SaltGae
algae to treat saline wastewater

Demonstration project to prove the techno-economic feasibility of using algae to treat saline wastewater from the food industry

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WP 8 **Innovation Strategy**
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Glossary

The glossary of terms used in this deliverable can be found in the public document "SaltGae_Glossary.pdf" available at: http://saltgae.eu/downloads-public/

Abbreviations and Acronyms

Abbreviation / Acronym	Description
BOD	Oxygen Demand
COD	Chemical Oxygen Demand
EC	European Commission
ETV	Environmental Technology Verification
EU	European Union
HRAP	High Rate Algae Pond
F&B	Food and beverage
LCA	Life Cycle Assessment
MS	Member State
N	Nitrogen
P	Phosphorus
SMEs	Small and medium enterprises
SWOT	strengths, weaknesses, opportunities and threats
PAOs	polyphosphate accumulating organisms
RO	Reverse osmosis
TIS	Technology Innovation System
UF	Ultrafiltration
UWWT	Urban Wastewater Treatment
RED	Renewable Energy Directive
WWT	wastewater treatment

Table 1: Abbreviations and Acronyms

1. INTRODUCTION

Water is an essential resource for human life and environment, as well as source of potential economic development. Since water scarcity is a threat to human, water reuse strategies deserve major attention. Human activities are contributing to an increase of water pollution, posing a major challenge for water management across the European Union (EU). At this regard, several EU directives have been implemented, establishing among others a maximum level of pollutants allowed in wastewater discharged to natural water resources. The European standards on water quality were aimed not only at conserving the environment, but also at safeguarding people from contamination risks from poorly treated wastewater. Industries are generating big amounts of wastewater, therefore there is a need to treat the wastewater and recover nutrients prior to discharging to the environment.

Currently, several technologies exist for treatment of saline wastewater. An innovative membrane technology, membrane distillation, is capable of desalting highly saline water. It is used for desalination of water and treatment of industrial wastewaters. However, the obstacles to implement innovative wastewater treatments are numerous. First, the adoption decision regarding environmental technologies depends on a large number of determinants that are context-specific and interact mutually. Secondly, the costs and rewards of sustainable innovation are distributed unevenly across the involved actors and communities. Their deployment involves multiple and institutionally diverse stakeholders that express different interests, and may have conflicting objectives (EIP Water, 2014). This multifaceted landscape introduces significant challenges for those who aim at easing the dynamic efficiency of the sector. The adoption of new technologies in the water and wastewater industries is becoming a key issue in public debate and policy arenas (EC 2013; EIP Water, 2014).

This debate is particularly important on the food and beverage (F&B) industries due to the high content of salinity contained on the wastewater. The accumulation of salt Na+ in industrial effluents is considered as a new challenge for anaerobic wastewater treatment. The large content of biodegradable matter and high salt levels of this waste stream requires complex sequences of physicochemical and biological treatment processes to meet EU standards for the management and protection of the water environment. Associated costs for water treatment for the 15,000 European SMEs, which represents 5% of the total F&B industry, are estimated at €4.46 billion and can represent up to 14% of companies' annual turnover. This is often perceived as unaffordable and non-compliance presents environmental risks. Therefore, some SMEs discharge the wastewater without prior treatment, causing severe damage to the environment. Salinity can cause eutrophication of water, salination and sodification of the soil. The high costs of saline wastewater treatment are due to the secondary and tertiary treatments, which are carried out using different types of bacteria for organic matter decomposition and nitrifiers/denitrifiers for N elimination and polyphosphate accumulating organisms (PAOs) for P removal.

1.1 Proposition of new innovative technologies

The SaltGae project proposes the implementation of innovative technologies for each step of the wastewater treatment. These technologies will promote energy, resource efficiency, and reduce costs. Amongst these, the use of halotolerant algae-bacteria consortiums to eliminate organic matter and nutrients, as an effective and ecological solution for wastewater treatment. Also, it represents an innovative way of producing algal biomass. Algal biomass will be afterwards valorised into different by-products to reduce the economic and environmental impact of the treatment.

1.2 Objectives of the study

The aim of the study is to identify main barriers and obstacles for the introduction on the market of SaltGae technologies, in particular the application of algae for wastewater treatment for F&B industries. The purpose is focused on main research question: What are the main barriers and challenges for the implementation of innovative wastewater treatment using algae into market?

In this report, a Technological Innovation System (TIS) analysis is presented for the treatment of wastewater through the cultivation of algae for biomass valorisation by using High Rate Algal Ponds (HRAP) technologies and by recycling saline nutrient-rich wastewaters from F&B industry.

The study is organised as follow: the introduction of the SaltGae project, and motivation behind it. A second chapter follows explaining the TIS method which will be applied in order to analyse the status of the wastewater technologies. The third section offers a description of the TIS components in term of environment, technology, actors, networks and institutions, followed by a section on the functional patterns of the TIS. The fourth section is dedicated the functional analysis and the fifth to identifying barriers. In the final chapter, the results will be discussed.

