked to discharge limits for waste effluents in water bodies. The objective is to prevent escalation of water pollutions. Environmental regulations play an important role in growth for the water market industry (Market Data Forecast, 2023). This is more pronounced for the food, microelectronics, pharmaceutical and chemical industries. Food industries need for clean process water and substantial volume of high purity water additives, as well as chemical and pharmaceuticals industries which hold the largest share, would be the end-users of wastewater treatment technologies, expertise and equipment (Wateronline, 2001).

Especially in Europe, the waste-water treatment service market is projected to increase by 3.12% CAGR from 2023 to 2028 (Market Data Forecast, 2023). The European water market will be revitalized driven by high innovation and investments on updating existing treatment facilitates and adopt new technologically advanced wastewater treatment solutions (Business Fortune Insights, 2021).

However, the market growth potential may be hampered by factors such as the high investment and production costs, as well as the harmful effects of chemicals, used in wastewater treatment, when do not be disposed properly to the environment (GrandViewResearch, 2019). Mostly, environmentally-friendly water treatment technologies like electrocoagulation (EC) and biofiltration, is likely to gain market shares in Europe. Environmental concerns like reductions of CO2 emissions in industries are expected to promote the use of microbes in the biological treatment of industrial water, which is now being used for the removal of phosphorus and nitrogen from industrial water (ibid).

5.4. Industrial Wastewater Market

Figure 7: Global industrial wastewater treatment market value (2021-2027)



Treating industrial wastewater is important because it reflects economic, and environmental benefits for the involved industries. The use of inferior water quality for industrial purpose can be harmful to the processes but also for the environmental and public health, due to discharge of heavy chemicals and pollutants to the environment. The treatment processes demand wastewater treatment equipment which can eliminate microbial contamination and suspended solid matter which might use chemicals or biological components to eliminate contaminants, such as iron, sodium bicarbonate, chlorine, coagulants and/or filters, clarifiers etc. (Verified Market Research, 2020).

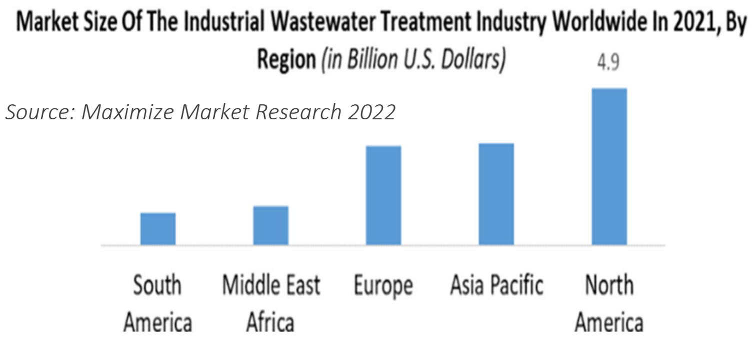
Advanced industrial processes and increased manufacturing products have accelerated demand on industrial wastewater treatment equipment and development of new technologies, such as treat-to-discharge, membrane-based fuel cell, MBR etc. (Verified Market Research, 2020). Oil and gas, pharmaceuticals, foods and chemical sectors have been driving market growth (ibid). Moreover, treated industrial wastewater can be used for other purposes such as potential supply to other organisations, industrial partners or even municipality (Transparency Market Research, 2022). Thus, the global industrial wastewater market treatment is expected to follow an increased pace due to application of treated water, especially in boiled feed water and cooling towers (ibid). According to market research analyses, the global industrial wastewater treatment it was valued at $12.9 billion in 2021, is projected to grow by 6.2% from 2021 to 2027. This growth has been projected to reach $20.89 billion by 2027.

Global industrial wastewater market	DRIVERS	BARRIERS
	Stricter regulations	Regular costs of maintenance
	Environmental concerns on public health	Alternative water management systems

Although the drivers are related with stricter regulations and laws for the protection of the environment and public health, barriers are mainly associated with the costs of developing and maintaining industrial water treatment processes and equipment. Regular maintenance costs might inhibit market growth, as well as growing demand towards alternative water treatment technologies (Verified Market Research, 2020). Advanced technological development as well as installation and maintenance costs may act as market barriers. Water treatment facilities costs vary considerably based on the volume of contaminants in the water, system equipment, technical labor force required, and maintenance costs associated with the duration of the installed equipment (Maximize Market Research, 2022). Therefore, expenses determined by the type of system and industry as well as associated costs for the construction of wastewater treatment plant (ibid). High costs of water treatment plants also reinforce the development of technological innovations and automated systems such as remote monitoring systems, predictive maintenance systems, analytics software and cybersecurity (ibid). Overall, the design of innovative products and industrial water treatment plants as well as technological development, offer opportunities for growth (Verified Market Research, 2020). But still there are specific economic costs associated with high costs and low margins of marketisation of treated wastewater and water reuse.

5.4.1. Regional distribution

Figure 8: Market Size of the Industrial Wastewater Treatment Industry WorldWide in 2021, by Region (US bn)



In the industrial wastewater treatment market, USA has the highest market share. Further growth is expected in the region, due to highly expansion of gas development operations (Maximize Market Research, 2022). The highest market share is in the Asia Pacific region (2021). India, Japan and China consist of the main markets in the Asia Pacific region due to highly industrialised expansion and populations growth (ibid). China has heavily invested in the environmental protection, so a further market expansion of water treatment services is expected the following period. Treated wastewater is applicable in "heavy" industries such as Energy & Power, Oil & Gas, Chemical & Petrochemical, Automotive and Others. Energy & Power industry holds the largest market share, as they are also responsible for the largest discharges of wastewater including metals which are harmful for the environment and public health (Verified Market Research, 2020).

6. Water treatment processes and digital technologies

6.1. Water treatment processes

This is used for manufacturing processes such as cooling tower water, coating and plating, washing and many other uses. Groundwater and municipal water sources contain dissolved minerals, which required treatment to improve water quality and also reduce manufacturing costs (Allied Market Research, 2022). There are three types of treatment that include preliminary, secondary and tertiary. This section provides a brief description and gives and overview of the market size for each process type.

6.1.1. Preliminary Treatment

Preliminary treatment is used to remove screenings and grit, flotation, equalization and flocculation, that enters a wastewater treatment plant from a sewered system (Oackley, 2018). Removal of coarse solids and other materials is necessary to enhance the operation and maintenance of subsequent treatment units (FAO, 1992). Air flotation and flocculation aid in the removal of suspended solids in the primary classifier to continue further treatment during sedimentation (Guyer, 2011). The demand for pre-treatment equipment is anticipated to witness growth due to its reducing the OPEX of the sludge management plants, reducing the risk of impairing the plant equipment in further stages. Preliminary treatment includes the use of screening products such as bar screens, waterfall screens, coarse screens, trash racks, and others equipment for oil and grease removal (GrandViewResearch 2021).

6.1.2. Primary Treatment

Primary treatment is used for the removal of organic or inorganic solids, which cannot be removed by preliminary treatment by sedimentation, and the removal of floating material by skimming (FAO, 1992). According to the latest available data, the primary water and wastewater treatment market was valued at $12.12 billion in 2019, and is foreseen to reach a compound annual growth rate (CAGR) of 3.5% by 2027 (GrandViewResearch, 2021). Primary treatment includes effluents treatment through screening, skimming and sedimentation. The primary clarifier led the wastewater treatment market and accounted for 28.7% of global revenue in 2019 (ibid). The largest market share in primary treatment held in Asia Pacific, which shared 33.5% of the global revenue (ibid).

6.1.3. Secondary Treatment

The secondary or biological treatment is used primarily for the removal of dissolved and commissural organic matter, with the involvement of microorganisms (bacteria, algae, fungi, protozoa, rotifers, nematodes) that decompose the unstable organic matter into stable inorganic forms (STRANE, 2022).

Secondary treatment includes the use of filters, bio-towers, biological contactors and activated sludge systems to remove organic waste and compounds (phosphorous or nitrogen) from water (Precedence Research, 2022). Aerobic or anaerobic biological process can also be adopted as subsequent treatment. A (microfiltration or UF) membrane bio-reactor is a cutting-edge treatment system, which combined with traditional biological treatment can remove organic particles more efficiently (ibid).

The secondary or biological treatment process is expected to grow at 5.1% of CAGR by 2030 (Precedence Research, 2022). The secondary treatment process accounted for 36.7% of the global revenue in 2021 (Grand View Research, 2022). The use of public sewers in rural home is expected to increase demand for secondary treatment equipment in municipal water applications (ibid).

Furthermore, the sludge treatment segment is expected to have the second-highest CAGR, during the second period (Precedence Research, 2022). Whereas, the biological equipment segmentation has reached up to 12.6% of the global revenue share in 2021 (Grand View Research, 2022). The growing needs for treated water have also increased demand for membrane bioreactor installations, thus a market opportunity has risen particularly in North America and Europe (Meticulous Research, 2021).

6.1.4. Tertiary Treatment

The tertiary treatment is the final stage which improved wastewater quality prior reuse and release to the environment, after the subsequent primary and secondary treatment processes. Through this stage all inorganic chemicals, viruses, parasites and gems which have remained after the effective treatment procedures are eliminated. Water and pollutants are separated through bypassing different filters and tanks (Precedence Research, 2022).

The tertiary treatment processes have the largest market share in 2021, amounting to 43% of the global revenue, and is expected to present the fastest growth at 5.3% CAGR from 2022 to 2030 (Precedence Research, 2022). During the projected period, it is anticipated that low operating costs and strong market visibility will be extremely important in expanding the main treatment's application area. Tertiary treatment market includes diverse technological innovations. One of the most promising is the membrane separation market category, which dominated the market by holding 19.81% of global sales in 2021 (Precedence Research, 2022). Membrane separation is used to remove certain components by forcing high-speed water through a semi-permeable membrane. It is considered a superior methods comparing to other methods because it occupies a small operational space and has great filtration effectiveness (ibid). Rising production activities and investments in industrial equipment are also expected to force market growth (Grand View Research, 2022).

6.2. Digital water management technologies

Digital technologies for water treatment applications have started to expand in various water applications. They are used as monitoring and sensor systems but also in combination with other technologies in order to achieve the highest efficiency of water treatment mechanisms in a cost-effective way. Smart systems such as the Internet of Things (IoT) has allowed smart water purification systems to be considered the next technological trends in the water market. Smart purifiers have been created to substitute traditional reverse osmosis and ultraviolet water purifications systems, which can easily be used with smartphones (Market Research Future, 2023).

IoT also utilises sensors which allow for large scale remote monitoring and can create a network of physical objects which in wastewater treatment management systems. This process permits competent authorities to monitor various activities in the water treatment facility (Maximize Market Research, 2022). A network of sensors allows monitoring of various characteristics such as chemical composition, TDS, pressure, temperature etc. Collected data be used by automation systems and analytics-infused centralised platform to synthesize information (ibid). Additionally, smart water flow meters can be used to measure the water flow throughout the treatment facility. IoT can further be used to calculate chemical composition after water treatment processes and to ensure water quality and standards (ibid).

Use of technological advancements for water management can be beneficial not only to the industries concerned and to the wider environmental benefits that can have, but can be economically viable and financially beneficial. Smart water management industry is segmented into solutions, services and water meters, which are further categorised into analytics and data management, enterprise asset management, smart irrigation systems etc. (MarketStudyReport, 2022). Smart water management can be offered for different purposes such as industrial, commercial and residential applications (ibid).

Technological advancements and innovation can play a vital role in securing health and safety, achieve better water efficiency, treatment and monitoring, industrial processes and data analytics. A great interest by industrial partners and other businesses has been observed on water management systems testing and implementation of new technologies on their industrial and business sites (FMI, 2022). Remote water sensing that helps with non-revenue water remediation, Internet of Things (IoT) which enables water quality control and smart irrigation, permit market actors to invest new complex models for water management (ibid).

According to MarketsandMarkets (2021), the global smart water management market is projected to double its value from US 13.8 billion $ in 2021, to 22.4 billion $ in 2026. Moreover, MarketStudyReport foresees a global market increase of smart water management of 11.1% CAGR through 2027.

Figure 9: Smart Water Management Market

Source: Research and Markets, 2021

Smart water solutions are expected to record the largest markets share with technology to become more advanced and businesses to adopt more innovative systems, thus driving their demand into growth (Research and Markets, 2021). Integrating smart solutions into existing operations, help businesses and current water management and treatment systems to increased their efficiency, which optimises current systems with low infrastructure investment (ibid). Moreover, digital technologies for water treatment applications have started to expand in various water applications. They are used as monitoring and sensor systems but also in combination with other technologies in order to achieve the highest efficiency of water treatment mechanisms in a cost-effective way. Smart systems such as the Internet of Things (IoT) has allowed smart water purification systems to be considered the next technological trends in the water market (Market Research Future, 2023). Smart purifiers have been created to substitute traditional reverse osmosis and ultraviolet water purifications systems, which can easily be used with smartphones (Market Research Future, 2023).

6.3. AquaSPICE processes and technologies

Following the analysis above, the main points relevant to the development of exploitable technologies into a business venture are that the water treatment market is expected to grow steadily in the foreseeable future as a whole, as well as within its different treatment levels (primary, secondary, etc.). AquaSPICE implements various technologies and technology combinations that are highly relevant to these treatment levels and as it has been identified by STRANE in D7.4, there are several KER’s within the various applications in the pilots. In particular, diverse technologies and treatment trains have been used to explore effective wastewater treatment methods for water treatment and reuse. Biological and chemical components are used for industrial wastewater treatment. Diverse treatment trains have also been applied in AquaSPICE case studies. The use of treatment trains was based on improving water quality production and treatment of wastewater with the removal of the industrial contaminants.

Table 4: Water treatment processes and digital technologies deployed in each case study of AquaSPICE project

Process/Case Study	CS#1A	CS#1B	CS#2	CS#3A	CS#3B	CS#5	CS#6
Aerobic granular sludge							✓
Biological granular activated carbon	✓	✓	✓		✓		
Membrane bioreactor			✓			✓	
Ultrafiltration	✓	✓				✓	✓
Reverse osmosis	✓	✓			✓		✓
Ion exchange	✓	✓	✓		✓	✓	
Rapid sand filtration		✓					
Neutralization		✓	✓				
Coagulation/Flocculation		✓					
Advanced oxidation process (UV/H2O2)					✓		
Advanced oxidation process (Heterogeneous Fenton process)			✓				
Electrodialysis	✓	✓			✓		
Chemical disinfection			✓				
UV reactor						✓	
RTMP	✓	✓	✓	✓	✓	✓	✓
Digital Twin WaterCPS	✓	✓	✓	✓	✓	✓	✓
Water level prediction + Salt intrusion detection				✓			
AI Inference Tools	✓	✓		✓			

Source: Table adapted by authors based on information of project deliverables @TUC Deliverable 4.1

Apart from treatment trains, other technological developments have been used in AquaSPICE trying to use digital innovation for water management, and resource efficiency. Digital technologies can apply modelling processes which can lead to freshwater intake reduction, water recovery and more efficient removal of water contaminants. Accordingly, digital technologies have been applied within each case-study framework, for optimization of existing water management process within their current value chain as it is described in section 9 of this report.

Possible exploitation pathways have been identified through research conducted in the framework of WP7 (D7.4), identifying Key Exploitable Results (KER's) of technologies and research products developed during AquaSPICE, that can further be up-scaled. The next sections reflect the highly exploitable project results based on which specific business models can will be developed based on their potential for business commercialization. According to D7.5, the highest potential for business exploitation present water treatment solutions (such as RO, or technology combinations such as CF+UF+RO), as well as the digital technologies around WaterCPS (e.g., RTMP, Digital Twin). A new start-up development is the ideal scenario for further exploitation and commercialization of project's results. We investigate these in the following sections.

6.4. Matching AquaSPICE technologies & market demands

6.4.1. Water treatment technologies

According to Key Exploitable Results analysis (D7.4), the most exploitable existing water treatment technologies into specific industrial WW streams are the following:

Table 5.Water Treatment Technologies and Market Potential

Treatment	Water Treatment	Market potential
Primary	Physico-chemical processes: Lamella settler, Ion Exchange (resins)	Market share of $12.12 billion in 2019; Expected CAGR of 3.5% by 2027

Tertiary	Membrane-based processes: Nanofiltration (NF), Ultrafiltration, Reverse Osmosis, Electro Dialysis Reversal (EDI)	Largest global market share by 43% of the global revenue; Expected CAGR of 5.3% (2022 to 2030)
Secondary/ Biological	Biological processes: Granular-Activated Carbon, MBR	Second highest market share 5.1% of CAGR by 2030 (Precedence Research, 2022). The secondary treatment process accounted for 36.7% of the global revenue in 2021

According to the market needs, exploitation pathways have high potential for those existing technologies, since a CAGR between 3.5% -5.3% is expected for all the treatment processes within next five years period. This can drive further exploitation of AquaSPICE existed applied technologies in the market, especially related to combination of technologies which proved to have satisfying results.

New treatment trains for complex industrial wastewaters, based on existing technologies have also been demonstrated. Their market value would be possible to be accessed after the conclusion of demonstration phases from all Case Studies. The following combinations of treatment trains have been identified according to potential market exploitation and not to actual treatment results:

Table 6. Technology Combinations and Market Potential

Treatment process	Water Treatment	Market potential
Primary & Secondary	GAC + UF + RO	Potentially Exploitable
Secondary & Tertiary	"Coagulation – flocculation and GAC (coagulation flocculation + lamella settler + GAC + UF + RO)"	High Market Potential
Secondary & Tertiary	"Coagulation – flocculation + UF (coagulation flocculation + lamella settler + UF + RO)"	
Secondary & Tertiary	IX scavenger resins + Electro Dialysis Reversal (EDI)	
Preliminary & Secondary & Tertiary	Pre-treatment + AOP (Advanced oxidation process) + Adsorption with metals in Fixed Bed column + Anoxic MBR	Potentially Exploitable
Secondary & Tertiary	BAC-GAC-RO-MB	Potentially Exploitable
Tertiary	AOP(-GAC)-RO-MB	High Market Potential
Secondary & Tertiary	AMBR + disinfection	
Secondary & Tertiary	Ion Exchange + MBR + AOP + Polishing	

The combination of new treatment trains also has a great market potential, considering the needs of the market for wastewater treatment technologies. Combination of technologies belonging to secondary and tertiary treatment have a higher potential, since tertiary process treatment occupies the largest share of the market, counting for 43% of the total global market, and is expected to grow by 5.3% by 2030. Treatment trains belonging to secondary treatment process, also have a high potential, since they occupy the second highest market share, reaching 36.7% of the global revenue.

6.4.2. AquaSPICE digital technologies

The digital technologies have identified to have the highest potential by providing opportunities to CS's to optimize their existing water management systems but also to create opportunities for the technology providers to further create commercialized opportunities of their final products. Available data below present the estimated market expansion for digital systems. According to market study and available scientific and economic data, smart water technologies, especially WaterCPS, have a great potential for various reasons. Digital technologies for water management can be solely optimize water systems, but a combination of them with other technologies can increase market penetration.

Digital systems are considered cost-efficient systems, which do not require high monetary investments in relation to heavy industrial equipment. In addition, they can provide real-time data which can monitor existing water management systems and can provide data analytics based on the quality of water, water inflow, substances existing in the water systems. In addition, more and more industries within Europe, are characterised by high innovation in the production supply chains, using optimized systems. Therefore, using digital water treatment technologies is expected to be the next market trends in the next 10-15 years period. Technologies such as RTM, Digital twinning and CPS have an increased market growth and their expected CAGR varies between 9.3% to 40.6%. Latest available data for CPS systems worldwide recorded a market value of US$ 78.42 Bn in 2021, which is expected to grow with a CAGR of 9.3% by 2030. While for Digital Twinning systems in the water sector, the market size estimated at $415.7 Million in 2019 and will grow at a 32% CAGR until 2026. For the RTM systems, the only available information in the water sector, is related to real-time flood monitoring & warning system market, which is expected to grow by 6.2% by 2031.

Table 7.Digital Technologies and Market Potential

Digital technology	Market value	sector market value	Market potential
RTM	Not available information	(Information only on real-time flood monitoring & warning system market) US$181.4 Mn in 2020 Estimated growth by 359.5 Mn by 2031; CAGR of 6.2% from 2021 to 2031	
WaterCPS	CPS systems worldwide and in different industries recorded a market value of US$ 78.42 Bn in 2021, which is expected to grow with a CAGR of 9.3% during the forecast period from 2022 to 2030	Not available information	High Market Potential
Digital Twins	Market size was accounted for $6.75 billion in 2021; Expected to reach $96.49 billion by 2029, reaching a CAGR of 40.6%	Market size estimated at $415.7 Million in 2019 and will grow at a 32% CAGR until 2026	High Market Potential
Water level prediction + Salt intrusion detection	Not available information	Not available information	-
AI Inference Tools	Not available information	Not available information	-

6.5. Conclusion: WaterCPS is the most exploitable technology

The analysis in this section suggests that the technologies and technology combinations implemented in AquaSPICE are highly relevant to the water treatment market and therefore, there is exploitation potential for some of them. The one that is transversal to all case studies and seems to be the major technology that AquaSPICE introduces is the digital technology WaterCPS. That is relatively unique and can be developed into the competitive advantage of a new venture.

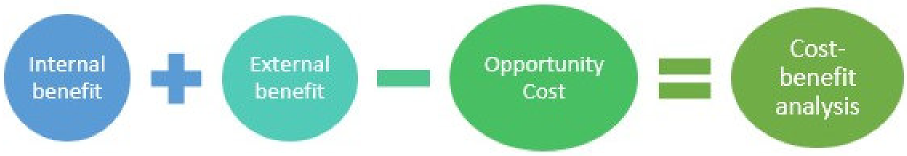
On top of it, there seem to be some technology combinations, which, although they are not unique in AquaSPICE, they can be also exploitable. From a business model point of view, these technologies might not be the basis for a new venture, but they could offer a viable organic growth pathway. This is fully in line with D7.1 and D7.4 and will be further discussed in Chapter 10.

7. Cost-benefits Analysis and Risk Assessment

7.1. Cost-benefit methodology introduction

The economic consideration of wastewater reuse projects is based on conventional methodologies of cost-benefits analysis which consider the internal benefit, the external benefits and the opportunity cost in an economic equation (van der Brugger et al, 2009; Segui, 2004; Hernandez et al, 2006).

Figure 10. Cost Benefit Analysis Elements



Therefore, the total benefit of wasted water reuse project is calculated based on the following equation, published in the paper of Molinos-Senante et al (2011), where BT is the total benefit (total income minus total costs); BI is the internal benefit (internal income minus internal costs); BE is the external benefit (positive externalities minus negative externalities); and OC is the opportunity cost. The cost-benefit analysis derives from the fact that economic viability should be foreseen only if income exceeds aggregate costs. So according to the Equation, if the BT > 0, offers the highest total benefit.

7.1.1. Internal benefit:

Internal impact can be identified as the processes related to wastewater regeneration and subsequent reuse (Molinos-Senate et al, 2011). The benefit is the differentiation between the internal income minus the internal costs. As internal costs can be justified any investment costs which facilitate the treatment of wastewater and reuse. Those can be labour costs; any types of costs for using the facilities and infrastructure; costs related to buy and/or rent machinery, pipes, equipment, etc.; operational and maintenance costs (staff, energy, sludge management, reagents, etc.), financial costs, and taxes for wastewater treatment plant, WWTP and distribution network of the regenerated water (ibid).

7.1.2. External benefit:

External impact are costs or benefits which have effect when actions by companies and individuals have effect on other people but themselves without necessarily identifying an economic compensation (ibid). Wastewater treatment might occur positive and negative externalities such as health and environmental benefits but can also increase biological and chemical risks (ibid). Calculation of externalities remains an obstacle on economic benefits analysis, since there are not quantified measures for environmental benefits or public health for example. Therefore, in wastewater management or reuse projects, externalities cannot be assessed based on real market values, since there are not as such. Thus, decision is taking into economic costs without taking into consideration non-monetary benefits such as environmental protection, public health, synergies with other actors, local development etc (ibid).

An alternative calculation which is proposed by Hernández-Sancho et al., (2010) and Molinos-Senante et al. (2010), is to quantify the undesirable outputs of a wastewater treatment process, which except of fresh water intake, the outcome would be undesirable pollutants such as (organics, phosphorus, etc.), which their uncontrolled disposal would have negative impact on the environment. Using shadow prices to quantify the undesirable outputs and environmental benefits, can be used as a method to create valuation of externalities (Molinos-Senante et al., 2011) using the methodology of Färe et al. (2006).

7.1.3. Opportunity Cost:

As opportunity cost in the CBA is considered the value of goods as an alternative use of these being lost or not used. So, as opportunity cost in wastewater treatment can be considered the use of water or any other goods, which can offer the greatest economic efficiency as an alternative of not using them. An example would be the clean water generated by water waste treatment processes to be outsourced in the local municipality or other industrial partners in the region, or even the last which the water treatment plant has been placed, which can be used for other purposes which can bring financial income (Molinos-Senante et, 2011). Indicating the opportunity cost of water is important to justify how water management can be allocated or future infrastructure would be beneficial (Rougé et al, 2017).

Table 8: Summary of cost-benefit analysis for wastewater treatment projects

Impact	Costs	Types of costs
Internal benefit	Facilities Costs	Buildings
		Industrial installations
		Research labs
	Infrastructure costs	Machinery
		Pipes
		Equipment
	Labour costs	Technical experts
		Financial experts
		R & D costs
	Operational & Maintenance costs	Energy
		Staff
		Sludge management
		Financial costs
	Taxes	Wastewater treatment tax
		WWTP
		Distribution Network
External benefit	Environmental impact	Decrease the diversion of water from sensitive ecosystems
		Reduce and Prevent Pollution
		Create or Enhance Wetlands and Riparian (Stream) Habitats
	Social impact	New jobs creation
		Protection of public health
	Territorial impact	Local development
		Synergies between public-private institutions
Opportunity Cost	Economic	Sell treated water to other industrial sources
		Reuse recycled water in other sources or municipalities
	Others	Use of land that was not used before

Table 9. The economic benefits of wastewater treatment

Purpose	Application	Benefits
More dependable water source	Municipal treated wastewater are less affected by droughts that surface and groundwater sources	Reduced production costs
		Sustained agricultural production
		Sustained industrial production
		Sustained associated employment
Substitution of fresh water	Use in industrial processes, cooling, irrigation etc.	Sustainable resource utilisation & demand management
Use of nutrients (e.g., nitrogen/phosphorous)	Use of nutrient-rich wastewater in agriculture	Reduction or elimination of fertilisers' application costs
Reduce economic costs	Save water consumption and treatment needs contribute to cost savings	Water treatment is more cost-efficient than freshwater pumping and desalination costs
Reduce investment costs	Reduce investment needs for water abstraction and treatment, and new sewage investments that might need infrastructure	Eliminating investment costs
Development of urban, rural and coastal landscapes	Support local development and tourism	Increase employment
		Support local economy

Source: Mediterranean Wastewater Reuse Report

7.1.4. Environmental value

The environmental benefits of recycled or treated water are tremendous. Except of the financial savings for the industries, municipalities or any other kinds of water reuse such as irrigation, among the most important factors are the environmental, which aim to prevent a) water scarcity, b) protect sensitive ecosystems. The US Environmental Protection Agency (2017) and the Mediterranean Waste Water Working Group, have indicated multiple beneficial reasons for wastewater treatment, recycling and reuse which among them is to:

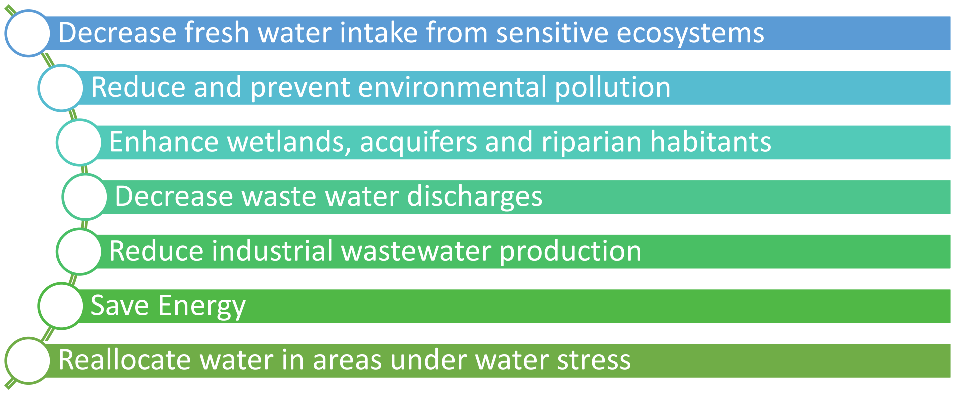


Figure 11. Waste Water Treatment Benefits

Source: EPA USA (2017)

The continuous use of fresh water due to industrial, urban and agricultural needs, affects the water quality and can also affect the available quantity of ecosystems. That is also related to water discharges to ocean and other sensitive ecosystems and nature life (EPA, 2017:5-7). Thus, using treated water can be beneficial for environmental purposes, which can once be used to create and restore wetlands, which effectively contribute to many other sectors such as natural and aquatic wildlife, flood diminishment and water quality (EPA, 2017). Aquifers' recharge has mainly benefited such as negligible evaporation, little animals contamination by animals and is less costly because it does not require the construction of any pipelines and can protect groundwater from saltwater intrusion (MED EUWI, 2007). In addition, using treated water can reduce and prevent environmental pollution to aquatic ecosystems, but can also enhance other sectors such as agriculture which can prevent the use of fertilizers, when the treated water used has high value of nutrients itself. Moreover, the extraction of fresh water intake demand high levels of energy use to pump the water or to transfer it to longer distances, thus reusing treated water saves energy costs by reducing treatment requirements in application where that is effective (EPA, 2017). According to EPA, the energy required to treat water is generally less than the quantity needed to collect, extract, convey and distribute water to end-users (ibid). The lower energy requirements can also act as an adaptation strategy to climate change, because of the lower related emissions (greenhouse gas MED EUWI, 2007).