2 METHODOLOGY

This section is dedicated to the methodological approach used to address our research question. The definition, according to the Carlsson and Stankiewicz (1991), the system is a group of components serving common purpose, working towards a common intention or overall function. The main components of an innovation systems are the actors, networks and institutions contributing to the overall function of developing, diffusing and utilizing new products and processes.

The concept of the innovation system stresses that the flow of technology and information among people, enterprises and institutions is key to an innovative process. It stresses the interaction between actors who are needed in order to turn an idea into a successful process, product or service in the marketplace. An innovation system is primarily an analytical construct, i.e. a tool used to be better illustrate and understand systems dynamics and performance.

The innovation systems may be emerging with very weak interface between components. Besides, interaction between components may be unplanned and intentional in a more developed innovation system. A number of different innovation system concepts have been put forward in the literature. The main components of an innovation systems are the actors, networks and intuitions contributing to the overall function of developing, diffusing and utilising new products and processes.

The concept of the innovation system emphasizes that the flow of technology and information among people, enterprises and institutions is key to an innovative process. It underlines the interaction between actors who are needed to turn an idea on pilot scale into a successful process and product in the marketplace. An innovation system is primarily an analytical construct, a tool used to better understand systems dynamics and performance.

2.1 TIS analysis

TIS is a systematic methodology used mostly by policy makers for analysing technological innovations and developing policies. TIS examines how the structure surrounding a technological innovation is currently functioning. The methodology was applied within the SaltGae project to analyse deployment of algae for wastewater treatment purposes in EU. The TIS contain components dedicated to the technology in focus, but also all components that influence the innovation process for that technology.

2.1.1 The Scheme of Analysis

The scheme shows a description of the number of steps that need to be taken by the analysis. There are six steps, illustrated in Figure 1, that will be discussed sequentially. The first step involves setting the starting point for the analysis, i.e. defining the technological innovation system in focus. In the second step is to identify the structural components of the TIS (technologies, actors, networks and institutions). In the third step, we move from structure to functions. With an analysis of functions, we first desire to describe what is actually going on in the TIS in terms of the seven key processes, and then a description of how each function is currently filled in the system will be explained. The fourth step is to assess how well the functions are fulfilled and set process goals in terms of a "desired" functional pattern. In the fifth step, we identify mechanisms that either induce or block a development towards the desirable functional pattern. We can then specify key policy issues related to these inducements and blocking mechanisms, and this is the sixth and final step.

The scheme of analysis is illustrated below in Figure 1.

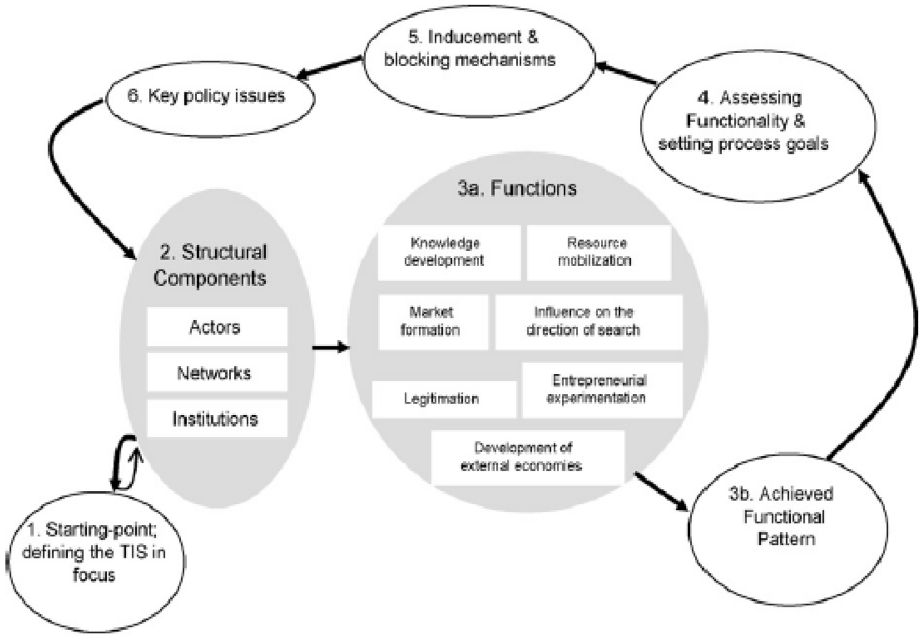


Figure 1: The scheme of analysis (adapted from Oltander and Perez Vico, 2005)

2.1.2 The core of the Analysis

The core steps of TIS analysis consists in the following:

- **Structure analysis**. The analysis of the environment surrounding SaltGae market structure will be elaborated at European level. This analysis includes the technology specification, key players' identification and drivers influencing the technology development. The structure analysis focuses on:
  - a) *Technology*: it includes the infrastructures identification and analysis, technical specification, economic competitiveness and scale up potentials.
  - b) *Actors:* list of relevant technology providers, industrial organisation, public bodies, intermediaries and other market actors playing along the value chain.

c) *Networks*: overview on national and international associations, projects, initiatives, technology platforms supporting the development, focusing on their role, mission and activities.

d) *Institution*: identification of policies, legislation, strategies, culture/legitimacy framework.

- **Functional analysis.** It focuses on the identification of the main barriers influencing the development, responsible of the present market status of the SaltGae technology. The analysis is articulated in 8 functions:
  1) Market formation; 2) Legitimation 3) Knowledge development 4) Knowledge exchange 5) Resource Mobilization 6) Influence of the direction of the search 7) Entrepreneurial experimentation and production 8) Development of external economies.

2.2 Data Collection

Main pathways for the data collection were interviews, questionnaires and information events such as conferences and workshops. The framework presented in this study is based on previous literature. The aim of the questionnaire is to analyse the structure of the innovation system and key processes that influence the development and diffusion of new technologies in EU. This questionnaire was addressed to research institutions, service and major national agencies, regulatory bodies, service providers within the water sector and algae production in EU.
Firstly, the questionnaire was sent to 16 Italian organisations since Italy was taken as a case study. The results were poor (only 2 replies) with few available information on the market, reason for which we needed to expand the research at EU level. The questionnaire was sent to 72 experts at international level, however, 9 replies were received. Initially. This creates a responsive percentage of 12,5%.

3 STRUCTURAL COMPONENTS OF TIS

This chapter offers an overview of the main structural components of the TIS objective of our study. The chapter starts with a definition of the System to be analysed (Saltgae environment) regarding wastewater and algae species, and conventional treatment of wastewater, followed by description of innovative technology treatment for high saline wastewater. It carries on with a report of main actors, networks and institutions.

3.1 System definition. SaltGae environment

3.1.1 Characterization of the waste water

Wastewater are characterised in terms of its physical, chemical and biological composition. Physical parameters include Total Solids, Total Suspended Solids, Total Dissolved Solids, Turbidity, Conductivity, Color etc. Common chemical parameters include Total Organic Carbon, Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Total Nitrogen, Total Phosphorus, Total Kjedlhahl Nitrogen, pH, Alkalinity, Oil and Grease, as well as analysis of specific ions. Finally, biological characteristics comprise number of Coliform organisms, specific bacteria, toxicity etc.

High salinity wastewaters are characterised by high concentrations of inorganic salts, mostly NaCl, and are generated in various kind of industries. Some high salinity wastewaters are also discharged from drinking water treatment plants, i.e. concentrates from reverse osmosis (RO) processes or from ion-exchange units (Alameddine and El-Fadel, 2007). Wastewaters are classified in the high salinity range based on the Na^+ concentration (Madigan et al., 2000): highly saline >7.9 g Na^+ /L, hyper saline 15.8 – 47.2 g Na^+ /L, extreme saline >47.2 g Na^+ /L.

3.1.2 Conventional wastewater treatment

The treatment of wastewater in industrial plants takes place in four different stages:

1. Preliminary treatment: removal of the large suspended particles, typically using bar racks.
2. Primary treatment: removal of the remaining suspended solids, mainly small sized insoluble organic particles removed by settling.
3. Secondary treatment: removal of dissolved organic matter, typically by biological, bacterial processes. Organic matter content is generally measured by two parameters named Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD), which represent the amount of oxygen needed to biologically or chemically break down the organic matter present in a given water sample. In order to comply with EU quality standards, the BOD and COD reductions after the secondary treatment need to have maximum allowed concentrations of 25 and 125 mg/L O2, respectively.
4. Tertiary treatment: improve of the final water effluent quality by removing dissolved pollutants/nutrients (mainly inorganic matter, e.g. salt), remaining organic matter and pathogenic microorganisms.

3.1.3 Algae species and uses

In the SaltGae project we are working with the following algae species: Spirulina, Dunaliella, Tetraselmis, and Nannochloropsis suitable for different geographic locations, seasons, salinity levels (10 g/L to 60g/L) and wastewater compositions.

Dunaliella is the unicellular microalga and one of the best studied organisms for its higher tolerance to extreme conditions of salinity, light, temperature and pH, as well as for its richness in natural carotenoids, glycerol, lipids and many other bioactive compounds. Dunaliella salina is reported as the most halotolerant photosynthetic eukaryote with a remarkable degree of tolerance from 0.5 to 5 M salt concentrations.