Water treatment has registered benefits but also associated risks, which are mostly related with the efficient and regulated water reuse in order to prevent actions that might be hazardous for the environment and public health. Especially, industrial wastewater needs to be managed effectively due to containment of highly toxic substances and heavy metals.

7.1.5. Social value

Except environmental and economic benefits, wastewater treatment can also have social and health benefits. A direct benefit of wastewater treatment is the protection of public health which through an effective common mechanism for risk management of treated or reused water, especially in food industry at the EU level but also export markets. Therefore, the social value of water treatment applications varies considerably as it can touch upon different industries and sectors.

Table 10. Social Benefits of Water Treatment

Contribution to food security and possibilities for agricultural applications
Facilitates networking & knowledge-sharing among various stakeholders (environmental agencies, municipalities, industrial partners)
Contributes to local water reuse and local development
Creates opportunities for improving infrastructure through urban landscapes, increasing quality and well-being
Contributes to Sustainable Development Goals by increasing water availability and poverty reduction through the use of technological applications
Facilitates exchange of best practices among diverse stakeholders for water treatment and risk-management, thus benefitting the local communities

Water scarcity creates various problems and challenges for efficient water source uses, which does not touch upon environmental and economic risks but can hinder any industrial and municipal efforts for resource efficiency. Uncontrolled wastewater reuse can have significant social and health risks, and can further undermine any controlled water management methods to prevent water scarcity. In addition, lack of regulations and know-how, in addition with lack of strict operational environments might led to discharge of contaminated water sources, which can be harmful to the environment and public health.

7.2. Risk analysis

7.2.1. Water price risk

The main source of risk for the AquaSPICE venture is water price risk. It refers to the potential volatility and uncertainty in the cost of water that can have significant implications for AquaSPICE venture performance in the long run.

- This type of risk may be affected by the equilibrium between water supply and demand. Factors such as population growth changes and urbanization concentration may have significant implications for water demand, while other factors that may include climate change and water scarcity have the potential to affect water supply. When demand exceeds supply, water prices may increase that in turn may affect AquaSPICE revenue.
- The quality and adequacy of water infrastructure play a significant role in determining water prices. Investment in infrastructure development, maintenance, and upgrades is necessary to ensure reliable water supply and manage price risk. Insufficient infrastructure or lack of investment can lead to higher costs. This in turn may have a significant impact on water price risk.
- Water price is volatile according to geographic location. In other words, water price risk depends on regional characteristics. Regions that suffer from limited water resources or high population densities are more likely to exhibit high volatility in water prices. Moreover, areas that rely heavily on imported water or face geopolitical risk related to water disputes may experience higher risk.

7.2.2. Regulatory risk

To a lesser extent regulatory risk can have an adverse effect. It includes the possibility for regulatory changes or actions that can impact the operations, profitability, and compliance requirements of water companies or organizations involved in water management. These risks arise from government regulations, policies, laws, or directives that govern various aspects of the water sector.

- The water industry is a regulated market. Water companies must adhere to strict regulations related to water quality, treatment processes, waste management, and environmental protection. Failure to comply with these regulations can result in penalties, fines, or even legal actions.
- Regulatory bodies often determine the pricing mechanisms and tariff structures for water services. Changes in regulations governing pricing can impact revenue streams and profitability for water companies. Tariff adjustments may be influenced by factors such as inflation, investment needs, environmental requirements, or government policies.
- Water companies require licenses and permits to operate, and regulatory bodies oversee the granting and renewal of these permissions. Regulatory changes or delays in obtaining necessary licenses or permits can disrupt operations and pose a risk to the business.
- Regulatory changes can arise due to shifts in political priorities, changes in government, or legal challenges. These risks can include new legislation, policy shifts, or legal disputes that may affect the operations and strategic direction of water companies.

8. AquaSPICE Value Proposition Analysis per Case Study

In the previous sections we have reached the following conclusions:

a. There is healthy market with growth opportunities for water treatment technologies, specifically in Europe, but also in the global context.
b. Environmental but also policy related reasons drive the demand
c. There are several technologies and technology combinations implemented in AquaSPICE that match the ever growing needs of the water treatment market. In particular:
    i. The digital technology "WaterCPS" is the most prominent
    ii. There are technology combinations that meet the water treatment needs
d. There are qualitative benefits that go beyond purely the water treatment and/or water reuse.
    i. Positive externalities include environmental and social benefits
    ii. A more efficient use of water that might have synergetic benefits
    iii. Secondary benefits include reduced OPEX and more effective CAPEX expenditures

In this section, we delve deeper into the value proposition of AquaSPICE by investigating each specific case of early adopters separately. The primary objectives are:

A. To identify whether AquaSPICE creates value to each specific case
    a. Identify the value proposition of AquaSPICE in a qualitative manner in terms of tangible and intangible benefits, costs and risks. This will be based on the material in Chapters 5-7, as well as on the distributed questionnaires (Appendix).
    b. Assess the value proposition by assigning a monetary value to these benefits, costs and risks
B. To assess the financial viability of the previously (D7.4) identified exploitable technologies
    a. Do some technologies or technology combinations exhibit positive NPV in the pilots? An initial approach that focuses on the pilots will assess the relative profitability (NPV/TLC) of different scenarios in order to evaluate whether they can create value on a small scale
    b. Then, especially if not, we will try to evaluate whether there is a break-even point that would render these technologies or technology combinations profitable. This will be used further to identify the potential clientele of the exploitable technologies.
    c. Finally, a larger scale simulation study will investigate whether the identified solutions remain profitable.

We attempt to monetize the value proposition following a cash flow analysis. Several vital pieces of information are not available, either due to their proprietary nature (e.g., financial data) or due to technical challenges in the implementation of AquaSPICE. Therefore, we perform our analysis based on data retrieved from the initial proposal (targets) in combination with the information included in the deliverable 6.2. For this purpose we develop the following cross-sectional assumptions, that are applied across all case studies.

GENERIC	
Useful life	Constrained by the useful life of the membranes, estimated at a maximum of 5 years
Inflation	It will eventually be stabilized at 3% long term
Tax	The marginal (regional) tax rate will be considered. Assumed 22% If not available

Revenues are derived from reduction of fresh/waste water and energy usage and NZD benefits.

Revenue	Reduction in Water Intake	The monetary benefit is estimated as the cost reduction by lower water usage costs. This is estimated per m^3 at a local price, subject to inflation.
	Reduction of Water Waste	The monetary benefit is estimated as the cost reduction by lower water waste charges. This is estimated per m^3 at a local price, subject to inflation.
	Energy savings	The monetization is based on the conversion of water usage **after** the AquaSPICE solutions are implemented. The water volume saved is transformed into energy units and environmental costs in the following way: I. Water waste accounts for 25% of total water intake II. Carbon emissions count for 10% of water waste volume III. Environmental savings are monetized using the carbon prices, which are also subject to inflation IV. Electricity consumption saving is computed using the US Environmental Protection Agency (EPA) of 7.09×10^{-4} metric tons/KWh. The electricity cost is based on local industrial usage prices, which are subject to inflation.
	Other benefits	I. Near 0 discharge and water reuse is included in the water use and waste estimations. II. Recovery of materials and increased efficiency is included in the Energy Savings III. Non monetized externalities, such as reputational gains and green certificates are included into cost of capital premium reductions. A fixed rate of 0.2% will be applied as a benchmark
Cost	Water Treatment Technologies	There are no tangible results yet for the majority of technology combinations, while a lot of information is of proprietary nature. The objective of this section is to assess the financial viability of these solutions evaluating the benefits (identified in the revenue above) relative to their costs. In order to perform this initial evaluation, we employ the following assumptions: I. When there is information about the performance of the technology combinations we use the actual figures. II. If this information is not available, we use the figures stated in the previous WP's (theoretical targets). This provides a "best case" scenario. III. Then we test the sensitivity of the "best case" scenario to changes in its inputs, in order to account for the uncertainty involved. IV. At this stage of analysis and till the delivery date, no case study will be able to provide exact costs for CAPEX and OPEX of water treatment technologies. V. Consequently, for OPEX and CAPEX we use the theoretical full cost derivation from Plumlee et al., (2014), which is proportional to the quantity of water treatment. VI. The values in Plumlee et al., (2014) will be adjusted for inflation
	Depreciation	We assume a straight line depreciation of CAPEX
	Working Capital	Working capital needs will be 3% of Sales (Average in Europe).

8.2. Case Study 1A# Dow Terneuzen

The Dow Terneuzen Industrial unit is a chemical treatment company, hosted in an industrial parc area in the Netherlands. Specifically, it is processing hydrocarbon-based feedstock to produce plastic derivatives; a process requiring a high water intake, which is a rather scarce in the area. The main need for water is for cooling tower usage and Dow Terneuzen is already active in recycling the discharge; i.e., Reuse of (C)ooling (T)ower (B)low(D)own (CTBD). They aim to increase the efficiency of their water recycling in three streams of their activity, focusing on the following:

A. Stream 1:
    a. Target: 75% Reduction in water usage in CTBD.
    b. Technologies applied: CF+RO+UF
B. Stream 2:
    a. 25% Reduction of condensation losses.
    b. Technology:
        i. No specific technology identified at the timing of this report
        ii. At a later stage the following technologies were implemented: IEX, GAC, RO and UF, but they cannot be included in this report because they were not identified at a timely stage.
C. Stream 3:
    a. Water management with WaterCPS.
    b. Technology: WaterCPS

This will eventually result in the following measurable KPI targets that will be considered as the main sources of Cash Inflows that will create value to AquaSPICE implementation.

I. Reduce Water Intake by 1.5 Mm^3/y
II. Reduce electricity usage by 3MW

The 1.5 Mm^3/y reduction is a target figure that might not be achieved at the end of the pilot. However, in order to investigate and illustrate the potential viability of the different technologies applied, we will conduct a hypothetical cash flow analysis based on this target rate. There are three streams that contribute to the 1.5 Mm^3/y water intake reduction.

8.2.1. Value for Dow Terneuzen

AquaSPICE provides the opportunity to Dow Terneuzen to upgrade its site water management by using improved containers with different treatment trains (membrane units, (biological) activated carbon filters, ion exchangers and oxidative treatments, most of which are equipped with online sensors). In addition, the use of digital application in Dow Terneuzen site brings extra benefits on applying WaterCPS and RTM and management information systems in its current value chain. Other potential benefits that have been reported is to save at least 25% of fresh water intake and to develop sustainable water management practices which can have both environmental and economic benefits, considering that fresh water intake can be reduced in a water scarce area, and also water saving might imply an initial investment but can also have financial benefits in the upcoming years. The most important advantage of AquaSPICE is the replication potential to other industrial sites and locations (e.g., Taragona, Spain). Thus, the main opportunities identified are the following:

Opportunities	
Technological opportunities:	- Creation of a next level of site water management by using new technologies (smart monitoring, algorithms and control on steam and process condensate recycle streams); - Creation of a Water Cyber Physical System (WaterCPS) for DOW - Use of IMPROVED CONTAINERS comprising several water treatment technologies (coagulation/flocculation units, membrane units, (biological) activated carbon filters, ion exchangers and oxidative treatments, most of which are equipped with online sensors). - Application of RTM and management information systems
Expertise:	Not indicated
Synergies:	Not indicated
Others:	- Sustainable water management practices - Source 100% of its fresh water use instead of 75% which is now (so saving of an additional 25% of fresh water intake) - Replication of AquaSPICE results to Tarragona (Spain) site - Leveraging results to other DOW locations - Fit-for-Purpose (FfP) approaches development

Hence, diverse challenges have also been presented during AquaSPICE piloting phases which needs to be taken into account when discussing new investment opportunities and upscaling of existing technologies into full scale. Firstly, highly investment costs have been reported which account for €10-15 million. An extra cost that has been reported is the assessment tools for the industrial water reuse practices. Among the main challenges, compliance with EU and national legislations on water reuse and discharge limits, might also add additional costs for taking required steps and adopt technological equipment into the water use limits. EU legislation and strict regulatory environments for the chemical industries in the EU, require initial investments which needs to consider the environmental impact first and to the economic viability of the sector.

Apart from economic challenges that might be the main challenges for further investments on full-scale AquaSPICE technologies, technological challenges remain the most complex since accessibility to technologies is not often easy and prices for buying costly equipment have arisen and also there is a knowledge gap on applying new technologies in existing infrastructure. Adaptability to new infrastructure is required in order to handle new equipment without damaging existing installations.

Challenges	
Technological challenges:	- Technical infrastructure issues - Development of a flexible and robust monitoring system - Accessibility to the technology - Lack of awareness of technological capacity
Economic challenges:	- Required investment for the Terneuzen site is likely in the 10-15 mio € range - Required costly tools for the assessment of the industrial water re-use practices
Other challenges:	- Cybersecurity - Current data stage - EU & National legislations- reuse and discharge limits - Structured European policy for industrial water efficiency - Complex stakeholders' engagement

Considering the potential value for Dow Terneuzen, strong economic and environmental factors might drive further investment opportunities in the future. In case of Dow Terneuzen, environmental impact is the major value that can create in terms of fresh water intake 2.25 mio m3/y and energy saving of 180 GWh/y, as well as reduced CO2 fees (72000/y). In addition, through AquaSPICE, Dow will have the opportunity to acquire technical knowledge on wastewater treatment and water recycling systems as well. Considering the efficiency of water management mechanisms, further future investments for water efficiency, might create a positive economic benefits in anticipation with initial investment costs.

Impact	
Environmental impact:	- Fresh water intake savings of 2.25 mio m3/y, - Avoidance of CO2 fees (72000/y) - Reduced energy use of 180 GWh/y - Waste water treatment - Water recycling systems for the industry
Territorial impact:	- Water recycling systems for the local/ regional area
Social impact:	- Hasn't been recorded any

The most important drivers in case of Dow Terneuzen, are the environmental concerns and water and energy savings, which can be accumulated to potential economic benefits as well. Reaching near zero liquid discharge in relation to the cooling tower is an important driver for the industrial site.

Certain barriers such as compliance with the EU regulations and discharge permits, are very important to be considered. Compliance often means additional technological adaptation or changes in the current value chain, as well as lower levels of discharge of fresh water and waste treatment.

Drivers	Barriers
Decrease freshwater intake demand by approx. 1.1 Mio m^3/a	Complex technologies
Reach near zero liquid discharge in relation to cooling tower blow down	Water quality
Avoidance of CO2 fees (72000/y)	Technical expertise required
	Use of same technology and construction

	Meet permit requirements
	Required technical support from different DOW's units

Potential risks should also be taken into consideration when considering expanding specific business features or introducing a new technology. Risks might involve multiple areas such as financial, operational, technical etc. In case of Dow Boehlen site, new technological applications without prior knowledge might require adapting existing infrastructure to the new standards, which actually requires new investments into infrastructure and personnel. One of the main risks incurred is the lack of expertise for introducing a new equipment of technology which requires external experts or internal personnel to take advanced training or hiring new employees. Within AquaSPICE diverse tools were introduced which might all be easy to apply and understand the process, or even required additional software to read or understand. In addition, the process and water quality parameters need to be managed properly to avoid any negative impact on the reliability and robustness of the existing processes and assets. So, a risk for damaging existing infrastructure exists.

Costs are another element to be considered, since new equipment, new infrastructure and personnel required, advances the initial costs for making a new investment. New investments might have benefits other than economic such as environmental, social or others but a future plan should also foresee strategies to marketise and commercialise at least part or products of the new investments. A strategic approach would be to supply good quality water, coming as a result of the initial investment, into third parties. This possibility increases revenues and covers maintenance and other related costs such as personnel costs, transport costs etc. Personnel such as engineers, researchers, and other side staff can increase the costs of initial investments, considering maintenance costs in case.

The most important risks in the case of Dow are presented below:

Financial:	Costly equipment, new technologies and personnel.
Operational:	Lack of expertise for introducing new equipment Diverse technologies introduced through AquaSPICE which expertise might not exist or additional software
Strategic:	Implementation of enhanced water treatment technologies means, that water quality will improve. An improved water quality can diminish the downstream water demand. In case this water is supplied to third parties, the increased quality has to be included into f.e. contracts to enable a revenue from the investment.
Technical:	New technologies might not easily fit into existing building structure. In most cases new infrastructure has to be erected before existing can be taken out of service –> cost & time constraints Process and water quality parameters need to be managed properly = severe negative impact on the reliability and robustness of the related processes and assets.

8.2.2. CASH FLOW ANALYSIS CS#1.A: DOW TERNEUZEN

Based on assumptions and estimated numbers:

We develop the following, case-study-specific assumptions

Monetized Benefits (based on target rates and theoretical assumptions)	
Water intake saving	The pilot is not completed at this stage, but the feedback we receive is that the final output will be in line with the target values. I. We consider a reduction 1.5 Mm^3/y a. This comes from a 75% gain of a 1.5Mm^3/y water usage in CTBD. b. 25% in reduction of condensation losses resulting from a water stream of 1.5 Mm^3/y c. The remaining from the application of WaterCPS II. We consider a retail price of around €2, which is the regional average. III. This price will also be subject to inflation
Water waste saving	We apply the cross-sectional assumption that this corresponds to 25% of water intake. I. This translates into a reduction of Water Waste of 0.375 Mm3/y II. We consider the regional average price for water discharge that is below €2. A short term regional average price is around €1.7
Environmental Costs	We apply the following assumptions. I. The energy costs are incorporated into the carbon emission costs II. Carbon emissions account for 10.6kg per cubic meter of waste water III. The price for Carbon is around €90. IV. Following Carbon related policies, the inflation rate from Carbon prices is set at 4%

Monetized Costs (based on target rates and theoretical assumptions)		
Capital Expenditure (CAPEX)		I. For the CTBD water reductions the combination of UF, CF and RO are used. The costs will be derived accordingly according to the volumes treated. II. For the Reductions in condensation there is no specific technology identified III. The WaterCPS is a digital technology
	UF	The CAPEX for UF is assumed to be around $3.57 * (capacity\ in\ MGD)^{-0.22} * (1 + inflation)^{year-2014} * forex\ rate$
	RO	The CAPEX for RO is assumed to be around $7.14 * (capacity\ in\ MGD)^{-0.22} * (1 + inflation)^{year-2014} * forex\ rate$
	CF	The CAPEX for CF is assumed to be around $2.26 * (capacity\ in\ MGD)^{-0.54} * (1 + inflation)^{year-2014} * forex\ rate$
Operating Expenses	UF	The OPEX for UF is assumed to be around $0.3 * (capacity\ in\ MGD)^{-0.22} * (1 + inflation)^{year-2014} * forex\ rate$
	RO	The CAPEX for RO is assumed to be around $0.44 * (capacity\ in\ MGD)^{-0.13} * (1 + inflation)^{year-2014} * forex\ rate$
	CF	The CAPEX for CF is assumed to be around $0.016 * (capacity\ in\ MGD)^{-0.0.020} * (1 + inflation)^{year-2014} * forex\ rate$

Stream A. CTBD

First, we start our analysis with stream A, CTBD, which is identified by Dow Terneuzen as the most promising and efficient (75% rate) application of AquaSPICE technologies. Dow Terneuzen has focused its efforts in this venture and, at this stage, it is the only one that has some specific technologies identified; namely, UF, CF and RO. Overall, the water usage of 1.5 Mm^3/y is expected to be reduced by more than 75%. We use a conservative scenario (75% efficiency), in order to investigate the profitability of this combination of technologies, with a margin for error.

Based, on the Plumlee et al., (2014) assessment of all relevant costs, we arrive at the following cost structure for a venture that treats 1.09 MGD (equivalent of 1.5 Mm^3/y).

		Units (MGD)	Theoretical cost/unit (€/MGD)	Overall Cost (€)
Capex	RO	1.09	4.21	4,567,945
	UF	1.09	2.10	2,283,972
	CF	1.09	0.85	918,640
	Total CAPEX		**7.16**	**7,770,557**
OPEX	RO	1.09	0.26	264,254
	UF	1.09	0.18	191,930
	CF	1.09	0.03	38,297
	Total OPEX (subject to inflation)		**0.47**	**494,482**

Disclaimer: The figures in the table are theoretical estimates rather than actual figures.

With this theoretical estimates for the costs, we estimate whether the combination of CF+UF+RO could be profitable on a pilot scale, provided the specifics of Stream A, with regards to water quality and water output requirements. We consider the water quantity treated, as well as the available results for the efficiency rate (% of water intake and discharge reduction). This defines the monetary value of the benefits on a pilot scale. For the costs, there is no specific information provided and we use the theoretical estimates derived from Plumlee et al. (2014) instead. The findings are summarized below.

	NPV (€)	TLC (€)	Robustness	
Overall	1,141,029	7,996,618	IRR	40%
Per m3 intake saved	0.25	1.78	NPV/TLC	14%
Per m3 discharge saved	1.01	7.10	Min efficiency	64%
Per total (intake-discharge) saved	0.20	1.42	Min Mm3 treated	0.7
Per m3 intake used	0.19	1.33	Min water price (intake+discharge)	€2.08

Disclaimer: The figures in the table are theoretical estimates rather than actual figures.

The main findings can be summarized below:

- AquaSPICE value for Dow Terneuzen
  - In line with Dow Terneuzen's expectations, the combination of CF+RO+UF appears to be reasonably profitable with a NPV>0, a NPV/TLC>0 and an IRR that is significantly higher than the cost of capital.
  - The monetary value of this combination is derived from an overall cost per total water quantity treated of 1.43, which is less than the total price for water.
- AquaSPICE cost competitiveness.
  - Focusing on water reduction targets, a water intake reduction target is more realistic than a water discharge reduction target.

    - In particular, considering the cost per m^3 of water intake reduction, this is still lower than the market price of water.
    - Considering the cost per m^3 of water discharge reduction, the TLC appears to be rather high compared to market prices.
    - This analysis suggests that a potential marketing policy for this technology combination could be to focus on total water usage or only on water intake.
- Pilot and upscaling. The analysis suggests that there might minimum requirements that render this technology combination profitable.
    - The efficiency rater assumed here is a 75% reduction in water intake and discharge. Dow confirmed that this is feasible, but in order to account for efficiency losses when upscaling, we estimate what is the breakeven point that would render the venture non-profitable. This is estimated at around 64%, which is considerable lower than the current level
    - In the pilot the CF+UF+RO combination appears to be profitable for the quantity of water treated. Considering that CAPEX and OPEX do change with quantity, we estimate what might the minimum size of a venture be, without rendering it non-profitable. We estimate the minimum size to be at around 0.7 Mm^3/y, which is rather small. Two conclusions can be drawn
        - In line with the IRR estimate, this technology combination appears to be reasonably profitable within the context of the implementation in DOW Terneuzen.
        - This is a first indication that it might be reasonably profitable for smaller ventures, that might be the target clients, should AquaSPICE become a new venture.
- Technologies
    - The CF+UF+RO is reasonably profitable
    - There is an incremental benefit of WaterCPS, which cannot be assessed independently. However, it is consistently present in all ventures and thus, it is considered to be an integral part of AquaSPICE.

Streams B & C

At this stage, unfortunately, there is no other technology identified for the remaining streams. In addition, there is no data availability for stream B or stream C. The set of assumptions needed to perform a theoretical analysis on these streams would be to strong and, therefore, only the qualitative assessment (previous section) will be considered.

8.3. Case Study 1B# Dow Bohlen

The Dow Boehlen Industrial, like Dow Terneuzen, is classified as working on a water-scarce environment and water usage reduction is a top priority. It is aiming at reducing the overall water intake by around 25%. This will be done by increasing the water recycling through increased smart-monitoring in four streams. Different types of technologies will be tested in order to achieve:

- A better Cooling Tower Blowdown (CTBD) management. The objective is to increase recycling, reduce steam condensate discharge and ultimately, reduce water intake
- A higher usability rate of water discharge in order to increase water recycling and ultimately reduce water waste discharge.

This will eventually result in the following measurable KPI targets that will be considered as the main sources of Cash Inflows that will create value to AquaSPICE implementation.

I. Reduce Water Intake by 1.1 Mm^3/y.
II. Reduce river discharge of Blow down by $96m^3/h$.
III. Disclaimer: These are the initial targets. Not all pilots are completed. The revised targets are 0.75 Mm^3/y and 61 m^3/h (0.57 Mm^3/y) for reduction in water intake and discharge, respectively.
    a. We will run the analysis based on the initial targets
    b. Then we will test the sensitivity of the results to lower volumes with a breakeven point analysis.
    c. In addition, we will compare alternative technology combinations based on theoretical cost curves, even if the pilots are not run or competed.
    d. In order to provide some hypothetical scenario analysis (even for technologies that are not being tested), we consider the initial (theoretical) targets and then we conduct a sensitivity analysis, including the more realistic numbers provided by DOW.

This will be done with the following streams (all integrated into WaterCPS).

A: Reduce CT blowdown. EDR is not tested due to costs.	B: Treatment of condensate return Stream/technology combinations are not tested	C: Improve demin water quality Stream/technology combinations are not tested.
The treatment of 0.84 Mm^3/y water stream, with UF, BACF and RO membranes, will result in a water intake/discharge reduction of 0.57 Mm^3/y Efficiency rates about 75% Technology combinations i. BACF+UF+RO ii. BACF+RO iii. BACF+RO+EDR.	Treatment of condensate return to the production and partial recycling of water. The targets stated in deliverable 6.2 are a 0.06 Mm^3/y There is no technology identified yet i. DECARB+SRF+SCAV+IEX ii. DECARB+SRF+UF+IEX iii. DECARB+RO+IEX iv. CF+UF+RO+IEX v. CF+UF+IEX vi. CF+IEX vii. CF+RO+IEX	10% reduction in discharge targeting a 0.19 Mm^3/y reduction in water intake. For this there is no technology identified yet, but potential technologies tested i. DECARB+SRF+SCAV+IEX ii. DECARB+SRF+UF+IEX iii. DECARB+RO+IEX iv. CF+UF+RO+IEX v. CF+UF+IEX vi. CF+IEX vii. CF+RO+IEX

Disclaimer: The feasibility study is based on theoretical assumptions rather than actual figures.

8.3.2. Value for Dow Bohlen

To reduce the industrial site's water demand, the application of treatment combinations for cooling tower blowdown reuse (2) are considered highly-exploitable, as they may lead to approx. 15 % water savings, i.e. BACF+UF+RO(+IEX). Besides, the raw water treatment (1) can be advanced and optimized by the addition of a pre-treatment step, such as UF or SCAV to ensure quality and process efficiency. These pre-treatment technologies are also considered highly exploitable.

Diverse costs may occur for upscaling AquaSPICE potential exploitable technologies. Specific costs such as initial investment costs, equipment and personnel costs need to be identified. New investments coming from private investors and public funding can facilitate the process of wastewater management technologies, which require a large amount of funding for installation of equipment, maintenance, use and technical expertise. Investment can take the form of:

- Company investments into projects that show possible revenue due to increased water quality (investment based on lower downstream costs)
- Company investments for sustainability projects
- Company investments for projects that counteract water scarcity
- State funding for implementation of technology that is beyond state of the art

Therefore, AquaSPICE provides the opportunity to Dow Boehlen to check various technological approaches that can improve its current value chain. Through AquaSPICE piloting phases, different treatment technologies can be tested, providing important knowledge for possible treatment trains and expertise sharing into industrial applications. AquaSPICE opens possible ways for a more sustainable water supply to counteract water scarcity situation of Boehlen's site location. The participation within the consortium has also shown the advantages of working across different companies. AquaSPICE also enhances important partnerships for future synergies and collaborations.

Opportunities	
Technological opportunities:	- Optimization of cooling water treatment after discussion with partners; - Recommendations given regarding looming problems in the downstream processes and to adjust to upstream water treatment processes; - Use of IMPROVED CONTAINERS comprising several water treatment technologies (coagulation/flocculation units, membrane units, (biological) activated carbon filters, ion exchangers and oxidative treatments, most of which are equipped with online sensors);
Expertise:	- Cooperation with partners provides knowledge exchange about new technologies and simplifying understanding about other technologies;
Synergies:	- Building synergies among partners on water management issues and sharing knowledge across company boundaries; - Raising awareness on water scarcity issues and organizing counteracting activities;
Others:	- Leveraging results to other DOW locations; - WaterCPS shall be used for strategic decisions of possible water treatment technological evaluation within the entire water system;

Several challenges should also be considered for upscaling

Challenges

Technological challenges:	- Weather conditions have affected water quality during piloting phases and treatment trains. Treatments could not be tested in parallel, so technologies could be compared based on exact conditions and parameters; - Research conducted has shown that a more detailed monitoring systems is required to gather sufficient data; - Technological results are not only based on the treatment technology itself but also to the treatment processes. It is possible that improved treatment process might come with higher water consumption in step A, but this will enable water saving in downstream process B. Evaluating such complex loops has been a technical challenge.

Considering the potential value for Dow Boehlen, there are several factors that might influence economic and investment decisions, regarding their Environmental social and territorial impact.

Impact	
Environmental impact:	- Decrease freshwater intake - Waste water treatment - Water recycling systems for the industry - Avoidance of CO2 fees (72000/y)
Territorial impact:	- Water recycling systems for the local/ regional area
Social impact:	- Hasn't been recorded any

Factors other than economic costs might affect decision-making for further expansion of the current wastewater treatment technologies within the current value chain. Certain drivers such as legislation or environmental impact, as well as other components can create the conditions to by-pass economic costs. In relation to Dow Boehlen's site one of the main drivers were to decrease freshwater intake demand to the industrial plants, and also to reduce CO2 fees reaching 72000/y.

Certain barriers might also affect investment decisions for further exploitation and upscaling, such as the use of new complex technologies which require technical expertise, which is might be unavailable among current personnel or requires human resources which add additional costs to the current value chain. In addition, some of those technologies or the combination of them, especially concerning digital technologies, require additional knowledge which is not available among personnel or might demand cooperation and approval from other DOW's units. That requires time and knowledge investments, which depict the needs for additional personnel. Compliance with EU environmental regulations requires high investment costs as well, and industrial partners need to also meet specific permission requirements for the level of discharge of water into the environment.

Drivers	Barriers
Decrease freshwater intake demand by ≈ 1.1 Mio m^3/a	Complex technologies
Reach near zero liquid discharge in relation to cooling tower blow down	Water quality Technical expertise required
Avoidance of CO2 fees (72000/y)	Lack of awareness and information
Guarantee TOC < 0.2 mg/L in the boiler feed water	EU environmental regulations limitations
Guarantee conductivity < 0.1 µS/cm	Use of same technology and construction
	Meet permit requirements
	Required technical support from different DOW's units

Potential risks should also be taken into consideration when considering expanding specific business features or introducing a new technology. Risks might involve multiple areas such as financial, operational, technical etc. In case of Dow Boehlen site, new technological applications without prior knowledge might require adapting existing infrastructure to the new standards, which actually requires new investments into infrastructure and personnel. One of the main risks incurred is the lack of expertise for introducing a new equipment of technology which requires external experts or internal personnel to take advanced training or hiring new employees. Within AquaSPICE diverse tools were introduced which might all be easy to apply and understand the process, or even required additional software to read or understand. In addition, the process and water quality parameters need to be managed properly to avoid any negative impact on the reliability and robustness of the existing processes and assets. So, a risk for damaging existing infrastructure exists.

Financial costs are another element to be considered, since new equipment, new infrastructure and personnel required advances the initial costs for making a new investment. New investment might have benefits other than economic such as environmental, social or others but a future plan should also foresee strategies to marketise and commercialise at least part or products of the new investments. A strategic approach would be to supply good quality water, coming as a result of the initial investment, into third parties. This possibility increases revenues and covers maintenance and other related costs such as personnel costs, transport costs etc. Personnel such as engineers, researchers, and other side staff can increase the costs of initial investments, considering maintenance costs in case.

The most important risks in the case of Dow are presented below:

Financial:	Costly equipment, new technologies and personnel.
Operational:	Lack of expertise for introducing new equipment Diverse technologies introduced through AquaSPICE which expertise might not exist or additional software
Strategic:	Implementation of enhanced water treatment technologies means, that water quality will improve. An improved water quality can diminish the downstream water demand. In case this water is supplied to third parties, the increased quality has to be included into f.e. contracts to enable a revenue from the investment.
Technical:	New technologies might not easily fit into existing building structure. In most cases new infrastructure has to be erected before existing can be taken out of service –> cost & time constraints Process and water quality parameters need to be managed properly = severe negative impact on the reliability and robustness of the related processes and assets.

Key Activities	Key Resources	Distribution Channels
No changes required yet. Future implementation of AquaSPICE solutions requires investments	-Water treatment assets -Plant personnel -Technological knowledge of treatment technologies	-Internal distribution of water to production plants

Stakeholders/Key Partners		
Central Stakeholders	Peripheral Stakeholders	External Stakeholders
DOW Global	Power station (LEAG)	- Local authorities of river water basin Elster - LDS

Customer Relationships	Customer Segments
Costumers are mainly in the same company (Dow production plants). Third party companies on site have utility contracts with Dow.	Production Plants of Dow Site Böhlen

Cost Structure	Revenue Streams
Mixed cost structure for entire department. In order to describe cost savings due to AquaSPICE implementation, the area of implementation has to be defined to also describe their costs. This has not been finalized yet.	Not known yet

Value Propositions		
Economic	Environmental	Social/Territorial
- Use of new technologies on other DOW sites - Leveraging results to other DOW locations - Development of Fit-for-Purpose approaches diminishing economic spending	- Decreased fresh water intake by approx. 1.1 Mio m³/a - Reach near zero liquid discharge of cooling tower blow down - Sustainable water management practices	

Private financial mechanisms	Private non-financial mechanisms	Public financial mechanisms	Public non-financial mechanisms
No information provided	No information provided	No information provided	No information provided

8.3.3. CASH FLOW ANALYSIS CS#1B: DOW BOEHLEN

At this stage most of the combinations have not been tested and there are no results for their efficiency and/or their cost structure. Consequently, a holistic evaluation is not possible. However, there is enough information to conduct a theoretical cost-based analysis. More precisely, we will try to evaluate the different combinations of technologies, under the following assumptions.

Monetized Benefits (based on target rates and theoretical assumptions)	
Water intake saving	The pilot is not completed at this stage, but we will consider the following target values provided by Dow Bohlen I. We consider a total reduction 1.1 Mm^3/y. This will come from a. A 0.57 Mm^3/y in the river discharge b. A recycling of 25% in the condensate, equal to 0.06 Mm^3/y c. An additional step in demin water plant aiming at a 10% recycling of demineralized water, equal to 0.19 Mm^3/y II. We consider a retail price of around €2, which is the regional average. III. This price will be subject to inflation
Water waste saving	We consider the target stated in the AquaSPICE KPIs I. The target river discharge reduction is 61m3/h, which translates into 0.57M m3/y II. For all other streams it will account for 25% of water intake saving. III. We consider the regional average price for water discharge that is below €2. A short term regional average price is around €1.7
Environmental Costs	We apply the following assumptions. I. The energy costs are incorporated into the carbon emission costs II. Carbon emissions account for 10.6kg per cubic meter of waste water III. The price for Carbon is around €90. IV. Following Carbon related policies, the inflation rate from Carbon prices is set at 4%

Comparison of costs will be based no the following assumptions (*costs to be adjusted for inflation*)

Monetized Costs (based on target rates and theoretical assumptions)		
Technology	CAPEX ($^{€M}/_{MGD}$)	OPEX ($^{€M}/_{MGD}$)
Decarb	$2.26 * Q^{-0.054}$	$0.0068 * Q^{-0.051}$
SF	$0.825 * Q^{-0.59}$	$0.13 * Q^{-0.03}$
SCAV	$0.474 * Q^{-0.056}$	$0.038 * Q^{-0.052}$
IEX	$0.257 * Q^{-0.33}$	$0.0848 * Q^{-1.33}$
UF	$3.57 * Q^{-0.22}$	$0.3 * Q^{-0.22}$
RO	$7.14 * Q^{-0.22}$	$0.41 * Q^{-0.13}$
BACF	$1.43 * Q^{-0.17}$	$0.059 * Q^{-0.044}$
EDR	$0.94 - 1.11$, assume 1	$1.41 - 2.09$, assumed 1.55

TLC per combination

DOW Boehlen has identified Stream A and the combination of BACF+UF +RO, in particular, as the most promising. They are focusing their efforts on this stream. We assess this from a purely financial perspective, by conducting a theoretical investigation. For the benefits, we use the real data whenever available (only for Stream A), as well as the theoretical target rates (updated) whenever data is not available (EDR in Stream A and the other two streams. For the costs, we use only the theoretical cost curves estimation (e.g., Plumlee et al., 2014). We evaluate the alternatives using a cost comparison, assuming a *similar contribution* of each layer to efficiency.[2] The volume of water treated is assumed stable, but the overall efficiency changes proportionally with the number of layers. Of course, this assumption is rather rigid, but it is realistic in identifying big changes in the profitability index (NPV/Cost). Then we will evaluate the robustness of our findings with a sensitivity analysis. The objective of this analysis is to investigate the financial performance of the different combinations, given the water treatment conditions, and evaluate whether BACF+RO+UF is indeed the most suitable candidate from an economic point of view. Following the assumptions above the different combinations of technologies can be summarized below.

(based on target rates and theoretical assumptions)	NPV(€)/intake(m³)			TLC(€)/intake(m³)			NPV/TLC		
Stream	A	B	C	A	B	C	A	B	C
BACF+RO	**0.56**			**1.01**			**0.55**		
BACF+IEX		-0.19	0.00		1.78	1.18		-0.11	0.00
BACF+RO+UF	**0.87**			**1.50**			**0.58**		
BACF+RO+EDR	0.34			2.34			0.15		
BACF+UF+IEX		-0.35	-0.28		2.57	1.59		-0.14	-0.18
BACF+RO+IEX		-0.90	-0.59		3.13	1.91		-0.29	-0.31
BACF+UF+RO+IEX		-1.05	-0.88		3.92	2.31		-0.27	-0.38
Decarb+RO+IEX		-0.91			3.13			-0.29	
Decarb+SF+SCAV+IEX		0.47	-0.15		2.44	1.56		0.19	-0.10
Decarb+SF+UF+IEX		-0.18	-0.35		2.98	1.75		-0.06	-0.20

Disclaimer: The combinations with available data are the highlighted ones. The estimates for all the others are based on theoretical assumptions. The estimates for all combinations are theoretical cost estimates and not actual figures.

The table above is rather clear on the following findings, confirming the selection of DOW in focusing on reducing the river blowdown (Stream A), using in particular the technology combination BACF+UF+RO.

A. The effort to reduce the river blowdown (A in the table above) appears to be the most profitable overall. The NPV/TLC is always positive, and definitely higher than in the other two streams.
B. The technology combination BACF+UF+RO is the best performing with the highest NPV/TLC
C. Technology combinations with more layers are more expensive per m³ and mostly result in NPV<0

[2] Disclaimer: Please note that not all technologies are tested. However, we attempt a theoretical feasibility study based on the assumption that an additional layer of treatment improves the efficiency rate at a constant marginal rate. This might not be always realistic, since different technologies might overperform others. It is employed solely for the purpose of comparing the different technology combinations. Consequently, we focus only on the cost and not on performance, because we have no tangible information at this stage. This is done for illustration purposes only and it will not be taken into consideration in the final recommendation.

D. BACF+UF+RO seems to be the right balance between costs and efficiency (highest NPV/TLC)
E. BACF+RO+UF vs BACF+RO. The first combination exhibits a 50% higher cost, but the contribution of UF to efficiency renders it a combination with higher financial performance. This depends on our assumption that each layer of treatment contributes to overall efficiency proportionally. We test what is the minimum marginal efficiency rate for UF that would render BACF+UF+RO more profitable than BACF+RO. It appears that 33% (assumed here) is a marginal case with anything below it (should it meet the water quality requirements) making BACF+RO the preferred solution.

Contribution of UF to efficiency	10%	20%	30%	40%
BACF+RO	1.07	0.84	0.62	0.40
BACF+RO+UF	0.58	0.58	0.58	0.58

BACF+UF+RO Sensitivity analysis

The findings above confirm the previous findings in Dow Terneuzen. Collectively, we find that the combination of filtration technologies yields a robust return and DOW seems to prefer a combination of CF+UF+RO. Most, likely this is due to the combined performance. We confirm that this is, cost-wise, a profitable solution, with the combination BACF+RO following closely. We appreciate that the final selection does not depend solely on financial criteria and therefore, we abide by their choice and in this final part we develop an economic analysis based on the scenario that they aim to reduce the river blowdown, through a reduction of CTBD. This involves the treatment of 0.84 Mm^3/y of water and it involves the following BACF+UF+RO combination of technologies.

This would yield the following costs:

	(based on target rates and theoretical assumptions)	MGD	Cost in million €/MGD	overall
Capex	RO	0.61	€ 4.78	2,906,079
	UF	0.61	€ 2.39	1,453,040
	BACF	0.61	€ 0.93	567,729
	TOTAL CAPEX			**4,926,848**
Opex	RO	0.61	€ 0.26	159,568
	UF	0.61	€ 0.20	122,104
	BACF	0.61	€ 0.04	22,000
	Total OPEX (subject to inflation)			**303,673**

Disclaimer: The figures in the table are theoretical estimates rather than actual figures.

And the following results

(based on target rates and theoretical assumptions)	NPV (€)	TLC (€)		
Overall	2,923,044.61	5,028,502.72	IRR	66%
Per m3 intake saved	1.28	2.20	NPV/TLC	58%
Per m3 discharge saved	1.28	2.20	Min efficiency	42%
Per total (intake-discharge) saved	0.64	1.10	Min Mm3 treated	N/A
Per m3 intake used	0.87	1.50	Min water price (intake+discharge)	€1.89

Disclaimer: The figures in the table are theoretical estimates rather than actual figures.

The analysis here indicates that the BACF+UF+RO combination is robust enough from a financial point of view, with a sufficient profit margin (IRR is 66%), without a minimum treated volume required. In addition, it can still be profitable with an overall efficiency rate as low as below 60%, which is significantly lower than the target (updated 68%) rate, as well as with a lower price (intake+discharge) of water €1.89 (current €3.7).

Conclusions:

Based on the combined analysis of DOW Boehlen and Dow Terneuzen we can reach the following conclusions:

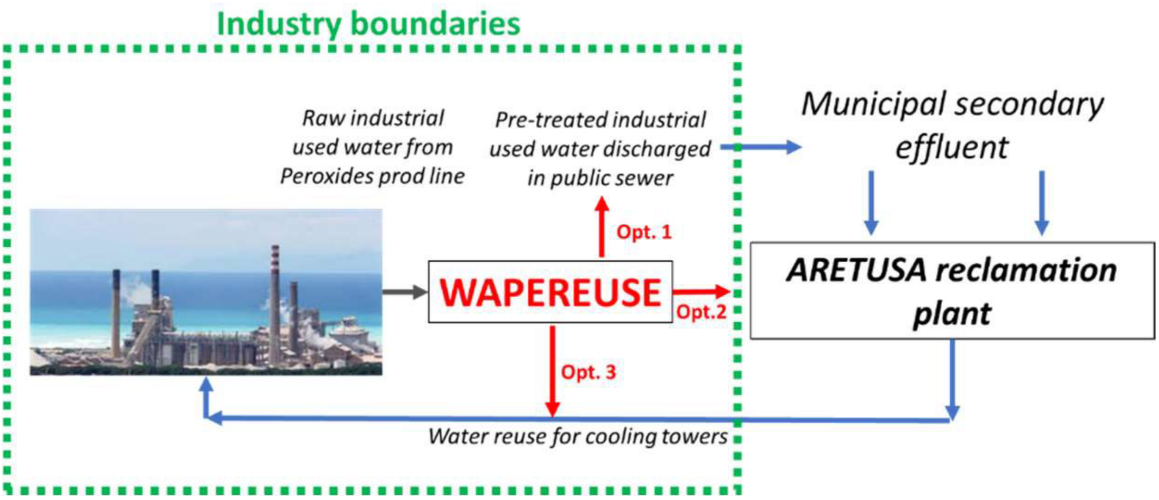
a. Technology combinations
   i. From a financial standpoint, the combination BACF+UF+RO appears to be the best balance between costs and benefits
   ii. The combination BACF+RO yields similar results and its performance depends on the contribution of UF to overall efficiency.
   iii. Technology combinations with more layers of treatment do not seem to justify the added costs from a financial point of view.
   iv. There is an incremental benefit of WaterCPS, which cannot be assessed independently. However, it is consistently present in all ventures and thus, it is considered to be an integral part of AquaSPICE. If AquaSPICE is to be sold as a product, it would be more relevant as a combination of technologies
b. Minimum values to break even
   i. The combination of CF+UF+RO appears to be adequately profitable,
   ii. Suitable for low to moderate water prices. Minimum price €1.89 for intake and discharge
   iii. Suitable for small/medium sized ventures, since it appears to be sufficiently profitable
   iv. Still profitable with an overall efficiency of as low as 60%
c. Cost competitiveness
   i. The overall TLC of this combination is still lower than the price of water. This seems to be the source of its value.
   ii. When focusing on water reduction volumes, the TLC for intake and discharge are higher than market prices of water. Therefore, a marketing policy based on water intake would be more suitable.

8.4. Case Study #2 Solvay

Rosignano Solvay is an exemplary case of a Public Private Partnership (PPP) that applies in practice the circular economy concept through industrial-public symbiosis. In practice the reuse of municipal wastewater enables a more efficient usage of water resources between a chemical plant (Rosignano Solvay) and a public Water Utility that manage the Water Reclamation Facility of ARETUSA. The aim of AQUASPICE project is to increase the amount of reused wastewater by treating the industrial wastewater produced by the peroxide production unit of Solvay Chemical plant. Hence, a pilot plant for industrial wastewater treatment (named WAPERUSE) is going to be realized to treat the mentioned wastewater in order to be usable in the cooling towers. According to the reached quality of treated wastewater by WAPEREUSE, there are three potential options for the use/discharge of the wastewater:

1. Discharge the treated wastewater in the municipal sewers of Rosignano Marittima. In this case, the industrial wastewater will be mixed with municipal wastewater, treated in the municipal wastewater treatment plant of Rosignano, and then sent to the water reclamation facility of ARETUSA. The final treated effluent from ARETUSA will be reused by SOLVAY.
2. Discharge the treated wastewater discharge in the ARETUSA headworks before it is treated and reused by SOLVAY.
3. Establish a close loop for internal re-use.

Figure 12. Close Loop for Water Re-use. Solvay



Solvay will contact only a small scale pilot that will treat no more than 365 m^3/y industrial wastewater for reuse, with the aim to save freshwater. If this becomes successful, it will then be expanded into a full scale installation that will treat 87,600 m^3/y. The stated target for water saving is set (at deliverable 6.2) at 8,760 m^3/y. This is an efficiency target set at 10%. We will use this in our economic evaluation below. We will start with the small scale pilot and then we will evaluate the suitability for larger venues.

If the pilot becomes successful, the full scale installation (with high potential for multiple replications) is expected to yield the following results (deliverable 6.2).

I. Increase water waste reuse by 8.76 Km^3/y or 10% of the total stream
II. Reduce Energy consumption by 70,000 KWh/y
III. Reduce the Carbon footprint by 5,000 tCO2eq/y.

8.4.1. Value for Solvay

In the case of Solvay, one of the main objectives is to evaluate environmental benefits with the aim to reuse of water on their industrial plant, avoid depletion of fresh resources, and create positive effects for preserving biodiversity. When evaluating further exploitation, what needs to be taken into account is also environmental benefits that can have a long-term impact. Solvay aims to also minimize energy costs, and gas emissions in alignment with Solvay's sustainability strategy "Solvay One Planet", that is considered the greatest value of AquaSPICE concerning CS#2. AquaSPICE will increase sustainability of the company and it will provide the opportunity to apply optimized technologies (e.g., circular and digital innovation). Although efficiencies and economic benefits are not known yet, there is a replication potential in other plants of Solvay. So future investment, can have multiple environmental and economic benefits. In relation to possible costs incurred which at this stage no available data exist to confirm the actual spending, related to operational, transport, treatment or reuse costs. In case of replication and further upscaling of Solvay, the company can extract additional public funding from its local and national partners, which can help to consider the costs of initial investment.

Opportunities	
Technological opportunities:	- Optimized technologies for water efficiency - Application of new technologies for energy recovery (ARETUSA reclamation plant) - Digital and circular innovation
Expertise:	- The solution can be replicated in all the Solvay plant located worldwide;
Environmental:	- The installation of the solution is in line with Solvay One-planet policy to increase the sustainability of the business of the company; - Create positive impact on final water and sludge quality effluent from ARETUSA water reclamation plant

Specific challenges occur when considering upscaling. The use of new technological equipment and water management modelling, requires extra expertise which increases operational and personnel costs. Adaptation to new innovative water management models might prove to cost-efficient for water systems optimization but requires new investments for buying and installing new equipment. Maintenance of water management and wastewater treatment also requires extra operation costs. Digital modelling has to be adapted to the existing systems in Solvay's plants. Another challenge is the regulatory and business environment, which set the quota for wastewater discharge into the environment, and also the quotas for water prices in case that Solvay supplies groundwater (about 2 million m^3/year), collected by Solvay wells in the coastal area of the lower val di Cecina, for civil purposes. This can also have a considerable economic impact.

Challenges	
Technological challenges:	- Technological equipment; - Water Management Modelling;
Strategic challenges:	- Regulatory and Business Enabling environment; - The implementation of the solution at full-scale will be a decision of Solvay. The solution will be installed in Solvay chemical plant;
Others:	- Governance changes - Institutional changes

The greatest impact of AquaSPICE in CS#2, is not only economic, but it has important environmental, territorial and social impact. Consequently, AquaSPICE technological solutions in full scale application, can change the whole environmental impact because it can contribute to less freshwater intake and less wastewater discharge to the environment and local aquifers. Optimisation of its existing wastewater treatment plants can have considerable positive effects on lowering energy consumption and gas emissions into the environment. In addition, in case of Solvay, through the industrial Consortium ARETUSA, its water reuse mechanisms can enable a very positive territorial impact which can further contribute to the local society both environmentally and economically. Environmentally, the local society can be benefitted by using 2 million m³/year of groundwater can be used for civil purposes instead of industrial, which the local government can be supplied in lower prices, which can negotiate among the main partners of ARETUSA Consortium. That has effective economic benefits as well for the local society. The whole value chain of Solvay can be built and supported by sustainability practices which will not only respect local biodiversity and aquatic ecosystems but would provide viable economic solutions both for Solvay, for the local government and for society.

Impact	
Environmental impact:	- Respect natural charging capacity of local aquifers - Reduction of freshwater use - Reduction of negative environmental impact
Territorial impact:	- Contributing to local society - Build cooperation structures with local government - Bring economic benefits to the local government - About 2 million m³/year of groundwater can be used for civil purposes
Social impact:	- A more sustainable production of the site

The main drivers identified during the pilot, is the reduction of fresh water resources (aligned with "Solvay One Planet"). In addition, other interventions aim on substances and energy efficiency, which can be proved a great potential for future investments. Substances can be reused or minimise their usage costs, in addition with energy efficiency which can be a great benefit, considering fluctuation in energy prices and substantial increase in energy costs that have almost doubled since the beginning of project. That can act as one of the main drivers, and can balance high treatment costs which have been recorded as the main barriers in this case study. If AquaSPICE technology gets industrialised, treatment costs include nutrients, chemicals, energy and capital depreciation. Prices in nutrients and chemicals have been increased together with energy prices, and that make initial investment more expensive that it was planned at the initial stage of the project. In addition, full scale implementation can be viable if accessibility to public funding can be ensured. Laboratory costs have also been considered as a barrier for Solvay. Laboratory costs can be considered a significant barrier when applying new technological equipment, especially digital technologies in industrial sites, due to complex industrial systems and lack of internal expertise. Costs for hiring new engineers and scientists can considerable increase investment costs. This gap can be filled by hiring external consultants instead of internal personnel but even in this case consulting fees might apply. The table below presents the main drivers and barriers reported by Solvay:

Drivers	Barriers
Reduction of freshwater resources	Laboratory costs
Reduction of waste disposal to the sea	Treatment costs (Nutrients, chemicals, energy, capital depreciation) if the technology will be industrialized
Reduction of the environmental impact	

AquaSPICE piloting application implying diverse costs, such as transportation, treatment, water reuse and organizational costs. In case of CS#2, the costs of biological treatment to remove TOC/COD and nitrates has been reported as the highest. In addition, addition costs concern the construction of new installed treatment units which will transfer reused water into the cooling towers. At this stage of the project, none of the costs are known yet. Relevant costs implying AquaSPICE technologies:

Costs	Before	After
Transport costs:	None	None
Treatment costs:	Currently the effluent is pretreated by separation (sedimentation) and adsorption techniques	By AquaSPICE project a new biological treatment will be tested to remove TOC/COD and nitrates. The cost quantification of the treatment will be available after the pilot test trials
Water treatment/ reuse costs:	None	The reused water will go to the cooling towers through a pipe. The cost of the treatment is related to the cost of construction, operation, and maintenance of the new installed treatment units. These costs can be estimated after the pilot tests.
Organisational costs:	None	Not significant. It will be managed by the production unit. In any case, possible costs can be estimated after the pilot tests.