Spirulina is a blue-green algae used as a nutritional supplement, which are microscopic freshwater organisms. It occurs naturally in warm, alkaline, salty, brackish lakes, but are also commonly grown by aquaculture and harvested for commercial use. Spirulina contains many nutrients, including B vitamins, beta-carotene, gamma-linolenic acid, iron, calcium, magnesium, manganese, potassium, selenium, zinc, bioflavonoids, and 65%. These proteins are complete, in that they contain all essential amino acids, plus some nonessential ones.

Tetraselmis comprises an assemblage of photosynthetic organisms that live in water, but also inhabit the surrounding land surface that are washed into the aquatic environment. The genus Tetraselmis is unique among the green algae in its cell wall formation. The cell body of Tetraselmis is covered by a solid cell wall, which is formed by extracellular fusion of scales. Certain specific bacteria are habitually associated with Tetraselmis cultures and are highly adapted for degradation and utilisation of extracellular carbohydrates including cast off cell wall and organic exudates. Several Tetraselmis species are economically important because of their nutritional value and ease of culture. Based on the production of various bioactive compounds, Tetraselmis has enormous potential as a source of functional foods.

Nannochloropsis is a genus of algae mostly been known from the marine environment but also occur in fresh and brackish water. All of the species are small, nonmotile spheres which do not express any distinct morphological feature. The algae of the genus Nannochloropsis differ from other related microalgae in that they have chlorophyll A and completely lacks of chlorophyll B and chlorophyll C. In addition, they are able to build up a high concentrations of a range of pigments such as astaxanthin, zeaxanthin and canthaxanthin. Nannochloropsis is considered a promising algae for industrial applications because of its ability to accumulate high levels of polyunsaturated fatty acids. Nannochloropsis is actually in use as food additive for human nutrition.

3.2 Technology

3.2.1 New technologies for saline wastewater treatment

Technological innovations are vital to achieving true sustainability of our water supply. In the following section, the innovative WWT of the SaltGae project is described:

1. Primary treatment and pre-treatment:

a) Primary treatment achieving up to 90% removal of suspended solids (>0.15 mm) with costs < €4.4 m3 of WW ensuring < 10% variation in salinity.

b) Innovative anaerobic digestion process for the pre-treatment of high BOD content saline WW (operating at 40 g/L salinity) achieving a reduction of BOD content (< 500 mg/L of BOD) producing methane for energy (800 KWh/tonne of BOD), heat for utilisation in the SaltGae system and CO2 for use in the High Rate Algal Ponds (HRAP) with capital cost <€550/year/tonne of BOD.

c) Anaerobic digestion of saline sludge (operating at 40 g/L salinity) producing methane for energy (700 KWh/tonne of BOD), heat for utilisation in the SaltGae system and CO_2 for use in the HRAP with capital cost < €500/year/tonne of BOD.

2. Secondary and tertiary treatments consisting on:

a) Development of innovative halotolerant algae and bacteria consortia for the effective removal of organic matter and nutrients from saline wastewaters, (BOD, P and N removals > 90%).

b) HRAPs with innovative designs and materials (e.g. pond design and depth, insulating covers, etc.) so as to optimize cost (< €100/m2) and treatment efficiency (BOD reduction > 20 g/m2/day) for algae cultivation (15 g/m2/day).

c) Sensorisation, monitoring and control strategies for the management of the HRAP different working conditions (e.g. seasons, culture development, etc.).

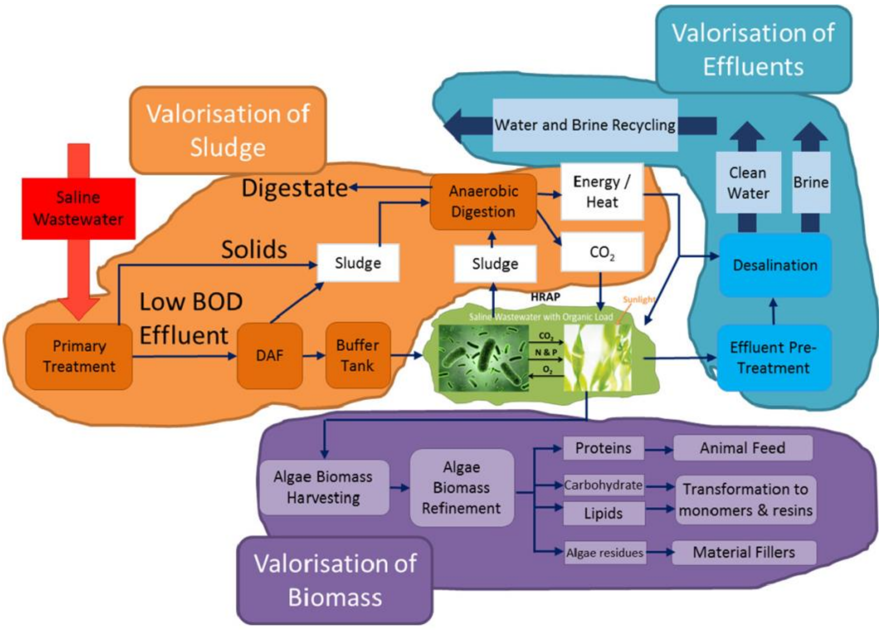


Figure 2: High BOD configuration (>500 mg O_2/L)