Possible investments implying significant risks that might need to be taken into consideration before its full scale implementation. From a financial perspective a cost-benefit analysis should require to calculate the costs of initial investment of buying and installing relevant technologies, in addition to energy consumption. This calculation should result on significant environmental benefits which counterbalance significant spending for investments and energy consumption. Financial spending it is considered a significant cost, because prices on materials and energy are fluctuating and are unpredictable. Also, capital depreciation on industrial sites is a factor that needs to be considered in long-term investment, because existing equipment need adaptation and additional plant to be developed. Apart from financial risks, operational risks are also worthy considering, because new investments also imply that new equipment needs to be managed additionally in the current value chain. In CS#2 would be another plant to be managed within the current operational unit. Other technical risks which have been identified, include the compatibility of new technology and its optimization. Potential risks of AquaSPICE technology have been identified below:

Financial:	The treatment cost has to be comparable with other equivalent technologies. In the same respect the consumption of materials and energy has to be compatible with the concept of overall reduction of the environmental impact
Operational:	Another plant to be managed. It can anyway be part of the current Production Unit operation
Strategic:	None
Technical:	The technological solution is not easy to find and optimize

<table>
<tr><td rowspan="2">Key Activities

WW treatment</td><td rowspan="2">Key Resources

WW Stream</td><td rowspan="2">Distribution Channels

none</td><td colspan="3"><u>Stakeholders/Key Partners</u></td></tr>
<tr><td>Central Stakeholders

Solvay</td><td>Peripheral Stakeholders

ASA Livorno

ARETUSA</td><td>External Stakeholders

none</td></tr>
<tr><td colspan="3">Customer Relationships

N/A</td><td colspan="3">Customer Segments

N/A</td></tr>
<tr><td colspan="3">Cost Structure

To scale after pilot</td><td colspan="3">Revenue Streams

N/A</td></tr>
<tr><td colspan="6">Value Propositions</td></tr>
<tr><td colspan="2"><u>Economic</u>

Energy saving</td><td><u>Environmental</u>

Respect natural charging capacity of local aquifers

Reduction of freshwater use

Reduction of the environmental impact</td><td colspan="3"><u>Social/Territorial</u>

A more sustainable production of the site

Contributing to local society

Build cooperation structures with local government

Bring economic benefits to the local government

About 2 million m³/year of groundwater can be used for civil purposes</td></tr>
<tr><td colspan="2">Private financial mechanisms

Not indicated</td><td>Private non-financial mechanisms

Not indicated</td><td>Public financial mechanisms

Not indicated</td><td colspan="2">Public non-financial mechanisms

Not indicated</td></tr>
</table>

8.4.2. Cash Flow Analysis Case Study 2: Rosignano Solvay

We develop the following, case-study-specific assumptions:

<table>
<tr><th colspan="2">Monetized Benefits (based on target rates and theoretical assumptions)</th></tr>
<tr><td>Generic Assumptions</td><td>I. At this stage, there are no tangible results and we assume for the small scale pilot, the full scale targets.
II. The sole technology evaluated will be the MBR system.
III. The final cash flows will depend on the final selection
a. Option 1: discharge in the municipal sewers
b. Option 2: discharge at the entrance of ARETUSA reclamation facility
c. Option 3: Direct use at Solvay</td></tr>
<tr><td>Water intake saving</td><td>I. The water reuse will result in an equivalent reduction in water intake
II. We consider a 10% efficiency rate (independently of volume treated)
a. For the pilot we will consider a water intake of 365 m^3/y
b. For the full scale we will consider 87.6 Km^3/y
III. We consider a proportion of 25% for discharge
IV. We consider a retail price of around €1.81, which is the regional average.
V. This price will be subject to inflation</td></tr>
<tr><td>Water waste saving</td><td>Difficult to estimate. There is no specific information on the selected solution
I. Scenarios
a. Option 1: All the treated water will go to public sewers. There will still be some reuse of water. This will, however, require additional treatment in Rosignano WWTP and then in Aretusa. In the absence of specific information on further treatment, we assume that there is no tangible benefits for waste water savings. This is rather strict and we will test its validity by investigating what would be the breakeven point for water waste reuse.
b. Option 2: This option capitalizes on an existing facility and then results in water waste recycling. We assume a 90% of treated reuse.
c. Option 3: This option assumes that the quality of the water will be sufficient for direct reuse. All the water will be reused.
II. We consider the regional average price for water discharge that is below €2. A short term regional average price is around €0.5</td></tr>
<tr><td>Environmental Costs</td><td>The major environmental saving will come from the reduction of electricity usage. There is no specific data communicated and the targets stated might be slightly optimistic. For consistency we will investigate the sensitivity of the findings to different assumptions. Initially, we consider two separate environmental benefits
I. Electricity usage reduction (proportionally to water usage)
a. We assume that the KPI target of a reduction will be achieved
b. The overall reduction is estimated at around 70,000 KWh/y
c. The cost per KWh in Italy in 2022 was €0.25.
d. This price is subject to inflation
II. Carbon Reduction (proportional to water usage)
a. This will be 5,000 tCO2eq/y
b. The price for Carbon is around €90.
c. The inflation rate from Carbon prices is set at 4%</td></tr>
<tr><td>Reputational</td><td>There would be a reputational gain that is reflected on a cost of capital premium reduction of about 20bp. The average wacc for solvay is around 7.5%.</td></tr>
</table>

Monetized Costs (based on target rates and theoretical assumptions) adusted for inflation and forex			
CAPEX	MBR System	We consider a Key et al. (2018) cost structure	$6.4917 * Q_{MGD/d}^{-0.137}$
	Chemicals	We consider a generic cost curve	$0.474 * Q_{MGD/d}^{-0.056}$
OPEX	MBR	The following O&M costs curve will be considered	$0.2231 * Q_{MGD/d}^{-0.21}$
	Chemicals	We consider a generic cost curve	$0.038 * Q_{MGD/d}^{-0.052}$

Pilot

We apply these assumptions in the pilot (365 m^3/y) and we find that the MBR system might be possible with all three options.

	NPV	TLC	NPV/TLC
Option 1	€ 18.74	€ 24.13	€ 0.78
Option 2	€ 19.05	€ 24.13	€ 0.79
Option 3	€ 19.09	€ 24.13	€ 0.79

Disclaimer: The figures in the table are theoretical estimates rather than actual figures.

As expected the third option is the one that should be preferred, because it does not incur any additional costs. However whether it is the one that that can be achieved, it depends on the final outcomes of the pilot. At this stage we have no additional information to evaluate this, we will assume (arbitrarily) that the second option is the most likely to be promoted. Then we will investigate the breakeven point of efficiency and of the proportion of waste water that can be recycled.

Full Scale

For the potential full scale installation the volume of the treated water would come up to 87,600 m^3/y. This would yield the following costs.

(based on target rates and theoretical assumptions)		MGD (€)	Cost (€)/MGD	Overall (€)
capex	MBR	0.06	5.68	360,380
	Chemicals	0.06	0.33	21,045
	TOTAL CAPEX			**381,426**
Operating	MBR	0.06	0.24	15,147.66
	Chemicals	0.06	0.03	1,668.66
	TOTAL OPEX (this is subject to inflation)			**16,816**

Disclaimer: The figures in the table are theoretical estimates rather than actual figures.

And the following results (assuming option 2 with 90% recovery rate).

(based on target rates and theoretical assumptions)	Option 1		Option 2		Option 3	
	NPV	TLC	NPV	TLC	NPV	TLC
Overall	€1,078,290	€382,614	€1,089,650	€382,614	€1,090,912	€382,614
Per m3 intake saved	€ 30.26	€ 10.74	€ 30.58	€ 10.74	€ 30.62	€ 10.74
Per m3 discharge saved	N/A	N/A	€ 33.98	€ 11.93	€ 30.62	€ 10.74
Per total saved	€ 30.26	€ 10.74	€ 16.10	€ 5.65	€ 15.31	€ 5.37
Per m3 intake used	€ 3.36	€ 1.19	€ 3.40	€ 1.19	€ 3.40	€ 1.19
IRR (NPV/TLC)	52%	(2.82)	52%	(2.86)	52%	(2.86)
Breakeven point						

% or water recycled	N/A
# Allowances	876/y or ≈0.01/m³ treated
Total Price for water	N/A
Total volume treated	N/A
Efficiency rate	4%

Disclaimer: The figures in the table are theoretical estimates rather than actual figures.

The final option does not play a detrimental role in the viability of the project. The most important determinant is the number of EUA's saved. We assume that the full scale project will save 5,000 allowances. This is attributed to the technology used, which in general can result in significant gains in electricity consumption. The breakeven point of EUA's (NPV=0) is around 1% of the volume of water treated, which is comparable with the rate applied in the other case studies.

The number of allowances (5,000) guarantees a consistently profitable project. This however, is relatively high and SOLVAY has confirmed that it might be unattainable. Due to the fact that the MBR system results in significantly higher electricity gains than conventional technologies, we apply a cross-sectional rate of 0.01tCO2eq/m^3 inflated by 100%, as a more attainable rate. This is more inline with the findings in the other cases studies. We conclude that the most detrimental factor in deciding whether the project should be expanded into a full scale version is its ability to reach a high efficiency in reducing electricity consumption.

Finally, the minimum efficiency rate required is around 4%, which is considerably lower than the current rate (water saved/water intake≈10%). Thus, the project can be relatively easily profitable.

Conclusions:

Based on the analysis above we can reach the following conclusions:

a. The AquaSPICE implementation appears to be again profitable
    i. The main source of profitability is the energy savings achieved with the MBR system and there is plenty of room for miscalculations.
    ii. The overall efficiency rate (water saved/water intake) of around 10% is considerably higher than the breakeven point, so there is plenty of room for improvements.
    iii. The NPV to Costs ratio (similar to a Profitability Index for capital rationing) is rather high
b. Technologies
    i. MBR seems to be a better technology for water discharge management, compared to the combination CF+UF+RO that has been found better in water usage reduction.
    ii. The focus is more on electricity consumption, rather than on water discharge reduction
    iii. This could be a marketing strategy to promote water discharge management.
    iv. There is an incremental benefit of WaterCPS, which cannot be assessed independently. However, it is consistently present in all ventures and thus, it is considered to be an integral part of AquaSPICE.
c. AquaSPICE cost competitiveness
    i. The water intake/discharge reduction is minimal and the cost per m^3 saved is prohibitive
    ii. Only the cost per volume of water treated makes sense as a metric that can be compared to market prices of water
d. Overall recommendation, relevant for the development of the business model.
    i. Water waste management is important for policy, environmental and regulatory reasons
    ii. Value in water waste management is derived from electricity savings and EUA's
    iii. A realistic marketing strategy would focus on volumes treated and electricity savings.

8.5. Case Study #3A Port of Antwerp

8.5.1. Value for Water-Link

1) Due to climate change, there is an increasing salinization of the dock waters in the port of Antwerp, as well as of the River Scheldt and the Albert Canal. During drought periods Water-Link is vulnerable to rapid deterioration of the raw water quality caused by an increase in conductivity and possible presence of micropollutants (WWTP Deurne). The saline water becomes potentially untreatable by the conventional treatment schemes of Water-Link. In drought periods a lower water depth in the harbour can also become an issue, which impacts pumping activities of de Vlaamse Waterweg.

2) The available amount of freshwater is declining. The area is facing increased problems of managing freshwater resources – for drinking water, industry and transport (inland shipping) – in terms of both water quantity and water quality

3) The stakeholders in the area need to develop strategies that ensure that water quality and scarcity are factored into decisions that protect current operations and support business growth.

This will be facilitated within AquaSPICE by the deployment of a real time smart monitoring and management information system for monitoring water quantity and quality in order to: (2) manage water allocation decisions (right quality for right use), and (b) assess scenarios for long term water and salt balances to assess climate adaptation strategies.

According to D7.1 the following technological solutions will be applied:

	Activity	Streams & Characteristics	Treatments Applied	Key results
Port of Adverp & Water Link	Water Quality Monitoring and Operational Model			- Monitoring - Water salinity modelling and analysis

1) Sensor network: Deployment and operation of a monitoring network with 45 CTD sensors measuring water temperature, water depth, and electrical conductivity (proxy for salinity) at 45 locations in the case study area (Antwerp harbour + Albert Canal + upstream area). This includes the preparation of customized dashboards for data visualization and data analysis, providing a real time overview and a better understanding of the system dynamics to WL and relevant stakeholders (e.g. Vlaamse Waterweg, Port of Antwerp). Sensors have been in operation and following up for already more than one year and a half, generating valuable information for WL and stakeholders. The real time data is being used for continuous follow-up during normal operation condition, and also to follow-up climate change related events like drought and floods affecting the area under study.

2) Operational model: to support operational decisions on water intake by Water-link from the Albert Canal and on pumping activities by the Vlaamse Waterweg. The model will provide an estimation of conductivity and insight in the effect of different operational actions allowing for comparison of different operational scenarios (normal/drought, pumping, ship traffic, intake rates). A hybrid model (Data-driven statistical module + Process-based concept module) is being developed. First result on the statistical model have shown satisfactory results. Focus for the next months is on the further elaboration of the statistical and process-based module to provide near real-time predictions.

The main value in case of Water-Link and Port of Antwerp is primarily environmental and secondly technical. Therefore, AquaSPICE has an environmental and know-how exchange value in this Case-Study. Weather conditions have affected salination levels of the dock water in the port of Antwerp, as well as of the River Scheldt and the Albert Canal. Yet, this situation affects availability of freshwater, the quality of water and also decision-making on water allocation. Providing technical solution which would create incremental benefits for the region is one of the main objectives of AquaSPICE in this particular case. The cost-benefit analysis should take into consideration the economic benefits that AquaSPICE investment would bring to keep business development in the region, by building climate adaptation strategies. Managing water allocation through AquaSPICE optimization and digitization of services is of incremental importance considering water scarcity conditions in the near future, and the direct impact on the local economy. Therefore, the technical value of AquaSPICE has been highlighted below:

Sensor network:

Data being generated by the sensor network is providing a real time overview of the system dynamics, with the following benefits and potential uses:

- Provide a better understanding of the water system in the study area
- Provide information that can be used for the definition of operational strategies
- Analyse spatial and temporal salinity patterns in Albert Canal and Antwerp Harbour
- Identify drivers for salinization
- Support stakeholders in planning & decision making (normal periods and climate-change related events)
- Optimize lab-sampling campaigns

Operational model:

Support the decision making and optimization of water intake by Water-Link and pumping by Vlaamse Waterweg by:

- Providing insights in the effect of different operational actions
- Allowing for comparison of scenarios/strategies under different conditions: normal/drought, pumping, ship traffic, intake rates
- Providing near real-time predictions for conductivity (salinity) in the Albert Canal

So, in this case the main opportunities for a potential future full-scale investment are the technical expertise of creating a sensors' network with incremental environmental and economic benefits, considering the business development in the area and possible disruptions in the future due to environmental conditions. Through AquaSPICE an effective climate-adaptation mechanism can be created which can also involve other stakeholders in the region and can have a strong territorial benefit by combining benefits for Albert Canal, and Water-Link.

Opportunities	
Technological:	- Optimized technologies for water efficiency;
Expertise:	- Framework of collaboration with other stakeholders; - Creation of a synergic environment in the area towards an efficient management of the available freshwater resources;
Environmental:	- Creating climate-change adaptation strategies;

Possible full scale operation of AquaSPICE and operation of sensors network after the demonstration period, can be very challenging in case that new stakeholders need to be involved. A full operational mode of the sensors network, need compliance with shared rules and responsibilities between all stakeholders involved in the area, including public and private stakeholders. Therefore, defining new roles and responsibilities for stakeholders that have not previously involved in AquaSPICE, also requires a synergic environment, where all would recognize the benefits from the outcome of the project, and they would need to take on extra duties.

Challenges	
Technological:	- Not provided
Strategic:	- Not provided
Others:	- Operation of the sensor network after the project may require the involvement of additional stakeholders in the area and define new roles and responsibilities;

The greatest impact of AquaSPICE in CS#3a, is not primarily economic but it is considered the environmental effects and less the social and territorial. AquaSPICE technologies, also in full scale application, can control potential pollution impact from climate-change related events in the area. Therefore, can contribute effectively on climate-change conditions and possible worst-case scenarios in the region. Optimisation of the existing systems can also have considerable positive territorial impact because it can enable to control salination level and create adaptation strategies for local stakeholders according to a range of weather conditions which might impact water levels and quality of water. This outcome is positive for the circular economy and for exchanging resources in a symbiotic model such as Port of Antwerp. The local society can also be benefitted by increasing public awareness on water quality, water saving and scarcity conditions.

Impact	
Environmental impact:	- Control potential pollution impact from climate-change related events;
Territorial impact:	- Circular water, symbiosis;
Social impact:	- Public awareness on water quality;

In case of Port of Antwerp and Water Link, the main driver which has been recorded and remains important related to demonstration of AquaSPICE solutions and possible full-scale investment, is the sensors network with the possibility of further exploitation. In full-scale operation of AquaSPICE, important barriers which can hamper further investment include the operational costs and capital expenditure which remain high due to increased personnel and equipment costs. OpEx and CapEx costs have been considered a serious burden for further exploitation, since a full operational unit needs to be employed to actually monitor sensors' network. The application of new technological applications can have significant barriers due to initial investment costs of adapting to existing operational systems, and hiring new experts. The table below presents the main drivers and barriers reported by Water Link:

Drivers	Barriers
Further exploitation of the sensor network	OpEx cost, Capex cost, collaboration with stakeholders

So far, some of the registered costs include field visits for maintenance of sensors' network, which include preventive and corrective actions for the correct operation of sensors; adaptation costs for applicability of AquaSPICE technologies within the current operational systems and treatment costs which would be occurred after AquaSPICE treatment period. Within operational costs, an important cost includes required technical personnel which increases investment costs. A dedicate service for water management and a technical team which would perform maintenance of the sensor network is required. Technical expertise is also required for data analysis and use/ interpretation of the model. Therefore, possible interventions which could counterbalance the initial costs, is to attract private investments and the economic support of local businesses, considering the environmental and economic impact of water scarcity in the future. Extra public funding can also be extracted in the form of subsidies through regional funds. Relevant costs implying AquaSPICE technologies:

Costs	Before	After
Transport costs:	-	Field visits for sensors network maintenance (preventive and corrective actions)
Treatment costs:	-	Any relevant treatment costs applied after AquaSPICE treatment period
Water treatment/ reuse costs:	-	Additional technological components/ adaptation costs for applicability of AquaSPICE
Organisational costs:	-	A dedicated service for water management A dedicated team to perform the maintenance of the sensor network. Technical expertise is also required for data analysis and use/interpretation of the model.

Upscaling should consider a multitude of risks. From a financial perspective the costs of initial investment of buying sensors, communication devices and infrastructure for sensors installation either in new locations or replacing previous ones should be estimated, as well as potential maintenance costs. Therefore, financial spending should be counterbalanced by environmental benefits, and possible economic disruptions which can be occurred, due to weather conditions, in shipping and local businesses. These events cannot be easily monetized, but further future investments for climate change adaptation, costs to respond to specific damages in case of climate changes events, can counterbalance full-scale investment costs of AquaSPICE. Operational risks should also be taken into account, because new investments also imply that additional technical personnel would be needed to manage the new operational system. Moreover, the involvement of new stakeholders, such as the local authorities, might be proved challenging, but it can also translated to potential regional funds which can be assigned for this specific reason. Potential risks are identified below:

Financial:	CapEx: investment for sensors, communication devices and infrastructure for sensors installation (either for new locations or replacements) OpEx: maintenance activities to keep the sensor network running properly and ensure meaningful data
Operational:	Need for technical expertise: sensors deployment and maintenance, data analysis Further exploitation of the full network after the project will require to identify a strategy for operation and maintenance of the network, for which additional stakeholders (e.g. local authorities) may be required.
Strategic:	Not indicated
Technical:	Not indicated

8.6. Case Study #3B BASF

BASF Antwerp, a chemical company, is the largest consumer of water resources in the area, mostly for heating/cooling related purposes. Water-link aims at a better water supply management, based on the use of smart-sensors that will capture in real time the water attributes that make it suitable for use the network. In parallel, BASF Antwerp aims at increasing its water reuse by installing the pilot MERADES. There are three streams that aim at increasing recycling of water

1. CT Make-up water. Target volume treated between 1,000 and 4,000 l/h or 0.365-1.46 Mm^3/y. Based on the pilots, BASF confirmed that:
   a. No chemical treatment is needed
   b. Acid injection + CT replacement should be sufficient
   c. Target efficiency rates can reach 30%
   d. There is limited digital technology used, but this is evaluated in order to reach the target efficiency rates
2. Reuse of the RO concentrate. Target volume treated around 150 m^3/h or 1.314 Mm^3/y.
   a. Technology combinations
      i. PFRO
      ii. CCRO
   b. Costs and benefits
      i. Both technologies are expected to result in similar efficiency rates, recovering 80% of the waste.
      ii. Both of them are expected to result in similar costs.
      iii. BASF raises awareness about the potential issues of licencing.
      iv. At this stage, no comparison can be performed. Only an economic valuation of profitability will be performed.
3. Steam Cracker waste recycling. Target volume is around 400l/h and 50 m^3/h, with the following technology combinations:
   a. RO with or without MB (at full scale it will be included) for NTBA
   b. (B)GAC+UF+RO+MB
   c. (B)GAC+SAC+DEG+SBA+MB
   d. Scav+SAC+DEG+SBA+MB
   e. EDI

8.6.2. Value for BASF

The main value for CS#3b is of technical and environmental benefits, which can be enhanced by economic benefits in the long run. To reduce industrial fresh water, the application of the following combinations is considered high-exploitable: CC-RO & PF-RO for reuse of RO-concentrate from all the available demonstration results. Moreover, for the CS#3b, the main reasons which have been indicated as having great value is that enhanced recirculation over cooling tower reduces intake of fresh water (OpEx & sustainability). That signifies considerable sustainability benefits due to reduction of fresh water, and economic benefits in large scale investment because it reduces the overall operation costs (OpEX). Another similar benefit which emerges as a positive result of AquaSPICE, is that reuse of RO concentrate reduces intake of fresh water for demineralized water production (OpEx & sustainability). This is a two-fold benefit which creates environmental and economic benefits again, due to environmental impact created by the reduction of freshwater intake, but also as having significant cost reduction in the overall operating costs. A further positive value of AquaSPICE is the reuse of water streams which can diminish operating costs and enhance sustainability impact. So, future investments need to take into consideration not only economic benefits, but also environmental benefits and "shadow" prices within a cost-benefit analysis.

Diverse costs might occur from further upscaling AquaSPICE as a full-scale application. Although costs have not been specified, the potential environmental benefit that AquaSPICE can have, could outsource public funding in the form of subsidies or even public-private partnerships.

Hence, AquaSPICE provides the opportunity to BASF to actually apply new technologies in its current value chain, which has significant benefits considering the exchange of expertise at European level, between research clusters, industrial labs and industrial partners covering diverse settings and needs. Yet, the most important opportunities generated through AquaSPICE is to align with sustainability goals, and explore opportunities which can achieve water reduction and reuse within current industrial site.

Opportunities	
Technological:	- Application of new technologies;
Expertise:	- Building expertise around new technologies;
Environmental:	- Align with sustainability goals;

Although AquaSPICE can have considerable economic and environmental benefits, still specific challenges might hamper further exploitation of the project's results. Some of the technical challenges that were identified was the installation of pilot MERADES on site, and acquisition of historical data. Moreover, transporting cooling water to Laborelec and installing IMPROVED containers on existing site were other challenges of technical nature that have been identified. Installation of new equipment in existing sites require internal expertise, or external expertise which might actually increase the costs of initial investments on-site. The costs of those installations also vary and need to be taken into consideration as well as off-site operational costs such as adjustments of process control by external parties or conforming with safety regulations.

Challenges	
Technological challenges:	- Installation of pilot MERADES on-site (electrical connection) - Transport cooling water to Laborelec, acquisition of data; - Installation of IMPROVED containers on-site;
Strategic challenges:	- Not indicated;
Others:	- Conform safety regulation & adjustments of process control by external party;

The greatest impact of AquaSPICE in CS#3b is environmental, social and territorial. At this phase, it is important to consider primarily the environmental impact of AquaSPICE overall. However, upscaling can change the whole environmental impact because it can contribute to less freshwater intake, and water recycling within internal industrial operating systems.

Impact	
Environmental impact:	- Reduction of freshwater use - Reuse of water - Align to sustainability goals
Territorial impact:	- Not indicated
Social impact:	- Not indicated

So, in CS#3b, the main drivers which have been recorded related to piloting of AquaSPICE and possible further full-scale investment are the related to direct environmental effects. The reduction of freshwater resources and waste disposal to the sea, have been recorded to be positive outcomes of this project. Water savings can also have incremental economic benefits.

In terms of barriers, the ones registered for CS#3b, mainly concern treatment costs such as the nutrients applied in water treatment processes. In general chemicals prices have been increased together with energy costs which make initial investments highly priced. Also laboratory costs can create a burden since it increases general personnel costs which were not initially calculated since the beginning of the project. Covering salaries for technicians and technical scientists in industrial sites exceeds the initial investment costs. In case of CS#3b, a positive outcome that could be achieved is to register the positive environmental results through AquaSPICE investment, in order to be able to increase the possibilities of reaching public financing in the form of subsidies or in the form of further synergies with public entities.

The table below presents the main drivers and barriers reported by CS#3b:

Drivers	Barriers
Reduction of freshwater resources	Laboratory costs
Reduction of waste disposal to the sea	Treatment costs (Nutrients, chemicals, energy, capital depreciation) if the technology will be industrialized
Reduction of the environmental impact	

AquaSPICE demonstration has shown that possible investments might imply specific risks which need to be taken into consideration. From a financial perspective, the additional operational and capital expenditure costs can be considered a significant risk. Investments on new equipment, when installing new technologies, and personnel costs can increase the overall costs calculation. Implementing a new model requires extra expertise which need to be covered by extra personnel which needs familiarization with the new model processing. Moreover, new infrastructure is need to be able to integrate in the existing treatment plants the outputs delivered by the model. This implies that on a possible cost-benefit analysis the costs of initial investment should cover the extra installation, equipment and personnel costs. Energy saving might counterbalance the financial costs incurred due to new investment. Apart from financial risks, technical risks are also worth considering in this CS. What has been registered as a potential technical risk is the maturity of new AquaSPICE applications which cannot guarantee reliability of the applied modelling. New technologies which are first applied without prior testing can be technically difficult and risky to full integrate them in current wastewater treatment models.

Potential risks of AquaSPICE technology have been identified below:

Financial:	CapEx & OpEx, Allocation of a separate PC for implementing the model. Infrastructure required to integrate the output delivered by the models to the current decision making process.
Operational:	Need for expertise of new technologies, training required for familiarizing with the model
Strategic:	Not applicable, integrating energy reduction strategies into current operations
Technical:	New technologies not reliable or mature enough (robust, low maintenance), building confidence in the reliability of the model.