3. Valorisation of HRAP effluents via desalination aimed to obtain <500 ppm salinity and comprising:

a) A new preliminary treatment to prevent fouling of the membranes characterised by an overall removal of foulants above 99% (mass basis).

b) Electrodialysis process to achieve low conductivities (1-2 mS/cm) to obtain safe water to be reused in the process or released into the environment and to demineralise with sufficient yields (min. 50%) to be considered a viable industrial installation.

c) Reverse Osmosis equipped with a new energy efficient pumping system (efficiency > 95%) and Energy Recovery Device (98% energy recovery) to decrease the energy demand due to pumps for such desalting technology.

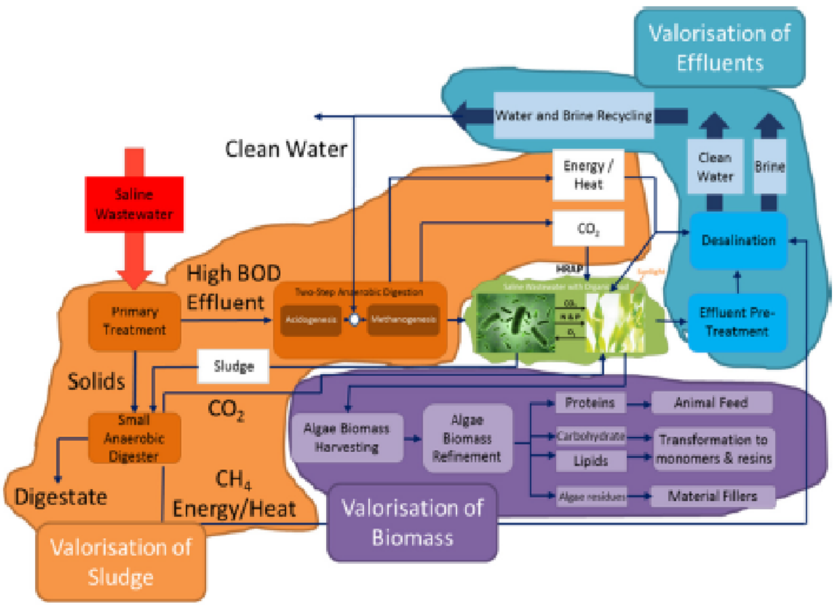


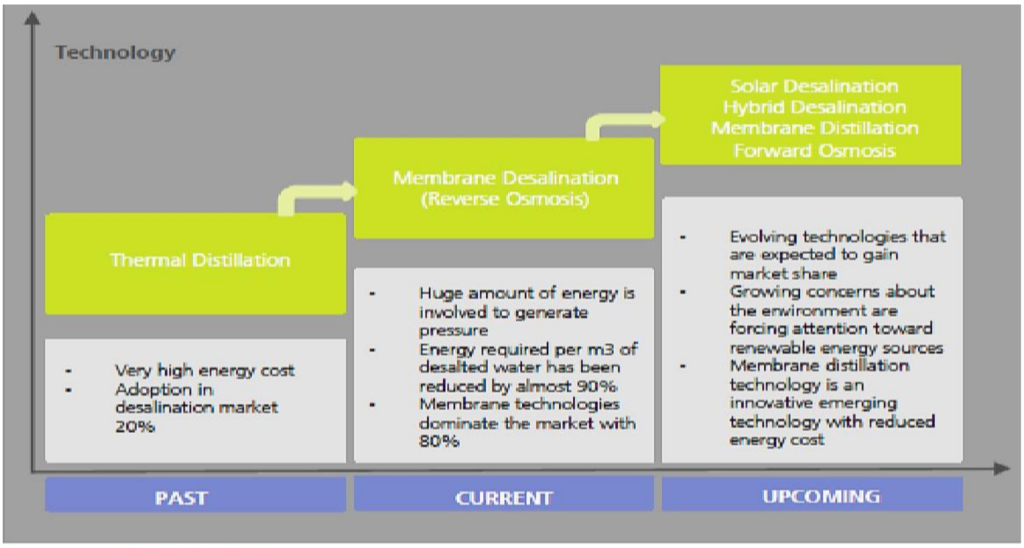
Figure 3: Low BOD configuration (<500mg O_2/L)

Implementation of DEMO scale

These technologies will be implemented at DEMO scale in three different sites in order to operate and validate them under real environment conditions and scale. Archimede Ricerche (Camporosso, Italy) uses their existing high-performance ponds to treat water from the milk industry, KOTO and Algen (Ljubljana, Slovenia) use existing pond, built within the AlgaeBioGas project, to treat the water from warehouse (representative of tannery wastewater), and Arava (Israel) will use water from the fish farming to grow Spirulina. Processes in each of these sites are as diverse as they will be in the real industrial sites.