Key Activities	Key Resources	Distribution Channels
WW treatment	Port of Antwerp shipping services	none

Stakeholders/Key Partners		
Central Stakeholders	Peripheral Stakeholders	External Stakeholders
Water-Link Port of Antwerp BASF	Albert Canal	none

Customer Relationships	Customer Segments
N/A	N/A

Cost Structure	Revenue Streams
Sensors' network installation & maintenance costs MERADES & Improved Containers costs	N/A

Value Propositions		
Economic	Environmental	Social/Territorial
Not indicated	Developing climate-change adaptation strategies Reduction of freshwater use Improve water quality Align to sustainability goals Reuse water	Increase awareness on water quality Create an effective circular water system

Private financial mechanisms	Private non-financial mechanisms	Public financial mechanisms	Public non-financial mechanisms
Not indicated	Not indicated	Not indicated	Not indicated

8.6.3. Cash Flow Analysis CASE STUDY 3: BASF and Water-link

Water-link

Water-Link is water supply utility company operating in the port of Antwerp and faces increasing challenges with regards to the quantity and quality of water sourcing from the Antwerp canal, mostly related to climate change. The installation of a smart monitoring system is a new technology tested aiming at providing real time (evolution over time) information about the quality (e.g., salinity) of water, as well as its quantity (depth). There are three areas that covered at a cost that reaches approximately €186k (Hardware: €65k, Maintenance: €85k, Data management: €1k, IT: €15k). Although this is a hard cost that occurs upfront, the value that emerges in the case of Water-link is mostly through non-monetary externalities. These benefits might apply to a wide range of regional stakeholders and not necessarily to solely Water-link. We consider these more related to policy rather than an economic analysis, and, therefore, we do not perform an explicit cash-flow analysis for Water-link. This does not mean that there is no value proposition for Water-link (this is identified in the section above), but rather that this is mostly out-of-scope for the analysis pursued in this document.

BASF

At the same time, BASF Antwerp, a chemical company, is the largest consumer of water resources in the area, mostly for heating/cooling related purposes. Water-link aims at a better water supply management, based on the use of smart-sensors that will capture in real time the water attributes that make it suitable for use the network. In parallel, BASF Antwerp aims at increasing its water reuse by installing the pilot MERADES. There are three streams that aim at increasing recycling of water

1. CT Make-up water. Target volume treated between 1,000 and 4,000 l/h or 0.365-1.46 Mm^3/y. Based on a 20 l/h pilot BASF confirmed that:
   a. No chemical treatment is needed
   b. Acid injection + CT replacement should be sufficient
   c. Target efficiency rates can reach 30%
   d. There is limited digital technology used, but this is evaluated in order to reach the target efficiency rates
2. Reuse of the RO concentrate. Target volume treated around 150 m^3/h or 1.314 Mm^3/y.
   a. Technology combinations
      i. PFRO
      ii. CCRO
   b. Costs and benefits
      i. Both technologies are expected to result in similar efficiency rates, recovering 80% of the waste.
      ii. Both of them are expected to result in similar costs.
      iii. BASF raises awareness about the potential issues of licencing.
      iv. At this stage, no comparison can be performed. Only an economic valuation of profitability will be performed.
3. Steam Cracker waste recycling. Target volume is around 400l/h and 50 m^3/h, with the following technology combinations:
   a. RO with or without MB (at full scale it will be included) for NTBA
   b. (B)GAC+UF+RO+MB
   c. (B)GAC+SAC+DEG+SBA+MB
   d. Scav+SAC+DEG+SBA+MB
   e. EDI

Monetized Benefits (based on target rates and theoretical assumptions)	
Operations	In terms of volume of water treated, we consider the target rates by BASF: I. Stream 1: We consider a small scale CT of 100 MGM II. Stream 2: We consider a 150 m^3/h flow with recovery rate of 85%. 15% of the flow goes to waste before the treatment, i.e., 22.5 m^3/h. PFRO and CCRO aim to achieve an 80% recovery of the waste. III. Stream 3: We consider three scenarios. a. Technology RO: A flow rate of around 80 m^3/h, with a recovery of 80-90%. We will test for the breakeven point. b. Various filtration combinations: A flow rate of 50 m^3/h with an 80% recovery. c. EDI: A flow rate of 400 l/h (pilot) with a recovery rate of minimum 90%. We will test for the breakeven point. EDI is expensive.
Water intake and waste saving	The assumptions here are a combination of responses to WP6, the analysis of WP2 and peer analysis: I. We consider a proportion of 25% for discharge II. We consider a retail price of around €1.5 per m^3 of intake water. This price will be subject to inflation III. We consider the regional average price for water discharge that is below €2. A short term regional average price is around €1.5 per m^3.
Environmental Costs	We apply the following assumptions. I. The energy costs are incorporated into the carbon emission costs II. Carbon emissions account for 10.6kg per cubic meter of waste water III. The price for Carbon is around €90. IV. Following Carbon related policies, the inflation rate from Carbon prices is set at 4%
Reputational	There would be a reputational gain that is reflected on a cost of capital premium reduction of about 20bp. The average wacc for BASF is around 8.7%.

We also develop the following assumptions with regards to the costs of the technologies. The theoretical cost functions are all converted to € and expressed in nominal values considering inflation.

Monetized Costs (based on target rates and theoretical assumptions)
We perform our analysis based on the available information collected and based on theoretical cost functions. We will employ theoretical cost curves for both CAPEX and OPEX. This considers full economic costs and economies of scale that depend on the volume of water treated A crucial element is the efficiency rate achieved with each combination. There is no specific information for each combination and we will assume an equal marginal improvement by the addition of a technology. I. This focuses solely on costs, but it can also be refined when results about the performance of the technologies becomes known. II. Should the results be inconclusive, a breakeven point of incremental efficiency can be estimated. The WaterCPS is a digital technology that is the common denominator of all other technologies.

Technology	CAPEX ($^{€M}/_{MGD}$)	OPEX ($^{€M}/_{MGD}$)
SCAV	$0.474 * Q^{-0.056}$	$0.038 * Q^{-0.052}$
MB SBA (IEX)	MB is not an incremental technology (efficiency known). It will be considered like SBA with the following cost function $0.257 * Q^{-0.33}$	MB is not an incremental technology (efficiency known). It will be considered like SBA with the following cost function $0.0848 * Q^{-1.33}$
SAC	We will consider a generic cost curve for chemical treatment $0.474 * Q_{MGD/d}^{-0.056}$	The same for the OPEX, we consider a generic chemical treatment function $0.038 * Q_{MGD/d}^{-0.052} * Forex_{\$/€}$
UF DEG	$3.57 * Q^{-0.22}$	$0.3 * Q^{-0.22}$
RO CCRO and PFRO	$7.14 * Q^{-0.22}$ Hayar and Lienhard (2020) suggest that the capital cost of CCRO is approximately double the cost of conventional RO	$0.41 * Q^{-0.13}$ Hayar and Lienhard (2020) suggest that the OPEX cost of CCRO is approximately 80% of the cost of conventional RO
(B)GAC	$1.43 * Q^{-0.17}$	$0.059 * Q^{-0.044}$
EDI	This is a rather new technology (combination) and no robust cost function is identified. BASF confirms that it is an expensive technology with wither CAPEX, but lower OPEX. For illustration purposes only, we will consider a 200% higher cost than a “conventional” EDR system using the following costing.	
	In the DOW case we considered a cost per MGD of $0.94 - 1.11$. Here we will start with €2 and we will test for the breakeven point.	In the DOW case we considered a cost per MGD of $1.41 - 2.09$. Here we will start with €1 and we will test for the breakeven point.
CT	Cooling Towers’ market price is around €50k to €200k per ton. We will consider a 100 MGM installation for €50k x 2. This includes Feeder Water System, Blowdown System, Circulation Water Systems, Cooling Tower Refurbishing and CT Installation.	

We summarize the collective results from all streams in the table below and we will discuss the theoretical viability/profitability prospects of each combination.

(based on target rates and theoretical assumptions NOT actual figures)		**Performance**			**Breakeven point**			
		NPV/intake m3	TLC/intake m3	NPV/TLC	efficiency rate	price	volume (Mm^3/v)	New tech multiplier
Stream 1	CT+ACID	1.13	0.4	2.83	7%	1.4	4.09	
Stream 2	CCRO/PFRO	-0.99	2.64	-0.38	N.A. 139%	4.39	N.A.	1.14
Stream 3	RO+MB	0.57	1.18	0.48	46%	2.19	0.44	
	(B)GAC+UF+RO+MB	0.17	1.43	0.12	74%	2.24	0.73	
	(B)GAC+SAC+DEG+SAB+MB	0.2	1.54	0.13	69%	2.71	0.33	
	Scav+SAC+DEG+SBA+MB	0.33	1.41	0.23	63%	2.53	0.29	
	EDI	-0.6	2.87	-0.21	N.A. 125%	3.84	N.A.	1.43

Disclaimer: The figures in the table are theoretical estimates rather than actual figures.

From all the technology combinations the one that seems to be considerably more profitable is the replacement of CT. This, however, cannot be considered as a new technology combination, so we will focus our attention on the relatively “new” technology combinations. The new RO technologies (CCRO and PFRO) or the EDI combination cannot be profitable, unless they become a lot more cost efficient at a price range that is comparable to existing technologies. Something like 1.14 or 1.43 times more expensive than "conventional" technologies, respectively.

From the other, more "mainstream" combinations that can be tested in Stream 3, the conventional RO technology seems to be the most profitable, being followed by the Scav+SAC+DEG+SBA+MB and the (B)GAC+UF+RO+MB combinations. This complements the findings in CS1 (Dow), where the CF+UF+RO combination was the only reasonable one. This shows that there are cross-sectional factors, such as water quality and/or regional factors, that affect the economic performance of different technologies.

Collectively though, the results here show that filtration technologies are suitable for water saving and some of them (e.g., RO+MB, (B)GAC+UF+RO+MB, (B)GAC+SAC+DEG+SAB+MB, Scav+SAC+DEG+SBA+MB), exhibit high margins and thus, they can still be profitable even with a considerably lower performance of the technologies. Consequently, they exhibit lower levels of financial risk.

Conclusions:

Based on the analysis above we can reach the following conclusions:

a. Technology combinations
    i. Several technology combinations (save for the replacement of CT) can be profitable
        a. From the "new" technology combinations, the filtration technologies appear again to be profitable with relatively high margins.
        b. Combining the results with DOW, UF might be more cost efficient than DEG
        c. With respect to the most advanced technologies, such as the CCRO, PFRO and EDI, they can only be profitable if their cost decreases significantly, or if the total price for water (intake/discharge) increases significantly.
    ii. There is an incremental benefit of WaterCPS, which cannot be assessed independently. However, it is consistently present in all ventures and thus, it is considered to be an integral part of AquaSPICE.
b. Cost competitiveness
    i. The analysis confirms previous findings in the sense that benefits solely on water waste treatment might not be sufficient in covering their expenses
    ii. Cost per water intake unit are lower than market prices

III. Overall recommendation, relevant for the development of the business model.
    i. Water waste management might be important for policy, environmental and regulatory reasons
    ii. Targeting water intake reductions might be more realistic due to water pricers, rather than water waste reduction targets
    iii. New technologies might not be adequately cost competitive. Main advantage comes from a better combination of technologies, ideally managed with digital solutions like the WaterCPS technology. This has two very important implications:
        ii. AquaSPICE might be better offered as a bundling service (combination of technologies or consultancy on what might be the best combination)
        iii. Water waste treatment projects might need to be subsidized

8.7. Case Study #5 AGRICOLA

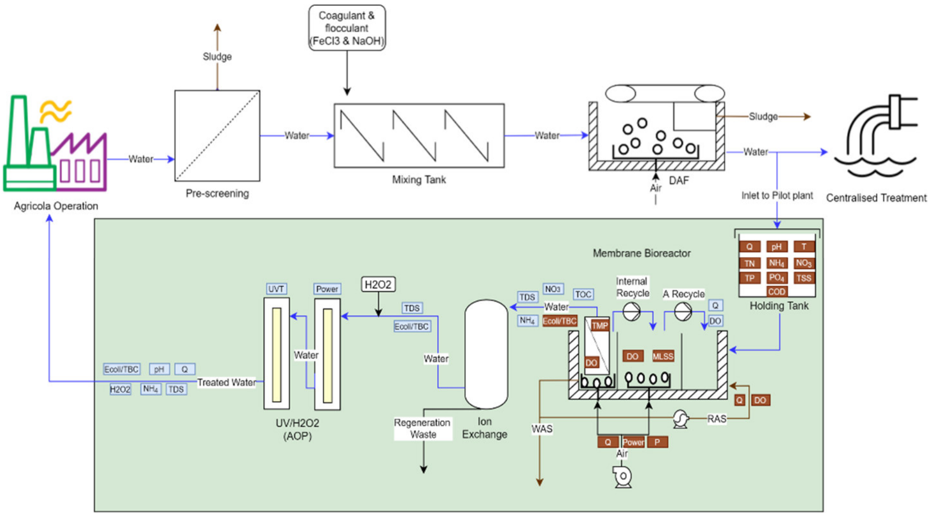
Agricola's International redesigned its old WWTP, which was built to align with the EU standards. The current WWTP has been partly refurbished, also in process with AquaSPICE development. Agricola is interested in improving its water management process and technologies within its current value chain, because it can provide costs savings inside the business unit. Moreover, this model it can replicated in other companies within Agricola group and food industries in North Eastern Romania. The main activities of Agricola's value chain are:

Acquisition of raw material and meat processing according to the business model of the company including: transportation of chicken to slaughterhouse; networking and supply from local producers; placement and processing of meat; package and sales.

The piloting case in Agricola's site in Bacau is related to the perception of water waste and compliance with current legislation in food industry in Romania. Wastewater discharging of slaughterhouses in Romania takes two forms:

1. Directly in the courses on main rivers (when the industrial unit has a WWTP on their premises)
2. In the public local waste water network, which is very common in Romania. Specific norms (NTPA 002) and thus, it is encouraged to treat the water waste prior to discharging it.

Figure 13. Streams affected by AquaSPICE. Agricola (planned scenario)



The waste water from the Agricola process line is discharged in the pre-screening unit. The sludge resulted is deposited and a subcontractor is transporting outside the Agricola premises (probably used on agricultural fields). The next step is the mixing unit which delivers the waste water to the DAF unit (dissolved air flotation, considered the primary treatment process). It is expected that DAF systems removes 30-90% COD and 70-90% BOD, and large amounts of nutrients. At the exit of the DAF, a part is decanted as sludge and rest of waste water is discharged currently in the public waste water network.

Before discharging in the public waste water network, the AquaSPICE project designed and will implement an MBR system, which will be connected to the existing WWTP in Agricola Slaughterhouse.

According to D7.1 the following technological solutions will be applied:

Activity	Streams & Characteristics	Treatments Applied	Key results
Slaughterhouse	- cooling system - cleaning operations -WW from the thermal plant	MBR + IEX + AOP + Polishing	- Treatment train

8.7.1. Value for the Agricola's case (based on *planned* scenario):

The main objective of the CS#5 in Agricola pilot it is the reduction of fresh waste water consumption in the slaughterhouse by 30% using the waste water reuse technology. AquaSPICE can contribute in the case of Agricola, in many ways through building and transferring technological expertise to local industries, which would increase technological improvement and can have a considerable impact on local stakeholders. In addition, wastewater treatment technologies can be replicated in many other industrial sites in Romania, in food sector, and also in other companies belonging to Agricola Group.

The food sector is hardly regulated in terms of water quality so, the reused water will be specifically study for the ''in-factory'' usage (not for the ''in-process''usage) or out-factory usage (watering green areas, cleaning streets and pavements, etc.).

Opportunities	
Technological opportunities:	- Technological expertise; - Technological improvement;
Strategic opportunities:	- Replication of technologies to other sites and industries in Romania; - Cooperation with local stakeholders;
Others:	- Further improvement;

AquaSPICE can have significant environmental, social and economic benefits in the long-run but an initial investment and applicability of piloting technologies, have certain challenges which in case of Agricola vary between technological, economic and other forms. Firstly, technological expertise is a great advantage but it also consists significant challenge considering that innovative technologies need adaptation to existing plants, which require additional time, internal expertise and also adds extra economic costs and a percentage of investment that needs to come from the company's own financial sources. In addition, as it was reported by Agricola, prices of equipment since the initial phase of AquaSPICE have been increased the last year, so the initial investment costs have considerable increase, and that is a serious challenge. Moreover, the Covid pandemic contributed negatively in this case as well, since main procedures delayed the process of buying and renting new equipment, which significantly affected the initial projected costs.

Challenges	
Technological challenges:	- Technological applicability; - Adaptation to current industrial plant;
Economic challenges:	- Financial challenges due to increase in prices and equipment; - Covid pandemic increased costs and prices;
Others:	- Legal barriers and regulations; - Administrative barriers;

In relation to Agricola, apart from economic benefits that a full scale application of AquaSPICE technologies could have, there are different components that can provide a positive impact for the implementation of AquaSPICE. Initially the environmental impact that is added for Agricola is considerable, because improving the existing WWTP by adding an MBR pilot will decrease CO_2 emissions. In addition, if a reduction of 30% based on current consumption is achieved, then Agricola will also contribute to the local water scarcity situation. So, those reasons consist important environmental components that need to be considered in related to cost-benefits analysis, when an first investment takes place. Moreover, the water reuse system in place, will diminish the energy consumption to the local water operator but by reducing the heavy load of waste water and quantity delivered. The Agricola will increase probably the costs with electricity, but installing solar panels can counterbalance this situation. So, by redesigning its current water management system, Agricola can have considerable benefits in the long-run which can also be replicated to other businesses of Agricola group. Installation and use of digital systems such as WaterCPS, which will be advanced as part of AquaSPICE can have an impact of water quality monitoring, which can be of improved quality, considering that Agricola is operating in the food sector.

Apart from the environmental and economic benefits, Agricola is operating closely with the local municipality, so developing a strategy which can expand its operation but also respect local communities, is in alignment with Agricola's targets. Thus, cooperation between different local groups will help to also develop other projects in the near future and its local strategy.

Impact	
Environmental:	- Adding an MBR pilot will decrease the CO2 emissions - 30% of water saving contributing to water scarcity problem in the region - Reduction of energy consumption to the local water operator
Territorial:	- N/A
Social:	- Cooperation between local community will help to develop other projects

So, in case of Agricola the main drivers as have been recorded are the technological application of additional MBR technology which can improve the existing WWTP in use. Reducing water consumption and creating a positive attitude of water use, are also among them main drivers of AquaSPICE for Agricola. Achieving water reduction in daily industrial use is the main driver, but also changing the conception of the local community for reuse or saving water has wider purposes related to developing environmental awareness and sensitivity. Thus the contribution of AquaSPICE does not only have technological benefits, but can also apply to achieve further purposes.

Agricola has identified different barriers for applying AquaSPICE at full scale, considering the first investment and maintenance costs. The installation of additional equipment in the existing WWTP, can increase carbon footprint, a factor that acts contrary to the environmental benefits that Agricola aims to produce with this initial investment. In addition, a burden that has been registered is the lack of technological expertise that is required, which is difficult to find in the local market, as well as lack of data to further improve the site and apply new technologies. The lack of knowledge and information on water reuse is the most difficult, because Agricola is the first case of meat industry that is an innovative wastewater management technology would be applied. In addition, the inexistent cooperation structures between other sectors, do not further help in knowledge and information exchange. This situation is even worse due to lack of clear and applicable legislation on water reuse in Romania.

Drivers	Barriers
- Application of additional MBR technology improving the existing WWTP in use;	- Possible high investment (at full scale) for an Eastern European company and maintenance costs; - Increasing the Carbon footprint by additional equipment installed as pilot, as part of the same WWTP; - Lack of technological and specialized expertise and personnel required on local market;

	- Lack of data to build upon;
- Potential reduction of fresh water usage in daily consumption and reuse;	- Lack of data and information on water reuse, as being the first case in Romania in meat industry; - Lack of clear and applicable legislation.
- Exploring the benefits of community engagement in reusing water;	- Lack of cooperation between different sectors (water quality, health, IT, social, etc.); - Lack of knowledge;

Possible revenues that could be generated to counterbalance the initial costs of investments in Agricola's case might derive from water re-selling to local municipality and also more efficient use of in-factory purposes. In addition, in case that AquaSPICE proves efficient environmental and social benefits, Agricola could expand its operations and increase cooperation with public entities in water reuse. In this case, Agricola can generate some additional income, either by re-selling water for civil consumption or can also require some regional subsidies in addition with development funds by the EU, which can contribute on achieving a required amount of investment. In addition, if environmental benefits can be shown in the long-run, collaboration with public enterprises can be achieved more effectively, especially when AquaSPICE technologies can act as a potential for further replication to other industrial sites within the food industry in Romania.

Apart from the possible revenues for initial investment, AquaSPICE piloting and full scale installations have possible risks that need to be identified. The cost of investing in technological equipment is higher than the initial phase of the project, thus financial risks exist, if in a cost-benefits analysis, the initial investment costs bypass the environmental, social and economic benefits of Agricola. In addition, lack of available financial resources and financial products to improve their technological processes, create an increase risks of investing in a new technology without potential returns, which the company to require large budget for initial investments. One of the greatest risks, is the lack of required knowledge and expertise within the industry but also within the local job market. New technological investments require external expertise or internal personnel, which in case of Agricola situated in Bacau, engineers and other experts are not easy to be employed. Hence, there is a hiring external personnel risk.

Financial:	- Potential high costs for technology improvements in crisis times; - Lack of feasible financial products to help companies in improving their technological processes;
Operational:	- Lack of technological expertise on local market;
Strategic:	- Lack of adequate incentives and understating of saving fresh water resources in industrial sites; - Lack of environmental understanding of water resources within public sector in Romania;
Technical:	- Technological courses are not popular in Romania, and they are not taught widely in higher institutions;

Key Activities	Key Resources		Distribution Channels	Stakeholders/Key Partners		
1.Extracting and collection of wastewater from WWTP 2.Transporting to treatment pilot and storing. 3.Treatment for water reuse 4.Storage the reused water 5.Distribution(selling) the waste water	1.Own site waste water treatment plant in slaughterhouse Agricola 2.Potential other waste water producers in same region(industrial)	3.Infrastructure owners and service companies 4. Local and national regulations (NTP002, etc.) 5.Knowledge providers	1.Direct sales/delivery at the slaughterhouse gate 2.Direct delivery by transport trucks	Central Stakeholders 1.Agricola International SA 2.Technology providers(ADISS SA) 3.Local water public utility CRAB SA	Peripheral Stakeholders 1.All companies within Agricola Group of Companies 2.University ''Vasile Alecsandri'' Bacau(laboratory) 3.Local NGOs	External Stakeholders 1. Local Environmental Protection Agency 2.Local Health Division, Ministry of Health 3.Local Animal Health department, Ministry of Agriculture 4.Municipality of Bacau 5.Local Council Bacau

Customer Relationships	Customer Segments
1.Local partners(or on-site) laboratory for water reuse quality usage certification 2.Reliable buyers of planned water reused treated 3.Delivery water reuse on demand, quick responders(ex. Fire Protection Brigade)	1.Local municipal company for parks and streets administration(Bacau) 2.Industries in Bacau(same industrial area) 3. Agri-cultural/food local companies. 4.Private owners of vegetable gardens in same area 5.Local office of Emergency Situations(Fire brigade)

Cost Structure	Revenue Streams
1.Agricola investment in water reuse equipment, infrastructure(and their maintenance) 2. Agricola own costs with water reuse and management services (energy, salaries, etc.) 3.Amortization costs 4.Water reuse transport and delivery 5.Equipment security services	1.Income from value of invoices sent to customers(value of cubic meter of water reuse X volume sold) 2.Potential funding public subsidies for environment protection

Value Propositions		
Economic	Environmental	Social/Territorial
1.Decrease the fresh water consumption 2. Decrease of energy bill with local water utility 3.Decrease of local usage of infrastructure	1.Reduced water usage from natural sources 2.Replacing (improving) existing WWTP facilities within the slaughterhouse Agricola. 3.Lower CO2 emissions	1.Creation and consolidation of a Local Working Group on symbiosis water – industry(food), impacting on other counties in North Eastern Region 2. A continuous societal transformation with impact on youth 3.Development of local awareness programs on water consumption

Private financial or non-financial mechanisms	Public financial mechanisms	Public non-financial mechanisms
Not known	1.Government subsidies in various programs(adaptation to climate change, urban water directive implementation, recovery and resilience mechanism , drought and floods ,etc.) 2. European subsidies in water, different water reuse applications agriculture, etc.)	1.Adaptation of fresh water consumption with change behavior in industry, in accordance with crise topics(legal topic) 2.Special programs for private sector mobilization for update-ing water sector technologies(water, digitalization, circular economy, WEFE nexus, etc.) 3.Local partnerships (set up clusters) based on financial programs, subsidies from European Commission

8.7.2. Cash Flow Analysis Case Study 5: Agricola

Agricola is a Romanian end-to-end supply chain of poultry meat with very high requirements for water. The main objectives are to reduce its overall water intake, through increasing its water recycling. This will be pursued by applying smart water management and filtration. Overall, they aim at:

- Reduce its environmental impact
- Reduce its overall water intake
- Reduce its carbon footprint

This will eventually result in the following measurable KPI targets that will be considered as the main sources of Cash Inflows that will create value to AquaSPICE implementation.

I. Reduce Water Intake by 390 m^3/d or
   a. Increase water recycling by 100% in cooling areas and hanging area
   b. Reduce water waste by 50% (irrigation and industrial symbiosis)

We develop the following, case-study-specific assumptions

Monetized Benefits (based on target rates and theoretical assumptions)	
Water intake saving	The pilot is not completed at this stage, and the feedback we receive is that it will be scaled down due to costs. We consider the <u>*planned*</u> scenario in our economic assessment and we will compare our findings with the one <u>*implemented*</u>. I. We consider a reduction of 390 m^3/d II. This translates into 142.35 Km^3/y III. This corresponds to a 30% reduction in water intake IV. This is the overall measurable objective including the following treatments; AOP+MBR+IEX+Polishing V. We consider a conservative retail price of around €1.5 VI. This price will be subject to inflation
Water waste saving	We consider the target stated in the AquaSPICE KPIs I. 50% of existing streams will be reduced II. This is equivalent to 25% of water intake reduction III. The price per m^3 is around 40% of the overall water cost IV. This price is subject to inflation
Environmental Costs	I. The energy costs are incorporated into the carbon emission costs II. Carbon emissions account for 10.6kg per cubic meter of waste water III. The price for Carbon is around €90. IV. Following Carbon related policies, the inflation rate from Carbon prices is set at 4%
Reputational benefits	We consider a cost of capital ≈13% that is typical for a company with BBB+ rating in the Balkans. The reputational benefit is higher than in more advanced and, thus more saturated, markets. We consider an after AquaSPICE cost of capital of 12.5%

Monetized Costs (based on target rates and theoretical estimates) adjusted for inflation and forex			
	MBR	AOP	IEX
CAPEX	$6.4917 * Q_{MGD/d}^{-0.137}$	$2.26 * Q_{MGD/d}^{-0.54}$	$0.257 * Q^{-0.33}$
OPEX	$0.2231 * Q_{MGD/d}^{-0.21}$	$0.0068 * Q^{-0.051}$	$0.0848 * Q^{-1.33}$

Based on the assumptions above the CAPEX and OPEX of the AquaSPICE implementation in Agricola is:

(based on target rates and theoretical assumptions)		units	cost/unit	overall
capex	iex	0.10	0.33	€ 33,635
	MBR	0.10	5.32	€ 547,933
	AOP	0.10	4.63	€ 476,693
	TOTAL CAPEX			**€ 1,058,262**
Operating	iex	0.10	1.05	€ 107,710
	MBR	0.10	0.22	€ 22,229
	AOP	0.10	0.00	€ 472
	Total OPEX (subject to inflation)			**€ 130,411**

Disclaimer: The figures in the table are theoretical estimates rather than actual figures.