3.2.2 Alternative technologies of saline wastewater treatment

In this section are profiled the existing technological assets in the Europe that are associated to the scoped technology. In Europe, most wastewater treatment follows the same initial path. Membrane filtration has been developed and installed in the last decade, providing new and compact designs for wastewater treatment plants. Biological treatment of saline wastewater has not been easy and by far the most popular treatment method. Salt removal operations by physico-chemical processes such as reverse osmosis, ion exchange or electrodialysis before biological treatment are rather expensive. Lately, a new generation of membrane units have been developed working with low negative pressure and membrane aeration to reduce fouling. These are based on the immersed filtration system and are less costly to install and operate than the previous technology. The figure 4 is adopted from Fraunhofer MOEZ report from 2015 and described evolution of desalination technologies in Europe.



Source: Based on EBTC 2012

Figure 4: Evolution of desalination technologies

Hybrid growth system

A hybrid system consists of fluidized bed positioned in a biological reactor of an activated sludge process and it is used to treat saline wastewater. The removal performances of COD, BOD5, NH_4^+ of hybrid system is noticeably better than the conventional system. The advantages are that the hybrid system does not need to return sludge, due to its approximately constant concentration of mixed liquor suspended solids. Moreover, dissolved oxygen concentration of the hybrid system was observed relatively higher, in comparison with the conventional system. These features improve economic indices in wastewater treatment plants concerning the costs required for aeration and sludge return facilities (Salmanikhas, 2016).

Reverse osmosis
In the reverse osmosis process, water from a pressurized saline solution is separated from the dissolved salts by flowing through a water-permeable membrane. The permeate is encouraged to flow through the membrane by the pressure differential created between the pressurized feed water and the product water, which is at near-atmospheric pressure. The remaining feed water continues through the pressurized side of the reactor as brine. No heating or phase change takes place. The major energy requirement is for the initial pressurization of the feed water. The use of reverse osmosis technologies in industries is not widespread due to economically unattractiveness, limited application and complexity. The desalination techniques are energy-intensive relative to conventional ones. The development to improve this process is in progress and plans to overcome main challenges, such as membranes that are less prone to fouling, operate at lower pressures, and require less pre-treatment of the feed water. The development of more energy-efficient technologies and simpler to operate than the existing ones is a key target.

Ultrafiltration (UF)
UF is a current state-of-the-art water and wastewater filtration technology which as a low pressure driven membrane is extremely effective, with the added benefit of low energy consumption. The role of the UF membrane system is increasing both in the water and wastewater treatment sectors, as well as in industrial process separation. Some of the key applications for UF membrane systems are used in drinking water treatment, the pre-treatment process in desalination, and membrane bioreactors.

Microbial saline-wastewater electrolysis
A new type of ion exchange membrane-based bioelectrochemical system, called a microbial saline-wastewater electrolysis cell, is proposed for simultaneous removal of organic matter and salt ions from saline wastewater. The electric field created by the exoelectrogens is used to remove salt ions from the saline wastewater. This allows for simultaneous wastewater treatment and salt removal in a process that can generate net energy. Wastewater desalination is accomplished by placing a cation-exchange membrane next to the anode, and an anion-exchange next to the cathode. The key to successful treatment and salinity removal in this system is good performance of the microbial communities at different wastewater salinities. Exoelectrogens were found to be versatile at salinities as high as those of typical seawater (Kim and Logan, 2013).

Salt-tolerant halophilic organisms
Salt-tolerant halophilic organisms may be used singly or in activated sludge culture for effective biological treatment of the saline wastewater. Salt tolerant microbes can adapt to these saline conditions and degrade the organics in saline wastewater. It is suggested the possibility of successful application of identified salt tolerant bacterial consortia for efficient degradation of saline wastewater. Such application would compare well with other conventional biological treatment processes being used with activated sludge as a working culture.

3.2.3 HRAP with municipal wastewater

Wastewater treatment high rate algal ponds are a promising technology that could help solve growing energy demand and water consumption. HRAP has great potential for by-products of WWT, since the costs of algal cultivation and harvest for production are covered by the wastewater treatment function. Generally, 800–1400 GJ/ha/year energy can be produced in the form of harvestable biomass from WWT HRAP which can be used to provide, for example community-level energy supply (Mehrabadi et al., 2015). Figure 5 identify internal strengths and weaknesses of HRAP, as well as its external opportunities and threats in Europe.