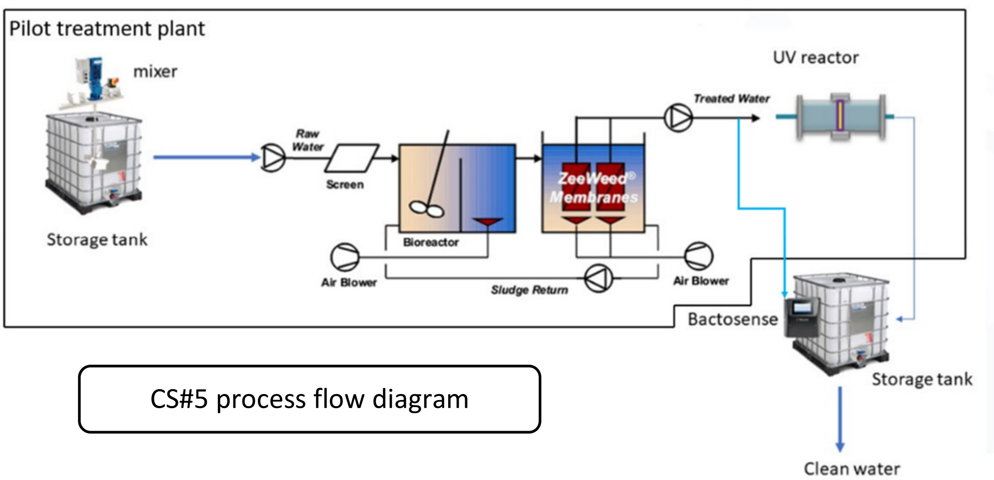
(based on target rates and theoretical assumptions)	NPV	TLC
Overall	-€ 424,086	€ 1,377,103
Per m3 of water intake saved	-€ 0.76	€ 2.45
Per m3 of water discharge saved	-€ 3.02	€ 9.82
Per total (intake-discharge) units saved	-€ 0.60	€ 1.96
Per m3 of total water intake	-€ 0.32	€ 1.05
IRR	66%	
Breakeven point analysis	Total Price	Minimum € 3.38
	Volume (current 1,300 m^3)	Minimum 2,727 m^3
	Allowances	Minimum ≈ 0.014/m^3
	Efficiency (current 30%)	Minimum 63%

Disclaimer: The figures in the table are theoretical estimates rather than actual figures.

The analysis above shows that there is little room for the initial technology combinations of AquaSPICE to become profitable in CS#5. The reason is the relatively low water price in Romania, in combination with the relatively high costs for the MBR technology. This was identified by Agricola itself and they decided to scale down the project. We investigate briefly the profitability potential of the small pilot.

Small Pilot

Agricola decided to investigate a much smaller stream of 10l/h, only applying the MBR technology in combination with UV filtering. The process takes the following form:



CS#5 process flow diagram

We employ the Plumlee et al. (2014) assumptions for the cost curves.

Based on theoretical rates and assumptions		units	cost/unit	overall		NPV	TLC
CAPEX	MBR	0.06	5.68	€360,380	Overall	€596,612	€370,639
	UV	0.06	0.33	€21,045	Per m^3 intake saved	€1.73	€1.07
	TOTAL CAPEX			**€381,426**	Per m^3 discharge saved	€1.73	€1.07
OPEX	MBR	0.06	0.24	€15,148	Per total m^3 saved	€0.86	€0.54
	UV	0.06	0.03	€1,669	Per m3 intake used	€0.46	€0.28
	Total OPEX (subject to nflation)			**€16,816**	IRR	56%	

Disclaimer: The figures in the table are theoretical estimates rather than actual figures.

This, scaled down version has the potential to become profitable, primarily due to its considerably lower cost. However, as Agricola is fully aware of and raised concerns for, the regulation in Romania is rather strict with respect to the quality of water that is used in the food industry. At this stage, there is no tangible results yet as to whether the treated water meets the strict criteria. Consequently, this analysis is purely theoretical and focuses solely on the financial performance of the scaled down alternative.

Conclusions:

Based on the theoretical analysis above we can reach the following conclusions:

a. Feasibility and Profitability
    i. The combination of MBR+AOP+IEX does not appear to be profitable,
    ii. This is primarily due to the large capital investment required for the MBR. This confirms Agricola's reservations and the scaling down due to costs. However, higher volumes treated could justify the necessary investment.
    iii. In contrast, the scaled down pilot, using only MBR+UV appears to be profitable from a purely economic perspective. There are no tangible results on whether it will meet the strict water quality criteria set by the Romanian regulatory framework.
    iv. There is an incremental benefit of WaterCPS, which cannot be assessed independently. But since it is present in all CS's, it is considered to be an integral part of AquaSPICE.
b. AquaSPICE cost competitiveness
    i. The overall cost (intake) is at a comparable level with previous CS's
    ii. However, the per unit of intake/discharge reduction costs are higher than the market prices. AquaSPICE might not be financially viable in regions with low water prices.
c. Conditions to make it profitable
    i. Water prices (intake+discharge)>€3.38 (EU levels)
    ii. Due to the large scale investment, there seems to be a critical size to breakeven, estimated ≈1 Mm^3/y.
    iii. A higher price of EUA's or a higher efficiency rate (water to carbon or electricity)

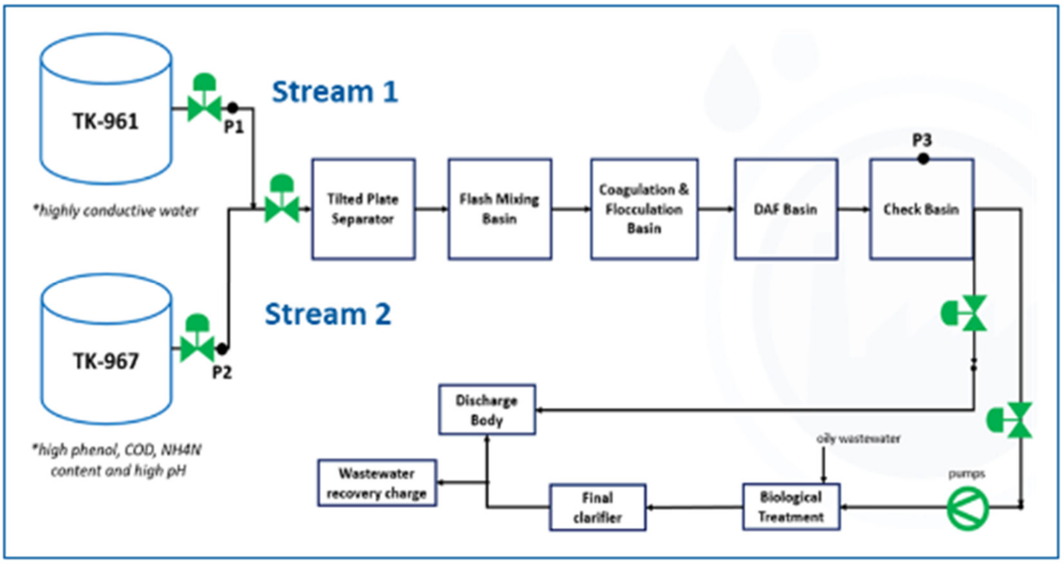
The current efficiency (target in deliverable 6.2) rate of 30% is not sufficient to make the venture profitable with low water prices. Either the efficiency rate has to increase to above 60% (rather optimistic) or a better ratio of price/efficiency rate should be applied.

8.8. Case Study #6 TUPRAS

Based on description provided at D2.3, AquaSPICE CS#6 is located at **Tüpraş**. It is the first producer in Turkey's refining sector and the largest industrial entity in Turkey, operating four oil refineries with a total annual processing capacity of 30 million tons of crude oil. Oil refineries demand large amounts of water used for industrial purposes (cooling water, demineralized water for steam production) or other purposes. There are also closed-loop water reuse opportunities in the factory, such as drum wash water, stripped sour water, desalter, make-up water, coke-cutting water.

Tüpraş Izmit Refinery consumes freshwater from a local lake, treated water coming from its internal refining processes in its own recovery plans. During maintenance operations, large amounts of freshwater are abstracted from the nearby lake. Therefore, Tüpraş aims to achieve near-zero liquid discharge, reduce freshwater intake and reach opportunities of water reuse.

Figure 14. Aquaspice in TUPRAS streams



Source: Current Ballast Water Treatment system in Tüpraş

Smart monitoring and advanced biological treatment, coupled with a separation process using regenerated membranes (end-of-life reverse osmosis (RO) membranes from desalination plants) will be tested to produce reclaimed water for industrial purposes.

The additional steps to be tested in the AquaSPICE project for the treatment of the Ballast Wastewater intend to minimize the environmental impact due to the discharge of the wastewater to the sea and to comply with the legal discharge regulations. Furthermore, it aims to recover water for reuse in the refinery by implementing advanced treatment technologies. To achieve this, the treatment plant has been designed to regulate the pH value as well as separate suspended solids and oil content. Also, the COD load of the streams is being decreased in contrast to the alkalinity, which is being increased. According to D7.1 the following technological solutions will be applied:

	Activity	Streams & Characteristics	Treatments Applied	Key results
Tüpraş	Refinery	Complex WW with high organic contents (with hard COD) + High conductivity	Activated granular sludge + ultrafiltration + reverse osmosis	- Use of aerobic granular sludge - Recycling of RO membranes for filtration

8.8.1. Value for the Tüpraş's case:

Challenging wastewater streams are produced as a result of refining processes. These streams are not easy to reuse with current technologies. Therefore, new technologies are required. Hence, Tüpraş, will have the opportunity to achieve at least 50% of water recycling in the pilot plant. Another key impact would be to reach 90% on the number of days achieving concentration in discharge water below limits. Thus, among the main objectives of wastewater treatment is to have a considerable environmental impact by reducing discharge levels to aquatic environment. Moreover, compliance with legal regulations on discharge levels is a top priority. Advanced treatment technologies and smart applications in wastewater treatment plants could efficiently recover used water and redirect it in the current process. AquaSPICE could prove to be a solution for reuse in challenging wastewater streams. Also it would be the first demonstration of optimization in auxiliary (water) units within the organization.

Therefore, besides technological opportunities, AquaSPICE can provide strategic opportunities related to the branding of the industry and its alignment with environmental sustainability goals. In a business environment, higher ESG rating attract more external investments.

Opportunities	
Technological opportunities:	- Demonstration of a new technology; - Technological improvement;
Strategic opportunities:	- Better branding and projection of the company;
Others:	- Projection of company's environmental sustainability efforts;

The use of new technologies poses several challenges that can overcome the potential investment benefits. For example, higher water treatment costs (CAPEX or OPEX) might render upscaling not financially viable. In addition, internal and external expertise such as consultancy firms, increase further the required expenditure. Finally, historical data on water streams in Tüpraş is not available except of some minor information from 2015, but more reliable is required. The status of equipment can be monitored on Honeywell's Distributed Control System (DCS) but there is not any information on the analysers. That consists a challenge, because the streams are being analysed by offline laboratory requirements, including COD, suspended solids, Cl-, oil, sulphur, NH4-N, phenol, and iron.

Challenges	
Technological challenges:	- Adapting the new technology; - Technological improvement;
Economic challenges:	- Start-up and commissioning fees;
Others:	- Lack of process data;

In relation to CS#6, considering the large-scale investment that is required by Tüpraş, the company could be benefited economically by reducing the operational and water costs by decreasing fresh water intake. In addition, replacing existing operations such as lab examination of water stream by online monitoring systems, can effectively reduce laboratory costs (chemicals, personnel etc). Regeneration of RO membranes can also reduce operational costs, and provide an opportunity to Tüpraş to further engage and partner with regenerated membrane companies.

Other benefits that AquaSPICE can generate for CS#6 is the environmental impact that can have in terms of water saving and respect to biodiversity and ecosystem. Moreover, positive environmental performance based on good rating of ESG criteria, has positive benefits on the strategic development of the company, since better environmentally performed companies have more opportunities to attract investments. Good environmental performance is also positively portrayed to the society and provides better branding and reputation of the company to the local society. Overall, what was also assessed as important in case to Tüpraş, is the contribution to environmental performance, and the respect to biodiversity and ecosystem.

Impact	
Environmental impact:	- water saving - sustainability and environmental performance - respect to biodiversity & ecosystem
Territorial impact:	- N/A
Social impact:	- Sustainable development - Improved environment

Possible interventions that could act as the main drivers for further investments of AquaSPICE are the application of new technologies that can optimise the current water treatment system with the addition of online monitoring systems, which are not currently used. Therefore, applying digital technologies as part of AquaSPICE can be of incremental importance for Tüpraş, because it can actually transform the whole operating water management system. Compliance with current legislations, concerning discharge limits, is another important driver for AquaSPICE implementation and full-scale investment. Moreover, increasing environmental impact and portray a positive impact under the "Polluter Pay Principle", is a considerable factor for building a concrete water saving system.

Possible investments for improving current water management system, have certain barriers which have been identified in almost of all new technological applications, which is the current capacity of the unit, and the need to dedicate personnel and expertise. Additional experts that are required increased the total investment costs, especially when internal personnel are not sufficient to cover the needs, and hiring external personnel outside the local job market or a consultancy firm, require higher investments. Therefore, the main drivers and barriers are identified below:

Drivers	Barriers
Application of new technologies	Expertise and personnel required
Legislations (Discharge limits)	Capacity of the unit
Environmental sensitivity	
Digital transformation	

New investments in new technological application have particular risks, which might act as preventive when considering that making new investments and upscale existing technologies. In case of Tüpraş, the main risks that have been identified are, the highly priced equipment, which needs to also be adapted in existing operational systems. That also signifies that also the operational unit needs to be dynamically optimised since it receives wastewater in different flows, so a dynamic system with changing wastewater properties is necessary. One of the main technical risks that have also been identified is, the capacity of the unit which is low in comparison with the wastewater produced. Therefore, the main risks as they have been identified are presented below:

Financial:	Highly priced equipment
Operational:	Dynamic system with changing wastewater properties -> Unit must be dynamically optimized
Strategic:	-
Technical:	Capacity of the unit is low compared to the amount of wastewater produced

<table>
<tr><td rowspan="2">Key Activities
Oil refining</td><td rowspan="2">Key Resources
Not indicated</td><td rowspan="2">Distribution Channels
Not indicated</td><td colspan="3"><u>Stakeholders/Key Partners</u></td></tr>
<tr><td>Central Stakeholders
Not indicated</td><td>Peripheral Stakeholders
Not indicated</td><td>External Stakeholders
Not indicated</td></tr>
<tr><td colspan="3">Customer Relationships
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Not indicated</td></tr>
<tr><td colspan="3">Cost Structure
Not known</td><td colspan="3">Revenue Streams
Not known</td></tr>
<tr><td colspan="6">Value Propositions</td></tr>
<tr><td colspan="2"><u>Economic</u>
1.Decrease the fresh water consumption costs
2. Decrease laboratory costs
3.Decrease of local usage of infrastructure</td><td><u>Environmental</u>
1. Water saving
2. Environmental performance
3. Biodiversity & ecosystem</td><td colspan="3"><u>Social/Territorial</u>
1. Sustainable development
2. Improved environment</td></tr>
<tr><td colspan="2">Private financial mechanisms
Not known</td><td>Private non-financial mechanisms
Not known</td><td>Public financial mechanisms
Not known</td><td colspan="2">Public non-financial mechanisms
Not known</td></tr>
</table>

8.8.2. Cash Flow Analysis 6: TUPRAS

Disclaimer: There is no reliable data retrieved from this case study and therefore any analysis would be solely based on theoretical values for costs and benefits. An additional constraint would be the lack of specific information about the volume of water treated in each stream, as well as the target efficiency rates. Consequently, any analysis attempted here should be based on a simulation, rather than on a realistic scenario and, therefore, it is not included here. The value proposition of AquaSPICE in CS6, will be solely based in the qualitative assessment of the benefits/costs/risks performed in the section

8.9. Case Study Conclusions

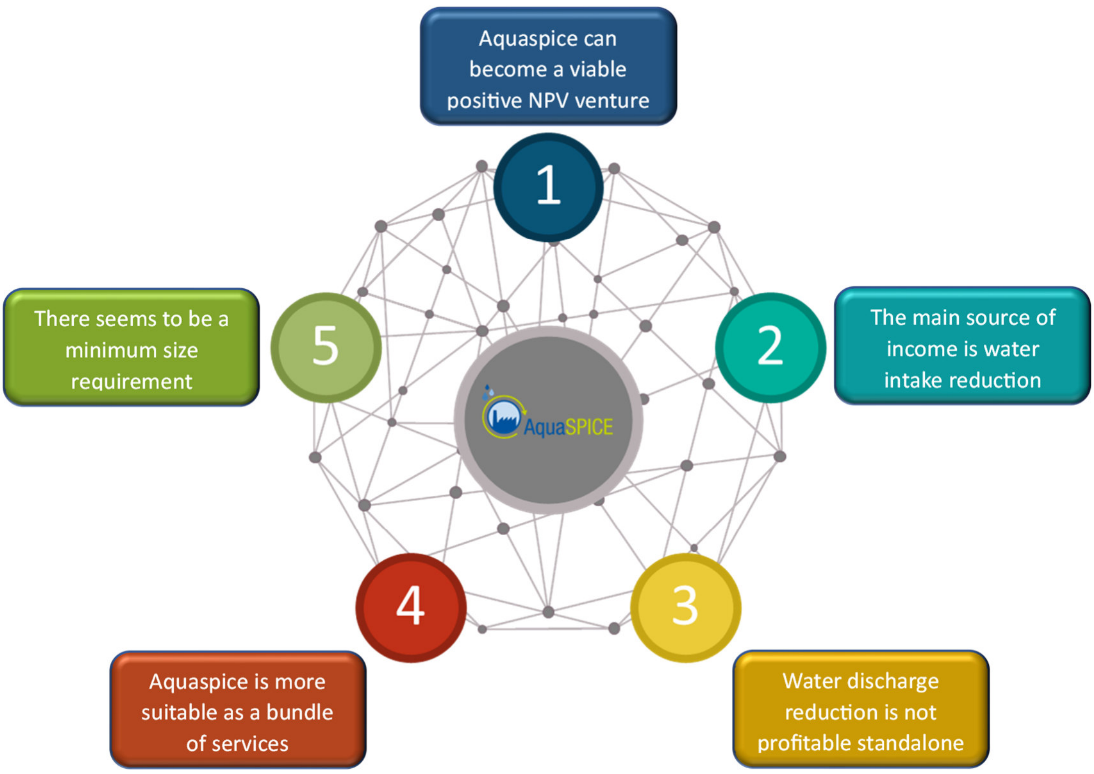
The main aim of the analysis above is to identify the value proposition of AquaSPICE in the early adopters and evaluate it in monetary terms. This is a necessary step in order to identify what the competitive advantage and its potential profitability of a new venture might be. Toward this direction, the analysis above serves the purpose of identifying the technology combinations that might render a future venture profitable, as well as the conditions that might be necessary. The main findings of this analysis can be summarized below:

- Technologies
    - WaterCPS is the common denominator of all ventures. The current analysis cannot evaluate its marginal contribution in monetary terms, but it concludes that it can be combined with different technologies to reach a higher efficiency rate. It can be developed to be the main competitive advantage of a new venture.
    - From the existing technologies, filtration technologies (especially the combination CF+RO+UF) seem to be the most realistic option
    - Water reduction targets cannot justify the implementation of AquaSPICE technologies, because the cost per m^3 is not competitive. However, the cost per m^3 of water intake is the most realistic pricing scenario that could be developed into a value proposition for future clients.

- Necessary conditions. There seem to be some minimum requirements. A minimum of:
    - Volume of water intake. Our estimate is ≈0.5Mm^3/y
    - Price for water (intake + discharge). Our estimation is >€2
    - Price for Carbon Allowances or Electricity savings
- Potential characteristics of the new venture
    - The minimum volume required is relatively low and thus, smaller companies might be a target group.
    - Regional aspects are important, primarily for water quality requirements, but also due to sensitivity to water prices. Regions with lower price for water might render AquaSPICE relatively challenging to turn profitable
    - AquaSPICE seems to be more appropriate for companies with water intake management needs. Water waste management only is hard to justify in purely economic terms.
    - The pricing policy or the marketing strategy of the new venture should focus on water intake, rather than on water waste management. This, from a pricing point of view, is the most realistic scenario.
    - Smaller companies with water intake management needs might benefit more from digital technologies and, thus, the WaterCPS technology might be a more suitable tool as a value proposition of a new AquaSPICE venture.
    - Depending on competition, as well as on the structure of the new venture, a "bundle" of services additional to digital technologies, might be a viable way to achieve organic growth.

The main findings can be summarized in the figure below

Figure 15. Main Findings from Case Studies



9. AquaSPICE as a solution: Business Models

Synopsis of previous sections

The analysis in the previous sections is focused on the identification of the value proposition of AquaSPICE from a macro- (water treatment market) and a micro-economic (early adopters) perspective. The main findings can be summarized into the following points.

Market Perspective	• There seems to be a growing market for water treatment technologies. Companies that do not actively optimize their processes might face adverse economic conditions or adverse regulation
Exploitable Technologies	• WaterCPS is a digital technology that can be developed as the main value proposition of Aquaspice due to market potential and low investment costs • Water intake management is a better value proposition than water waste management, primarily due to costs.
Conditions	• The minimum requirements for rendering some of the AquaSPICE technologies profitable are rather low and that makes them suitable for smaller companies
Future Venture	• A WaterCPS only venture would be a reasonable start for a new AquaSPICE venture, but because of the growing market for water treatment technologies, an expansion into other activities might be a reasonable pathway for organic growth

.

This section

The material in this section constitutes the main element of this deliverable; the development of business models for the exploitation of promising technologies or technology combinations. Drawing on our previous findings, with regards to the value proposition of AquaSPICE technologies, here we suggest the exploitation of primarily the WaterCPS. This is a digital technology that is relatively unique with respect to existing competition (macro-environment) and seems to be the most exploitable technology from the AquaSPICE value proposition (micro-level analysis). It is also suitable for smaller ventures, which might also be a potential target group. In this section we start with investigating the financial viability of such a venture, focusing only on WaterCPS, following a "software only" business model. Then, drawing on previous findings we investigate potential pathways for organic growth. In the following sections we also investigate potential target groups, as well as financing options.

WaterCPS only → Potential pathways for organic growth → Clients and Financig

9.1. The "AquaSPICE Inc."

Drawing on our previous findings, in this section we highlight the conditions and our assumptions for evaluating the financial viability of a new venture – we name it "*AquaSPICE Inc.*" – which will exploit the technologies that appear to be the most promising from a financial standpoint. The objective is to assess whether a new venture could be successful within the universe of the water treatment market. In order to assess this, we need to

- First, identify a suitable business model for the technology and/or the technology combinations that are promoted
- Second, estimate the cash flows that might be associated with the new venture.
- Third, evaluate the sensitivity of the cash flows to different scenarios

For the first, since the WaterCPS appears to be the most promising technology, the most appropriate venture appears to be a "software only" business model.

With regards to the second, we base our evaluation on a single metric, the (N)et (P)resent (V)alue (NPV hereafter), which focuses on estimating how much value can be derived from a new venture in present value terms. Within the context of investment appraisal it is the most suitable metric because it translates the cash flows into a single metric (monetary value), without disregarding uncertainty and risk.

With regards to the third, we opt for evaluating the sensitivity of the NPV metric to changes in the inputs evaluating different scenarios. We select a "scenario analysis", rather than a "ceteris paribus" investigation, in order to account for higher order interactions.

In order to assess the NPV of the new venture, we need to develop several assumptions for the Cash flows related to the costs and benefits of the new venture.

General Assumptions Applied in all Business Models		
Demand	I.	There will be a minimum of 10 interested parties the first year
	II.	The growth in demand will stay at 100% for at least the first 6 years
	III.	The conversion rate will be 25%
	IV.	Regulation and water scarcity will maintain the demand
	V.	The targeted companies are assumed to have an average/target volume of treated water of around 1.5 Mm^3/y or 1 MGD.
Supply	I.	The tangible parts, such as the use of membranes, smart sensors, etc, might be replicable
	II.	The optimization and the process design is a competitive advantage
	III.	This comes primarily by WaterCPS
	IV.	The customized combinations of digital solutions is a competitive advantage
Costs	I.	There is an increasing cost of materials, but we assume that this could be transferred to end clients at least partially.
	II.	This will be easier in the first period and then margins will be reduced
	III.	In order to maintain the competitive advantage a significant R&D expenditure is required
Miscellaneous	I.	Inflation is set at 3% and refers to all prices
	II.	A tax rate of 30% will be applied
	III.	Working capital needs in all cases will be 3% of total revenue
	IV.	Annual salaries are considered in a fully loaded amount at €100k
	V.	The assumption is that the AquaSPICE funding will act as initial investment and it has already been incurred. So, it is considered as a sunk cost.

9.2. The "*AquaSPICE Inc.*" as "Software only" Company (WaterCPS)

We understand that the implementation of AquaSPICE solutions is a combination of various digital and tangible technologies. We conclude in the analysis above that the value proposition (to potential clients) and the competitive advantage (of AquaSPICE) is derived from the most suitable combination of these technologies, customized according to the specific needs of the client (depending on idiosyncratic, as well as systematic factors). The central point of all combinations, e.g., filtration, RTM, digital twining, etc., is evidently the WaterCPS technology. Consequently, we conclude that WaterCPS lies in the heart of the competitive advantage and the value proposition of AquaSPICE solutions. AquaSPICE could focus solely on providing WaterCPS technologies, with potential extensions described below.

We investigate the viability of a "Software only" (WaterCPS) as an alternative business model. In this scenario" *AquaSPICE Inc.*" becomes a software development company that

1. Develops a highly customizable WaterCPS software
2. Provides a customized version of this software to potential clients
    a. To identify the needs, a feasibility study is required. This can be outsourced.
    b. WaterCPS has to be combined with other technologies. The cost for that is covered by the client
3. Installs and maintains the software

This software-only business model is comparable to a "Fees for Services" business model (discussed below), but it exhibits also the following characteristics:

A. There is a product: "The WaterCPS software" that is provided. This means that there are CAPEX and OPEX related to development, maintenance and operations.
B. The feasibility study is necessary to be performed, but it is not the main competitive advantage of the business. The software is. Therefore, the feasibility study costs can be part of the revenue or it can be outsourced.

For this purpose we develop the following assumptions (General assumptions remain unchanged).

Revenues		
Feasibility study	I. II.	30% of clients will contact the feasibility study independently. Due to competition it will be provided at a rate of €10,000
Software	I. II. III. IV.	The baseline scenario is that the software will be provided (per license/user) a. either for a one-off cost of €25,000 b. or on an annual subscription base of €5,000 p.a. c. minimum period of service 1 year d. 50% of clients will opt for the one-off payment The software will need installation. This accounts for a flat fee of €5,000 The software will need "Hosting" services a. Either a local server will be installed and maintained internally, at a cost of €50,000 b. Or it will be hosted locally (AquaSPICE) at an annual fee of €10,000 c. 80% of clients will choose the second option The software will need maintenance a. 10% of clients will do it internally b. The remaining 90% will require a project management assistance. c. The cost for the project management is €25,000 p.a.

Costs		
Development	I.	The initial version of WaterCPS is already developed (EU funding)
	II.	This needs to be updated and developed continuously. R&D will account for 12pm's p.a. and it is assumed to be funded by 70% by EU funding.
	III.	The overall load covered by AquaSPICE will be 3.6pm p.a.
	IV.	This will increase with every lot of 25 clients
Personnel (per lot of 25 clients, no R&D)	I.	12pm for maintenance
	II.	12pm for project management
	III.	3pm for commercialization and sales support
	IV.	6pm for internal operations
Other	I.	Hosting services will require a server and internal maintenance. This will account for an overall cost of around €0.3 per hour per lot of 25 clients. This is subject to inflation
	II.	Depreciations will be small, because a software company is not a capital intensive business. R&D will be depreciated entirely at a rate of 20% p.a.

Considering that macro-changes will affect all parameters, rather than one parameter ceteris paribus, we perform a holistic sensitivity analysis on the project considering the following scenarios:

	#1st year	Growth	License	Subscription	Hosting/ **Management**	Personnel	Cost of capital	Probability	NPV
Worse	5	70%	€ 5,000	€3,000	€20,000	€125k	20%	0.3	€290,567
Base line	10	100%	€25,000	€5,000	€35,000	€100k	13%	0.4	€9,722,708
Best	15	150%	€50,000	€10,000	€50,000	€75k	9%	0.3	€37,466,433
Overall	NPV			€15,216,183					

Conclusions:

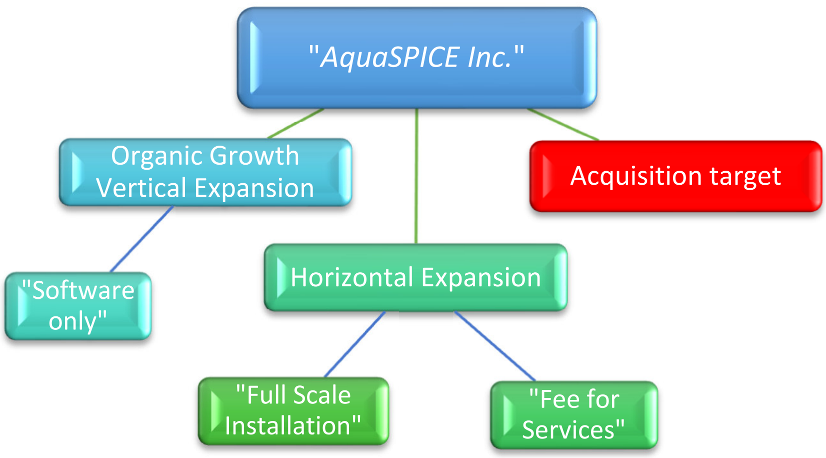
The analysis above suggests that

- Value
  - the "Software only" (WaterCPS) business model could be highly profitable. The overall NPV of the venture is around €15m and this represents the average value it could achieve, considering the scenarios above
  - This comes from a considerably high value if the venture is very successful. The WaterCPS exhibits a notable competitive advantage that might not be easily replicable and, thus, this scenario is likely.
  - However, the baseline scenario, still exhibits a decent value of around €10m.
- Risk
  - There seems to be very low downside risk, since the NPV stays positive in all scenarios.
  - There is a high variance in the NPV of the different scenarios, but even in the worst scenario (half the demand expected, lower growth, lower fees and higher costs) it can still be profitable, albeit rather moderately.

9.3. The "*AquaSPICE Inc.*" grows. What's next?

The business model that focuses on a WaterCPS only ("Software only) appears to be a viable choice as a starting point and it fits within the cleantech market as a startup (discussed further in the following section). The uniqueness of this digital solution and its customization can lead to a viable competitive advantage and should it remain non-replicable (with a patent or other entry barriers) it could lead to a substantial growth. If this growth is finally realised, then "*AquaSPICE Inc.*" will face the dilemma of either distributing a significant dividend with the accumulated cash or to invest it in new activities. The options we envisage at this stage are the following:

1. It stays a "Software only" company and its R&D activities focus on other digital solutions.
   a. Potential replication to other markets
   b. New software focusing on the cleantech market
   c. Using the existing customer base to develop more specialized pieces of software focusing on optimization. Other digital technologies, already implemented in AquaSPICE, such as the digital twins, the RTM, etc., could be employed toward this direction
2. It pursues organic growth by expanding to other activities
   a. It can expand its activities by including project management related activities, such as consultancy, feasibility studies, project management services, process optimization, etc. This is a feasible transition from a "Software only" to a "Fee for Services" business model
   b. It can expand its activities to become a "Full Scale Installation" company, where it provides all the above activities and on top of them installation of water treatment technologies (e.g., CF+UF+RO that is identified as exploitable above).
   c. Become a "Bundling Service" company, where the customers can select any level of service that suits them better.
3. Capitalize on its success and become an acquisition target
   a. Considering the market analysis in the early sections of D7.2 and in D7.1, there is a significant competition within the water treatment technologies.
   b. These companies could become competitors in the scenario of a "Full Scale Installation" business model
   c. Or they can add a "Software only" business in their portfolios.



We consider the first branch to be part of the "best scenario" in the "Software only" business model. In the following sections we will focus on the horizontal expansion.

9.4. The “*AquaSPICE Inc.*” grows horizontally

9.4.1. The “*AquaSPICE Inc.*” as a Consultancy firm: “Fee for services”

In this scenario, the “*AquaSPICE Inc.*” grows organically horizontally in the supply chain. More specifically, it capitalizes on the initial growth as a “Software only” firm and the customer base it creates and expands to exploiting other AquaSPICE findings. In particular, the additional services focus on the optimization and customization aspect of the exploitable technologies and the product that the new, expanded venture sells, on top of WaterCPS, is the “consultancy services”. This includes, feasibility studies, optimization, selection of technologies, project management, etc. The “*AquaSPICE Inc.*” does not merchandise the necessary technologies and technology combinations (this is outsourced to existing companies), but focuses on customization as a consultancy product.

We assess this scenario by developing the following assumptions:

- The feasibility study can reach a cost of €25,000. This is higher than before, because it is supposed to be more comprehensive and provide also technical details for manufacturing and installation. This is subject to change due to competition.
- However, all the costs are passed on to the companies. They decide how they will obtain, install and maintain the necessary equipment.
- Revenue will also come from a bundled offer of a feasibility study plus project management at a combined (discounted) cost of €40,000, should the company wish to outsource the project management to AquaSPICE solutions.
- All clients will get some kind of service. We assume that the conversion rate is 50% of clients will opt for the feasibility study only, while the remaining for both.
- Like before there will be 10% working capital and 10% OPEX
- Personnel will be 12pm per 25 clients.
- R&D is still necessary to maintain a competitive advantage and we assume that this will take the form of state funding (70%) with the remaining accounting for 5% of revenue

This model yields the following results

	#first year customers	Growth	Feasibility	Management	Probability	NPV
Worse	5	70%	€ 17,500	€ 28,000	0.3	€1,109,393
Base line	10	100%	€ 25,000	€ 40,000	0.4	€5,642,229
Best	20	150%	€ 27,500	€ 44,000	0.3	€31,175,494
Overall	€11,942,357.56					

The transformation from a “Software only” to a “Fee for Services” business model is an incremental transition and the value estimated above is also incremental (to be added to the value of the “Software only” scenario). The analysis here takes into consideration “holistic” scenarios where all major fundamentals affect the value of the new venture and the expected “value added”, should the “*AquaSPICE Inc.*” opt for this expansion alternative. This option on its own would be a more modest business model from a financial perspective, but it exhibits similar risk characteristics to the “Software only” approach. It appears to be a low risk alternative that remains positive NPV in all scenarios. However, this low risk alternative also exhibits a low profitability potential. The maximum value that can be achieved in the best scenario is still lower than the expected value of the “Software only” solution. In our opinion, this is because in this version, unlike in the WaterCPS case, there is high replication potential. WaterCPS is relatively unique and can be developed standalone. Feasibility studies and customization might be desirable, but they are easily replicable. So they would remain better as an expansion option, rather than as a primary business model.

9.4.2. The "*AquaSPICE Inc.*" as a Merchandise venture: "Full Installation"

In this second option to expand, the "*AquaSPICE Inc.*" opts for capitalizing on several exploitable technologies derived from AquaSPICE, both digital and water treatment. After building sufficient capital, the "*AquaSPICE Inc.*" can start competing with existing entities in the water treatment market in optimization (WaterCPS), but also in installing the technologies. In the previous scenarios all installation is outsourced. In this this one, the "*AquaSPICE Inc.*" focuses on a niche competitive advantage, which is optimization with WaterCPS or other digital technologies (from "Software only"), plus merchandizing the necessary equipment. In this part, we analyse the incremental (on top of the "Software only") cash flows that would occur, should the "*AquaSPICE Inc.*" opt for expanding its business into the merchandizing of water treatment technologies.

This is the most capital intensive scenario. The idea behind the "Full Installation" scenario is that the "*AquaSPICE Inc.*" can merchandize all the necessary elements for the implementation of technologies and technology combinations in potential clients. They should be expected to pay an annual fee for as long as they use the services, for a minimum time of no less than the useful life of the installed investment. The value proposition then could be

I. Customized feasibility/suitability study: AquaSPICE Solutions can perform a feasibility study in order to identify and assess the potential clients' needs, as well as the suitable combination of solutions. Cost: €15,000 and can evolve with competition.

II. AquaSPICE Solutions can merchandize and install all the elements.
   a. Drawing on the CS analysis above, we consider the scenario of CF+UF+RO, which appears to be the most exploitable technology (other exploitable technology combinations too)
   b. We also consider that the pricing policy should be focused on water intake/treated
   c. Relevant (full economic) costs (TLC/m^3 intake) can vary from ≈€1.3/m^3 for a small installation (1.5 Mm^3/y, like in the case study in DOW Terneuzen) to below €0.70 for a larger installation (e.g., 50 Mm^3/y; Plumlee et al., (2014) based estimate). Because in this scenario there is an existing competition, the pricing has to be competitive.
      i. We consider an average cost of ≈€1/m^3
      ii. For an average client of 5 Mm^3/y (break even point; Plumlee et al., 2014)
      iii. Sales price should remain competitive at below water price (intake), as well as competition. We consider a baseline scenario of €2/m^3.
      iv. Should its presence be established, then the pricing can be inline with competition. But a market penetration strategy, with existing competitors requires aggressive pricing.

III. Then we assume a project management fee equal to €25,000 p.a.

IV. In order to maintain the competitive advantage an annual investment in R&D equal to 20% (industry average) of total CAPEX is required. 70% of this could be subsidized.

V. AquaSPICE would need additional personnel for sales and project management. This is indivisible and we assume that there should be a requirement of 12 pm (6pm for sales and 6pm for project management) per 10 projects.

VI. Although production costs might be outsourced, there would still be other fixed costs like rental expenses and operating expenses. These will be considered within the working capital required and it will be computed as a proportion (10%) of total revenue.

	Sales price	Cost	Probability	NPV
Worse	€ 1.75	€ 1.50	0.3	-€51,265,218
Base line	€ 2.00	€ 1.00	0.4	€6,532,773
Best	€ 2.30	€ 0.50	0.3	€88,533,769
Overall	€13,793,674			

The baseline scenario yields a "value added" (on top of the "Software only" scenario) of around €6.5m, as well as an expected (all scenarios considered) "value added" of around €14m. This is marginally higher than the alternative scenario ("Fee for services"), but it is the output of significant volatility. In the best scenario, the "value added" is significantly higher than in any other alternative, so, this option has a high upside potential, even after considering a tight, aggressive pricing policy. Much higher than the initial "Software only" business model. In contrast, there is also a significant downside potential. In case that entry barriers become restrictive due to competition, then this expansion option might yield significantly negative results.

9.5. The "*AquaSPICE Inc.*" "a la carte": "Bundling" Service

The basic idea of this scenario is a combination of all scenarios, where the "*AquaSPICE Inc.*" offers an "a la carte" range of that range from a simple feasibility study to a full installation and project management. Of course different pricing will apply in all cases.

Offer	Details
Feasibility study only	I. 50% of clients will select this option II. The overall assumptions about personnel and costs are similar to the previous business models III. The pricing will be €25,000
Feasibility + Project Management	I. 30% of clients will select this option II. The pricing will be at €40,000
Feasibility + Installation + Project Management	I. 20% of clients will select that II. No feasibility study or project management fees will be charged

This scenario yields the following results

	worse	Base line	Best
Sales price	€ 1.75	€ 2.00	€ 2.30
Cost	€ 1.50	€ 1.00	€ 0.50
#first year customers	5	10	15
growth of customers	70%	100%	150%
Feasibility study costs	€ 17,500	€ 25,000	€ 27,500
project management costs	€ 28,000	€ 40,000	€ 44,000
Probability	0.3	0.4	0.3
NPV	-€10,831,931	€16,193,068	€126,610,117
Overall NPV €41,210,683			

Unlike the "Fee for services", the "Bundling" scenario exhibits a downside risk (NPV<0). In the worst scenario, the NPV turns negative. However, there is also an upside potential that is fairly sizeable and raises significantly the overall NPV of the project. This mainly comes from the fact that the biggest part of revenue comes from stable sources. Only 10% comes from a full-scale project. The resources for that, e.g., R&D expenses and project management personnel or sales, are sizeable and the firm can capitalize on them for other ventures. These economies of scale make it easier to:

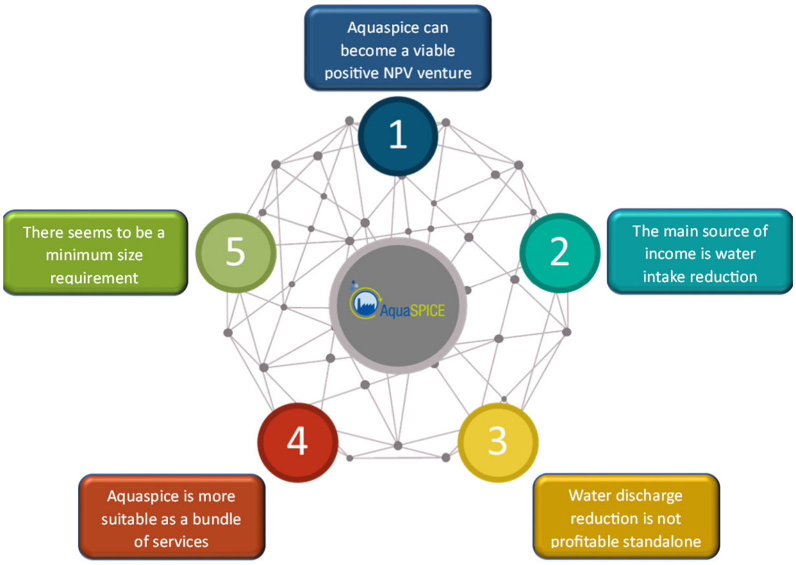
I. Manage the downside risk. In the case that the pricing is not favorable, the firm can turn its activities more to consultancy
II. Exploit in a safer manner the upside potential. In case the pricing is favorable, the firm can realize more full scale projects and gain from the larger scale of investments
III. In all cases, the combination of activities yields better results.

Consequently, comparing the alternatives up to now, the recommendation would be to exploit the benefits of "Fee for services" approach that is a low capital intensity, safe (consistently positive NPV) approach and combine them with the high upside potential of the full scale projects of the "Manufacture/Leasing" business model. This would result in a "Bundling" business model.

9.6. The *"AquaSPICE Inc."*: Conclusions

In this section we investigated the monetary value of the value proposition of the *"AquaSPICE Inc."* by applying a cash flow analysis on the incremental cash flows of each case study separately. The objective of this analysis is to identify potential benefits, cost and value per exploitable unit (m^3) and then investigate whether this can be expanded into an exploitable venture. The main findings of our analysis can be summarized in the following points.

Figure 16. Main Findings from Case Studies

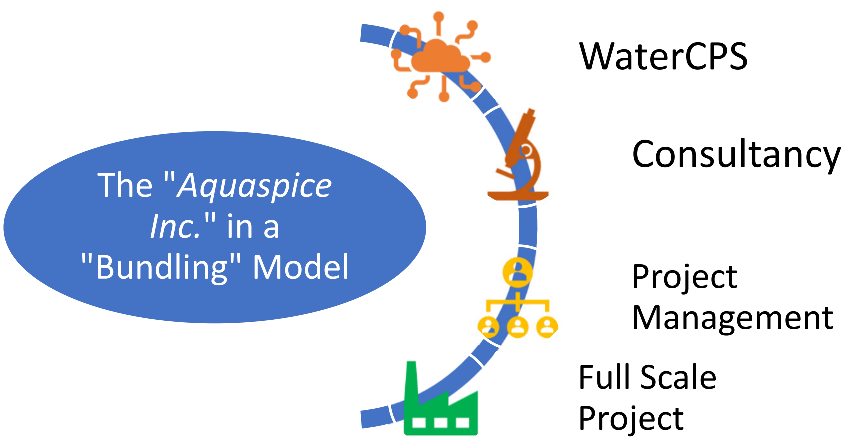


Beyond the limits of the pilots in the case studies, we explore the possibility of an *"AquaSPICE Inc."* startup to become a profitable venture. We reach the following conclusions

WaterCPS is the main competitive advantage

We start with the main competitive advantage identified in the analysis of the CS. This is the WaterCPS digital technology. There is low replication potential and a strong value proposition. Therefore, it is a valid candidate for setting up a new venture. We investigate its potential in generating a positive NPV and we find strong evidence in its favor. We continue by investigating how it could be expanded should it be successful in its early stages. We consider primarily two organic growth expansions horizontally in the supply chain, from a simple "Software only" to a "Full installation" firm, as well as an "a la carte" combination of services.

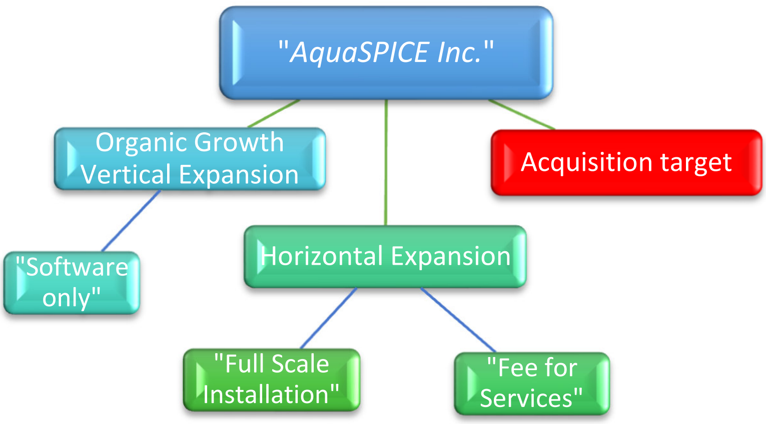
Figure 17. Summary of Business Models evolution for the "AquaSPICE Inc."



Upscaling potential

Our analysis suggests that the “Software only” (WaterCPS only) business model is profitable enough, while it generates decent returns. This is a low risk low return business model, that might reach a peak early on though. Consequently, it might need to expand in the foreseeable future, in order not to be taken over by an established competitor.

Figure 18. The “AquaSPice Inc.” expansion potential

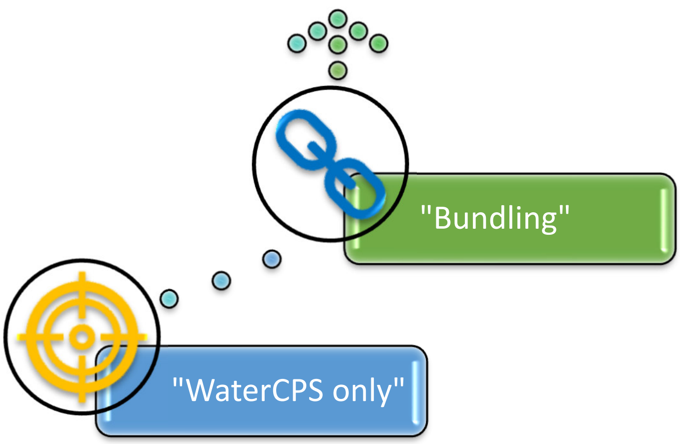


Although financially viable, we consider that staying as a “Software only” company might run the risk to be considered as an acquisition target of a company that is active in the water treatment market. As a viable solution forward we consider a horizontal expansion in the supply chain, either by including services of “Consulting only” nature, or by being active in a “Full scale installation” business model; or any combination between the two. Our investigation suggests that an “a la carte” offering of services might be the preferred way forward – as a “Bundling service” – because it has a high upside potential, with moderate to low downside risk. In brief:

II. <u>Start with “WaterCPS only”:</u> This business model exhibits a considerably lower operational risk and it appears to be, even marginally, profitable in all scenarios. We suggest starting with this in order to build “Goodwill” and “Financial Viability” first.

III. <u>“Bundling” service as an option to expand:</u> After the new venture attains financial stability and the necessary goodwill to expand on it, then we suggest an attempt to exploit the upside potential of the “Bundling” service. We place this after 3 to 5 years.

Figure 19. AquaSPICE Business Models: Initial Venture and Upscaling



10. "*AquaSPICE Inc.*" target clients

This section discusses potential clients the "*AquaSPICE Inc.*" may target. Existing evidence suggest that the chemical and the food and meat industry are among those groups that consume high volumes of water and deploy a rich set of wastewater management methods (Johns 1995; Awale and Soubaneh, 2014; Barbera and Gunari, 2017). This makes companies registered in these industries potential clients of the "*AquaSPICE Inc.*" service.

10.1. Holistic value of the "*AquaSPICE Inc.*"

Case studies shown that AquaSPICE has environmental, social and territorial values according to the needs and specifications of each industry. Investment costs differ per partner and case study, but overall investment needs counterbalance environmental benefits and needs to comply with discharge limits. Overall, the value proposition of AquaSPICE can be replicated to other industries with the same combination of technologies or custom-made. According to available data of D7.5, AquaSPICE's replication potential can reach up to 8,712 companies (Table 11). The majority of those companies concern large volume chemical and sub-chemical companies, slaughterhouses and refineries. Other application in food industries, petrochemical and pharmaceutical companies.

Table 11: Number of companies that could apply AquaSPICE's results (From Deliverable 7.5)

Industrial scope	Average yearly water consumption (millions m^3/year)
Large volume chemicals	3500
Other Chemicals	3875
Slaughterhouses	237
Refineries	1000
Full scope	8712

Source: more information on D7.5, @STRANE

A mapping of those industries is necessary to identify the needs and the size of the industries within Europe and the EU market economy, as well as the entry barriers and challenges they face.

10.1.1. Chemical industry

10.1.1.1 The Chemical industry within the EU

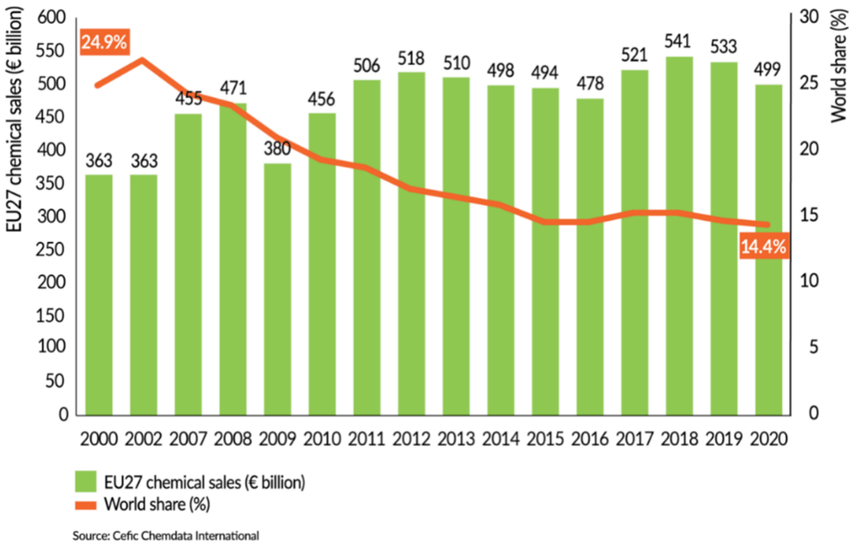
The Chemical industry is one of the cornerstones of EU's competitiveness contributing to societal, economic and technological challenges, but also to the improvement of living standards as a large employer. The sector represents 7.5% of EU manufacturing by turnover and provides 1.2 million direct highly-skilled jobs, and 3.6 million indirect jobs. Further, it supports 19 million jobs across all value supply chains (EUROPA, 2022). Furthermore, it has a labour productivity of 77% higher than the manufacturing average (ibid).

The overall importance of the chemical industry does not only derive from its direct purpose, but has a great importance for the manufacturing industry and other industries as well, since 56% of the EU chemical products are sold for use to other industrial sectors. In addition, the chemicals industry is a technological pioneer and through its R&D investments has contributed largely to challenges such as climate change, health/nutrition and energy efficiency.

10.1.1.2 Chemical Companies in Europe

In an overview of the chemical sales for the last decade (2010-2020), recent data revealed that global chemical sales were valued at €3,471 billion in 2020, with a decrease in global sales by 4.3% from €3,628 billion in 2019 to €3,471 billion in 2020 (CEFIC,2020). The Chemical industry is considered a pylon of the European economy, since Europe is the second largest producer of chemical products in the world (Kompass International, 2022), following China as the leading country. The EU28 generated €500 billions in chemical sales in 2020, whereas the rest of Europe had a revenue of about €128 billions (Statista, 2022). The European most important producers are Germany led by France, Great Britain and Italy. The German chemical industry is the largest, with a revenue surpasses €190 billions in 2020.

Figure 20: World Chemical Sales



The second most important chemical producers can be found in Spain, the Netherlands, Belgium and Ireland (Kompass International, 2022). Those countries produce 88% of the chemical products in Europe, while from the newer member-states, Poland produces 1,9% of the total productions. With a percentage of 14.4% in global sales, the EU27 chemical industry ranks second, while the US is the third in row, with total sales of 12.3% (ibid).

The specialty and consumer products, while petrochemicals and inorganic chemicals note a decrease on trade the same year (Statista, 2020). The EU is the largest exporter of chemicals worldwide, and that counts for its largest chemicals-related revenue . Only in 2020, the EU chemical exports revenue reached €170 billions, which recorder a 40% trade surplus over

10.1.1.3 Leading Chemical companies in Europe

The most important chemical companies are based in Europe. The largest chemical company is BASF, with its headquarters located in Ludwigshafen, Germany. The latest available statistics based on chemical companies' sales listing has placed BASF as the first chemical company with an overall revenue of €78 million and 111,000 employees (Statista, 2022). Other important chemical companies are also located in Europe, such as LyondellBasell Industries, DOW, Linde, Umicore, and Air Liquide. The latter, which is based in Ireland, it is considered the world's leading chemical company when it comes to market capitalisation (ibid). Regarding the petrochemical companies, while the two major global players are Chinese companies, three out of top 10 petrochemical companies in the world are based within Europe (Shell, Total Energies, BP) (Global Data, 2021). Therefore, the latest energy prices have placed an extra pressure on chemical companies in Europe, according to CEFIC, since they start to experience losses in income and much higher energy and production costs due to accumulation of raw materials (Chemistryworld.com, 2022).

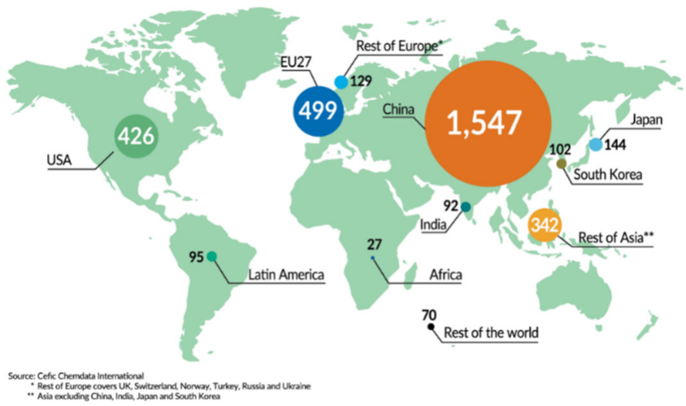
10.1.1.4 Competitive Advantage of the sector in Europe

The competitive advantage of the chemical sector in Europe in comparison with other industries worldwide, based in China or India for example, is its favourable business environment and stability. Another important factor is its chemical infrastructure such transport, supply chain, logistics and energy supply comparing to those in Asia or Latin America. Heavily investments in Research &

Development by European companies have provided an additional push-factor in comparison with similar companies in emerging countries. Chemical investment on R&D counts for 1.6% of the EU companies' expenditure comparing to 0.8% in China. Highly skilled workforce adds an extra factor which makes European-based chemical companies competitive compared to their peers.