Strengths

- **HRAP has lower construction and operating costs than activated sludge systems.**
- HRAP can be integrated with active sludge technologies or replace them.
- Capital costs decrease by increasing scales[1].
- **Extremophile algal strains reduces contamination by nutrient competitors and algae predators.**
- **Use of polar algal strains could improve algal productivity.**

Weaknesses

- **The technology has not been demonstrated in NW Europe (only in New Zealand that has similar climate to the UK)**
- HRAP have a larger land footprint than activated sludge systems.
- Algae will be contaminated by bacteria so it may need purification that adds an extra cost.
- **Cost of land is substantial for investing in countries like Luxembourg, Netherlands, Belgium, and Switzerland.**

Opportunities

- Algae from HRAP can be used for production of fertiliser, soil amendment, platform and fine chemicals, and fuels.
- **Inland aquaculture ponds are very popular spread all over NW Europe.**
- **Municipal wastewater prices is negative.**
- Export of biotechnology knowledge to other countries with warmer climates and higher available surface area for energetic algae cultivation[2].
- **Investments towards projects upscaling PBR technologies for other market products e.g. food/feed, will benefit energetic algae cultivation projects via technology transfer.**

Threats

- **Alternative biofuel production technologies are more cost effective than energetic algae and as such more attractive for investors[1].**
- Sewage tertiary treatment step may still be needed downstream.
- Depending on the end market, purification of products from contaminants may add an additional cost.

Figure 5: SWOT of available HRAPs in Europe

3.2.4 Natural and other material resources

In regard to its environmental performance, the technology for algae cultivation does not compete directly with food crops. The Figure 6 shows statistics of yield potential of algal biomass in the top 10 EU countries and area. Algae take up CO_2 as a carbon source during photosynthesis, and use also N and P nutrients that are often found in excess in wastewater streams. Algae are capable of substituting CO_2 and purifying nutrient-rich waste streams.

The technology setup that is studied here combines growing algal biomass in a HRAP that is constantly supplied with F&B industrial wastewater. This technology setup sources mean that the technology must be co-located and form an industrial symbiosis with wastewater producers. Possible industries that are producing saline nutrient-rich industrial wastewater streams that could be used for algae production are sectors such as: canned fish, vegetables, meats and fish processing, olive mills, leather tanning, aquaculture and dairy processing. A wide range of F&B industries would benefit from the capability to treat industrial wastewater (meat and poultry, food and dairy, biotechnology, metal finishing, catfish farms, chicken farms, pulp and paper, dyes and pigments, distillery and breweries, starch and cellulose, pesticides and insecticides).

The Figure 6 from Skarka (2012) shows statistics about algal biomass yield potential of the top 10 EU countries and area.

	*Available areas considering restrictions to**			*Yield potential*	
Country	*LU km²*	*LU + Slope km²*	*LU + Slope + PA km²*	*Mean yield** t ha⁻¹ a⁻¹*	*Potential kt a⁻¹****
Spain	11,284	3,182	2,679	126	33,867
Sweden	10,524	3,568	2,263	22	3,092
Italy	8,583	373	255	102	2,438
Portugal	1,240	288	185	109	2,016
United Kingdom	4,002	747	386	35	1,352
France	8,408	322	145	88	1,268
Greece	1,991	158	127	104	1,203
Cyprus	141	84	75	149	1,109
Ireland	340	116	99	60	587
Germany	495	201	97	60	581
EU-27	54,926	10,136	6,655	78	49,171

* = LU: land use, PA: protected areas
** = mean yield calculated for available areas only
*** = kilotons per year

Figure 6: Algae biomass yield potential of the top 10 EU countries and area statistics

3.3 Actors, Networks and Institutions

With the focus on the TIS, the next step is to identify and analyse the structural components of the system. The structural components are divided into three main groups: actors, networks and institutions.

3.3.1 Actors

The following paragraph provides list of the important actors potentially influencing the development of the new WWT technologies, desalination treatment of wastewater from F&B industries, stakeholders in algae/biotech/bioenergy sectors, institutions that regulate policies relevant to WWT, algae cultivation and algae products, and actors interfering between government, industry and developers.

For this reason, we identify a value chain of the SaltGae project (Figure 7: Value chain). The value chain is defined in a business context as: "the interrelated operating activities businesses perform during the process of converting raw materials into finished products”. The value chain of algae depends on composition, application, formulation, and on production scale (small, medium, large and very large).