10.1.1.5 World Market Share

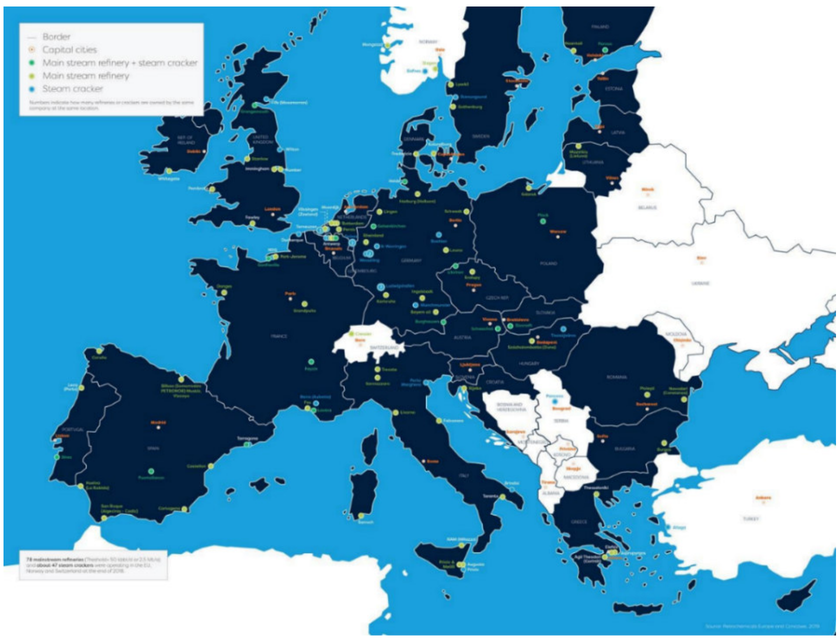
Figure 21: EU27 share in global chemicals market



The general trend is decreasing levels of chemical sales worldwide, apart from China has been leading on the chemical sector, technology innovation and trade and it positions itself as a global actor in the international markets (CEFIC, 2020). Overall, China's share in the global market increased since 2010, from 25.8% to 44.6% in 2020. The EU's share has dropped from 19.3% in 2010 to 14.4% in 2020 (ibid). Although the EU's general sales has been increased from the past twenty years since 2000, from €363 billion to €499 in 2020, its overall market share has sharply dropped from 24.9% to 14.4%, as steep growth in the chemicals industry worldwide, and several constraints in the EU including higher taxation and labour costs, strong regulatory environment and energy prices, have led to an increase of demand of chemical production from other countries.

10.1.1.6 Petrochemicals

Figure 22: Refineries and steam crackers in EU-28 (2019)



Petrochemicals is a sub-sector of the chemical industry, covering base chemicals or commodity chemical and their derivatives (polymers) and inorganic acids, which are produced in large volumes which marketized either within the chemical industry or to other industries as well (Mordor Intelligence, 2021). Base chemicals produce the largest in volume sales amounted for 58% of total chemical sales in 2020 (ibid). The global petrochemical market is projected to be worth $ 798.8 billion in 2030 from $ 523.56 billion in 2022, achieving a CAGR of 5.4% in the period between 2022-2030 (Precedence Research, 2022). Further market boost will be the adoption of petrochemicals in thermoplastics and oil production, which can increase future demand (ibid).

10.1.1.7 Challenges of the chemical industry

The sector faces various challenges due to its connection to environmental protection policies and laws and energy dependence. The fact that chemicals' production is connected not only to the environmental protection but also to public health, the sector is highly regulated not only at EU levels but also at national and regional levels too. The chemicals industry is imposed on health and safety regulations of the workers, the consumers and the wider environmental context including challenges emerging from the climate change and sustainability needs. As a sector is cumulative to higher costs than any other sectors (EUROPA, 2022).

Further challenges that the sector faces at EU levels is the energy dependency which the industry is obligated to follow, price fluctuations and severe international competition in the global market, by countries which might be privileged with less expensive energy prices (ibid). In addition, current economic challenges have also impacted chemical production processes and feedstock prices, which makes the EU chemical sector even more vulnerable to international shocks. The highly intensive EU regulatory environment adds extra burdens, since the sector needs to invest heavily on innovation and resource efficiency. In addition, compliance with EU regulations, costs the EU chemical industry around €9.5 billion annually (Exxon Mobil, 2016).

10.1.1.8 Possibilities of the sector to overcome barriers

Access to raw materials

- The EU chemicals industry need an access to biomass and competitive prices of raw material to be able to compete its share in international markets considering its declining trends of global production. Further investment in new resources, and technological advancement is encouraged but there is an increased need for the industry to have access to energy and raw materials at competitive prices to further adapt to the production costs and possible competition.

Coordination between policies

- Better coordination between industrial, environmental, climate, and energy policies is urgent in order to better accumulate costs incurred and how policies are impacted on the industry and its competitive environment.

Regulation

- The sector needs favourable legal and regulatory framework conditions, since it is affected by health and safety, environmental, climate related and energy issues. The regulatory environenment is key for the sector in order to ensure its further competitiveness.

10.1.1.9 Waste water treatment in chemicals markets

According to recent studies, the global market related to waste water treatment in chemical and water management is expected to expand in the following five years term. The latest trends with the increased production needs, urbanisation, climate change and rising water pollution levels, have demanded for efficient water and resource management, and less use of freshwater intake during production processes.

10.1.2. Food and Meat Industry

10.1.2.1 The Food and Meat industry within the EU

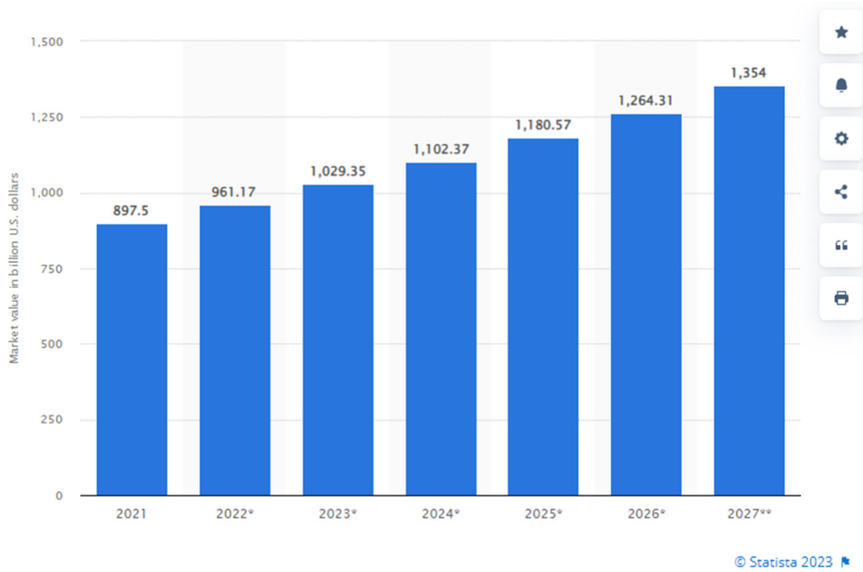
The food industry is the EU's biggest manufacturing sector and has generated many jobs. In addition, food trade with other non-EU countries especially in food specialties. The last ten years, the food exports have been doubled, creating together with drink exports and positive balance of almost €30 Billion (European Commission, 2023). The industry employs 4.6 million people across the EU-27, which places the industry as the biggest manufacturing employer in terms of jobs and value added (European Commission, 2023; FoodDrinkEurope, 2022). The sector generates a turnover of over €1.1 trillion and €230 billion in value added, making it one of the largest manufacturing industries in the EU (ibid).

The EU food and drink industry is generally competitive on a global scale and produces high quality, healthy and safe food. The last ten years, the EU food and drinks exports have almost doubled, reaching about €90 billion (FoodDrinkEurope, 2022). About 60% of EU food and drinks exports are destined within the EU's Single Market, while at the same time the EU remains the largest food and drink products exporter, reaching €156 billion and a trade surplus of €73 billion (ibid). While the overall food industry, has registered a positive growth for the upcoming years, the meat sector has to overcome several challenges, such as the declining consumption of red meat, EU citizens' concerns about environmental impact, climate change and animal welfare, and low farm incomes (European Parliament, 2022). The sector is quite diverse due to its size, farm structures, local production capacity and geographic distribution of farms across the EU. Still, in recent years, the sector faces a decrease in its relative competitiveness compared to other world food producers, mostly in terms of slower growth in labour productivity and added value. Especially for the meat processing industry, it reached €99 bn in 2022, but generally the industry profit is likely to decline the following years, due to amid weak demand, increased competition and volatile prices (Ibisworld, 2022).

10.1.2.2 World Market Share

The global market value is expected to increase the upcoming years, due to increase consumption demand and a shift towards healthier lifestyles along with increased demand for animal-sourced protein and a preference over poultry meat (Imarc, 2022; Statista, 2023).

Figure 23: Meat industry value worldwide in 2021 and forecast for 2022 and 2027(in billion U.S. dollars)



Source: Statista 2023

While the previous decade the largest food producer was China with over 50% of pork production and one third of all meat production, as of 2020, Asia Pacific and North America hold the largest shares of meat market, while the rest of the world produce one third of the global production (Statista, 2023). Specifically, Asia Pacific held the world market share of 57.5% in 2021 in pork meat production. While it is expected to further grow by 80% the following six years (MMR, 2021). The EU is the second largest pork producer and the biggest exporter of pork meat and its by-products (European Commission, 2022). Moreover, the EU is the third largest producer of beef and veal production and holds the fourth position in the production of poultry and its by-products in the world. In order to enhance its competitiveness, the EU negotiates bilateral free trade agreements with third countries, to facilitate exports of its meat products (European Parliament, 2022). While opening to global markets, can have a positive impact for the EU exports, it can also place a higher competition and internal pressure, since especially beef production is more competitive outside the EU (ibid). Overall, stronger market shares have countries like Brazil, the US, and India which export four to eight times more veal the EU (ibid). According to Statista (2023), the global revenue in 2023 in meat segments was $1,312.00bn in 2023, and it is expected an annual growth by 7.47% (CAGR 2023-2027). Regarding the revenue generated, the US has registered the highest revenue US$165.30bn in 2023 (ibid). In addition, the EU is one of the largest poultry meat producer in the world and an exporter of poultry products, with an annual production of 13.4 million tons of meat (European Commission, 2022). While the EU imports high value poultry products from third countries, as an exporter provides to global markets, products of a lower value (ibid).

10.1.2.3 Challenges of the meat industry

One of the main challenges of the industry within the EU, is the general shift of the European populations into vegetarianism and veganism, due to general concerns over the climate change, health concerns and animal welfare (Statista, 2023). This has also shifted traditional value chains within the meat industry, and many meat companies have started producing plant-based meat substitutes, in order not to lose their position in the market. Meat substitutes grew by 17% in Western Europe and 13% in Eastern Europe (Statista, 2023).

A considerable challenge regarding the meat industry within the EU-27, is the higher costs of meat production for European producers that its competitors (AVEC, 2022). European standards on food safety and quality of products, animal welfare and environmental protection, place EU products higher in excellence of its products, but increases production costs for the local producers, in comparison with the costs of production in third countries (ibid).

Another serious challenge that meat producers face is, the strict regulatory environment imposed by the EU is food production, tariff quotas, trade barriers and a diversification of products which demands higher investments through innovation and automation system. A higher demand of fast processing food and alternative meat products, also require a change in the supply chain of industries (AVEC, 2022).

Data Bridge Market Research analyses that the wastewater treatment market in food industry market which was growing at a value of 10.1 billion in 2021 and is expected to reach the value of USD 14.14 billion by 2029, at a CAGR of 4.3% during the forecast period. I

10.1.2.4 Possibilities of the sector to overcome barriers

Access to automated technology and innovation	• Adoption of robotics and automated technology can help industries maximise their production efficiency and simplify meat processing. Automatisation also helps companies to improve plant conditions, reduce contamination and ensure better health and safety conditions for workers and consumers.
Eliminate trade barriers	• Trade barriers and trade agreement with third countries need to be considered, along with tarrif quotas for imports, in order to keep the European market competitive.
Regulation	• The sector needs favourable legal and regulatory framework conditions, since it is affected by health and safety issues for public health, production and consumption of meat products.

10.1.2.5 Waste water treatment in meat markets

Industrial water treatment for food industry, increases the requirements of good quality and consistent requirements in the production processes but also on disinfecting water before discharge. Certification standards in the industry are being issued on the basis of approved water treatment systems (FMI, 2019). The meat industry covers both manufacturing plants for the production of meat products and slaughterhouses/cutting plants. The industry consumes 29% of total amounts of freshwater used by the agricultural sector worldwide and up to 24% of freshwater used in the food and beverage industry (Gerbens-Leenes et al, 2013). Considering that total meat production has been doubled the last decade and is projected to grow, slaughterhouse will be increased, as well as volumes of wastewater generated that needs to be treated (Bustillo-Lecompte, 2016).

Slaughterhouses and meat processing plants produce wastewater which contains fat, grease and protein content with BOD level of 1500–2000 mg/L (Irshad et al, 2016). Therefore, treating wastewater from slaughterhouses is of detrimental importance both for economic reasons and for environmental and public health, because inadequate disposal of slaughterhouse wastewater causes deoxygenation and groundwater pollution (ibid).

Table 12: Typical Content Levels of Industry Wastewater before Treatment

PARAMETER	RAW WATER	PRE-TREATMENT REDUCTION
Total Suspended Solids (TSS)	600 - 4,500 mg/L	up to 99%
Fat, Oil, & Grease (FOG)	100 - 2,000 mg/L	up to 99%
Biochemical Oxygen Demand (BOD)	2,500 - 8,000 mg/L	up to 85%
Chemical Oxygen Demand (COD)	4,500 - 12,000 mg/L	up to 75%

Source: Ecologixsystems

Pre-treatment can typically reduce contaminants in wastewater from the meat and poultry production plants by 75%-99%. The required levels of major contaminants in treated wastewater before it is allowed to be discharged to publicly owned treatment works (POTWs):

Table 13: Required content of contaminants in treated wastewater before discharge to public owner treatment works

CONTAMINANTS	INFLUENT CHARACTERISTICS	EFFLUENT (REQUIRED) CHARACTERISTICS
Total Suspended Solids (TSS)	600 - 4,500 mg/L	250 mg/L
Fat, Oil, & Grease (FOG)	100 - 2,000 mg/L	100 mg/L
Biochemical Oxygen Demand (BOD)	2,500 - 8,000 mg/L	250 – 500 mg/L
Chemical Oxygen Demand (COD)	4,500 - 12,000 mg/L	500 – 1,000 mg/L

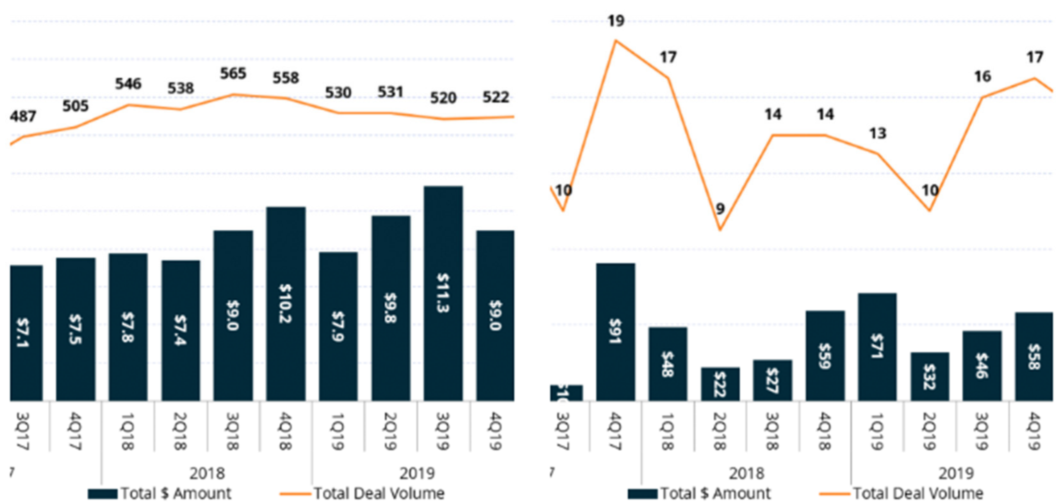
Source: Ecologixsystems

11. Potential sources of finance

As is the case of every young venture, capital is required for its growth. One of the most typical sources of finance for companies are loans. Banks however are reluctant to provide finance to young ventures due to the high risk they carry, as well as due to high information asymmetries (Colombo and Grilli, 2006). These ventures resort to professional investors that include Angels and Venture capitalists and crowdfunding. This section discusses potential sources of finance for a cleantech venture analysing the financial landscape for the cleantech industry in the UK and Europe. AquaSPICE venture can be viewed as a cleantech venture since cleantech encapsulates various companies and technologies aiming to improve environmental sustainability, among them water resources.

Professional investors. Typical source of finance for startups is equity investors that include Angels and Venture Capitalists. They buy shares in these firms with the expectation of a high return when they exit. They are not just a source of finance, they act as mentors as well (Macht and Robinson, 2009). There are very few firms, however, that receive equity finance from professional investors (Gompers and Lerner, 2001). Evidence is not in favour of a cleantech startup, although, recent evidence suggest that they turned their focus on the cleantech industry. Investments in cleantech have increased the last three quarters since 4Q 2020. Only in the last Quarter of 2021, private investments closed at $18.8 billion.

Figure 24: Cleantech Venture Capital Investment

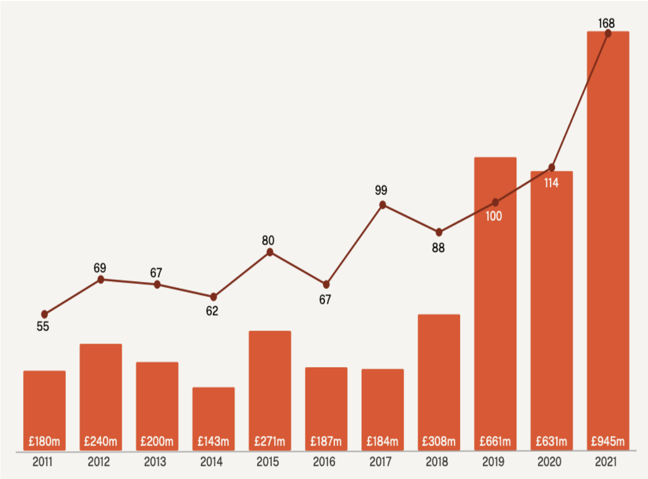


Source: Switzerland Global Enterprise

More and more companies and corporation have pushed on environmental investments and that becomes part of the investment portfolios. Venture investments in water innovation are equal to $100-$200 million per year, and those numbers are expected to increase accordingly to freshwater demand, and other phenomena which include water contamination (Switzerland Global Enterprise, 2021).

There are also strong signs of a flourishing market in the UK. Cleantech startup investments have increased significantly in the last decade. Beauhusrst (2022) reports an upward trend. It was only 180m in 2011 and this increased to 945m in 2021. This is around 9 times more.

Figure 25: Cleantech investments in the UK (Source: Beauhurst 2022)



Consequently, although it might be relatively rare for a startup to get funding from a VC or Angel Funding, the cleantech industry appears to offer a relatively decent growth and, thus, we suggest that in the future it might be a viable option for financing. Currently, it might be either scarce or expensive.

Crowdfunding. Another source of finance for cleantech startups may be crowdfunding. It differentiates from existing sources of finance in a sense that ordinary people – not just professional investors - can finance a cleantech venture. It has been deployed by cleantech ventures as a form of finance and evidence suggest that crowdfunding can be a supply channel for cleantech ventures (Vismara 2019)

Crowdfunding shook up the financial ecosystem by providing an alternative way of finance for small young unquoted firms (Thies et al, 2019). It can be used to test future success of a product a company is willing to launch in the future (Chemla and Tinn, 2019). There are four types that include donation, reward, equity and crowdlending. Equity crowdfunding (ECF hereafter) is a crowdfunding type in which any type of investor may become shareholder in a startup. Its benefits are multidimensional. It gives the opportunity to unsophisticated investors become shareholders at a low cost and offers a wider pool of investors for startups which is not restricted to Business Angels and Venture Capitalists. The ECF market experienced tremendous growth since 2011 and is expected to grow in the future (Tiberius and Hauptmeijer, 2021).

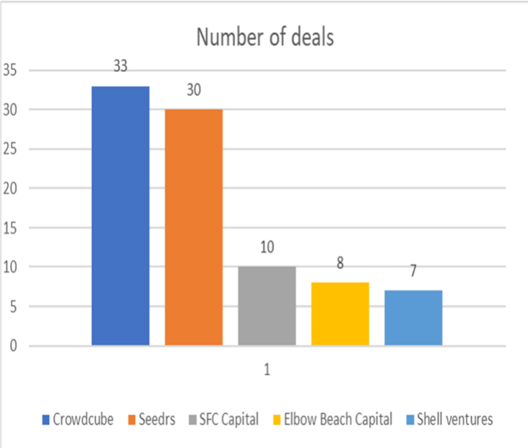
Recent ECF studies show that professional investors co-invest with the crowd and this improves the overall efficiency of the market (Wang et al, 2019). ECF can be used as a channel for market validation information (Stevenson et al, 2022). Another advantage is the nominee structure of the platform. It is the legal shareholder whereas investors are the beneficial shareholders. Thus, it monitors the venture and ensures that the corporate governance employed that protects investor rights. This has a positive effect on the long-term performance of a venture (Coakley et al, 2022). This along with the wisdom of the crowd distributes equally all benefits for stakeholders.

In summary equity crowdfunding may be the optimal choice for the AquaSPICE venture because it has the following advantages,

- Professional investor involvement that may offer coaching services
- Wider pool of investors that may result in higher capital
- Market validation information
- ECF platform nominee to deploy an efficient corporate governance that may positively affect AquaSPICE performance in the long-run

Specifically for the cleantech industry, Beauhurst (2022) identifies different types of investors for cleantech ventures in the UK. Two established equity crowdfunding platforms – Crowdcube and Seedrs – are leading the race in terms on number of investments. It is worth noting however, that professional investors account for half of the investment volume in equity crowdfunding (Zhang et al, 2018). In other words, ECF investments come from professional investors and ordinary people.

Figure 26: Number of deals in the UK cleantech industry (Source: Beauhurst 2023)



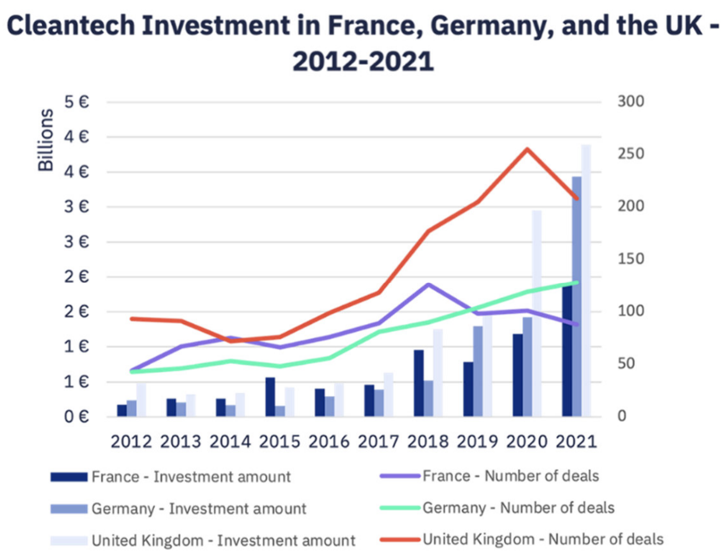
European cleantech investors. This section provides briefly information about european investors in the cleantech industry. Evidence suggests that most of them are located in Germany and France. This is further supported by investment volume in figure. Germany outperforms France in 2020 and 2021. Given that professional investors are more likely to finance ventures located nearby, AquaSPICE venture could be located in one of these EU states.

Table 14: EU investors in cleantech.

Name	Location	Name	Location
2150	Denmark	Planet A	Germany
Nordic Alpha Partners	Denmark	World fund	Germany
Alantra/Kilma	Spain	Eureka Fund I	Italy
Aster	France	Mito	Italy
Demeter IM	France	Inven capital	Czech Republic
Eirazeo Smart city	France	Kiko	Sweden
Beamline accelerator	Estonia	Verdane	Sweden
Capricorn partners	Belgium	Rockstart Energy	Netherlands
Energy impact partners europe	Germany	Rubio impact ventures	Netherlands
Matterwave ventures	Germany	Set Ventures	Netherlands
Munich venture partners	Germany	Xista science ventures	Austria

Source: cleantechforeurope.com

Figure 27: Cleantech investments in France and Germany, and the UK-2012-2021 (Source: cleantechforfrance.com)



In summary, an appropriate source of finance for AquaSPICE venture may be equity crowdfunding in which professional investors and ordinary people may invest in. Due to the presence of local bias, this venture could be located in a region where cleantech professional investors are concentrated. These may include France and Germany. Equity crowdfunding is more developed in Germany and on the rise for cleantech startups (Crowdfundinghub 2021). This possibly makes Germany the optimal choice for the location of AquaSPICE venture.

12. Conclusions and limitations

Conclusions.

This report conducts a multi-dimensional investigation for the upscaling potential of AquaSPICE. The first objsective is to analyze the market that AquaSPICE refers to. Results suggest that the water treatment market is already large and expected to grow in the future.

Then it proceeds at assessing the value proposition of Aquaspice; at a macro- (the water treatment market), as well as at micro-economic (early adopters, case studies) level. The main findings suggest that AquaSPICE has a robust value proposition that evolves around optimization and customization. The digital technology WaterCPS can be developed into a competitive advantage that would be relevant to the water treatment market. We conduct a deeper analysis at a water treatment technology/technology combination level and we conclude that some filtration technology combinations have the potential, with WaterCPS, to create value, from an economic point of view, to potential clients. We provide evidence that this will primarily come from water intake management, rather than from water waste management, primarily due to costs. We conclude that a cleantech startup focusing solely on WaterCPS could be a viable solution to start exploiting the Aquaspice results. However, we suggest that it can only reach its full potential by expanding horizontally on the supply chain offering a wider range of services.

Finally, we perform a specific market analysis for the potential new venture (cleantech startup), aiming at identifying a potential customer target group, as well as potential sources of financing. we argue that equity crowdfunding may be the appropriate source of finance since it may include investments from professional investors and people without investment experience. Regarding location, Germany seems to be the best option.

Highlights	
Business Model	Start with a software only venture: “WaterCPS only”
Upside potential	Option to expand into a “Bundling” service business model
Target clientele	Large companies in chemical and meat and food industry
Optimal Location	Germany
Optimal Financing type	Equity Crowdfunding

Limitations. Several limitations took place due to overall delays related to project progress and restrictions in data collection. The researchers encountered various challenges related to data collection during primary and secondary research process. Related to primary data collection, information was collected through qualitative questionnaires and workshops conducted within a period of 8 months. Due to several delays in the piloting phases within Case Studies, data that would be valuable for this study were not yet available, within the given time-framework for the finalisation of this deliverable. Another limitation was the proprietary nature of economic information related to financial expenditure that could justify spending costs occurred during piloting phases. As a result, this report could only make propositions based on projection costs and costs reported during the financial progress reports but not on actual figures.

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14. Appendix: Assessment Questionnaire and Business Analysis Framework

AquaSPICE Value Assessment Questior

AquaSPICE Business Model Framework