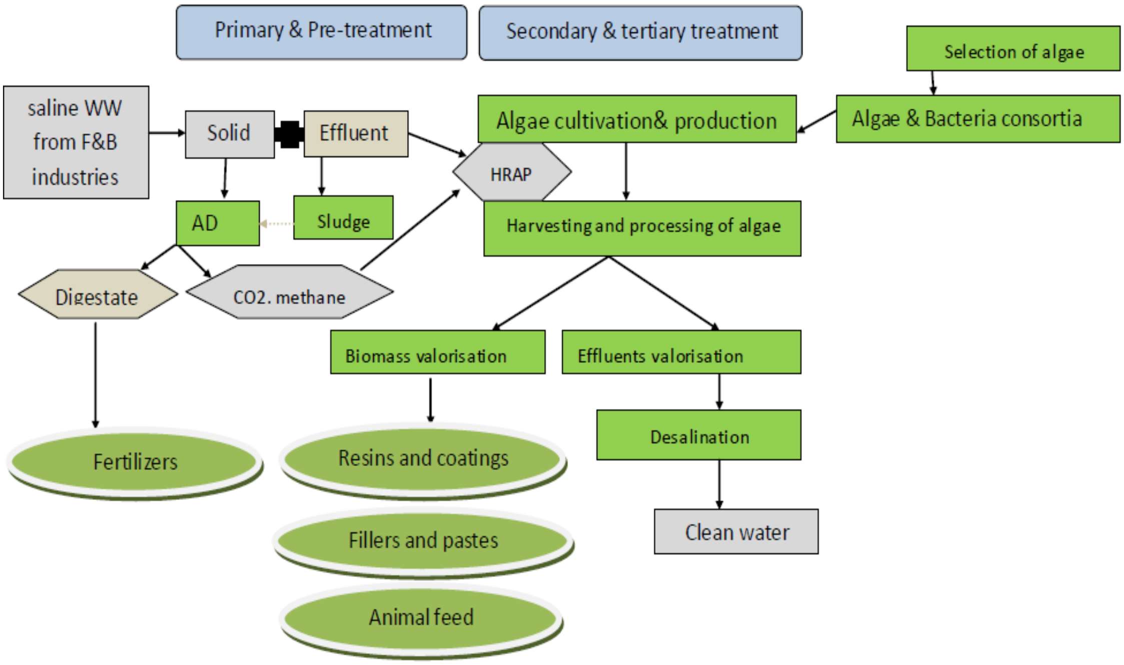


Figure 7: Value Chain of the SaltGae project

First of all, we need to include all actors involved in the SaltGae project (see table below).

Table 2: The SaltGae project members

Project Member	*Abbreviation*	*Country*
Tecnologias Avanzadas Inspiralia Sl	INSPIRALIA	Spain
Biboaqua Sl	BIBOAQUA SL	Spain
Archimede Ricerche Srl	ARCHIMEDE	Italy
Algen, Center Za Algne Tehnologije, Doo	ALGEN	Slovenia
Koto Proizvodno in Rgovsko Podjetje Doo	KOTO DOO	Slovenia
Arava Building And Development Ltd	Arava Building	Israel
Dublin City University	DCU	Ireland
Fondazione Parco Tecnologico Padano	FPTP	Italy
Oxidine Water Technology Sl	OXIDINE Spain	Spain
Nova Id Fct - Associacao Para A Inovacao Edesenvolvimento Da Fct	NOVA ID	Portugal
Produmix Sa	Produmix	Spain
Centre De Valorisation Des Glucides Et Produits Naturels	CVG	France
Consorzio Interuniversitario Nazionale Per La Scienza E Tecnologia Dei Materiali	INSTM	Italy
Instituto De Biologia Experimental E Tecnologica	IBET	Portugal

European Biomass Industry Association	EUBIA	Belgium
Enco Srl	ENCO SRL	Italy
Asociacion Cluster Food+I	CF+I	Spain
European Desalination Society	EDS	Italy
Sp Sveriges Tekniska Forskningsinstitut	SP	Sweden

In EU, WWT is divided between private and public sector providers. The EU is home to the top utilities in the global water and wastewater treatment industry. These companies include Suez, Veolia, SAUR, AGBAR and RWE. These largest utilities are both the leading technology suppliers and users of such technologies. The EU WW market is a mature market where Germany is the largest exporter of water and sewage treatment technologies. Germany is investing in domestic production of sewage systems and also becoming an exporter of sewage centred technologies. The next four largest intra-EU exporters are Belgium, Netherlands, France and Italy, as it shown below.

Table 3: Technology supplier in EU

Technology suppliers	***Country***
Veolia	France
Degrémont	France
Keppel Seghers Belgium NV	Belgium
OSMO Membrane Systems	Germany
Novasep France	France
Membran-Filtrations-Technik	Germany
Membranteknikk AS Norway	Norway

Companies for desalination and wastewater treatment from F&B industry in EU

According to the Environmental XPRT, a global environmental industry marketplace and information resource (www.environmental-expert.com), there are 97 WWT companies using streams from the F&B industry in Europe. These companies differ on business types, such as Manufacturer, Distributor, Engineering service provider, Technology, Consulting firm, Service provider, Software vendor, Laboratory and Market research company. 70 companies are engaged in innovative water treatment. However, companies accountable for desalination wastewater treatment in F&B industries in Europe, it was found 20 manufactures, 8 distributors, 2 service providers, 5 technologies companies and one engineering services provider. The names and location of the companies are listed below.

Table 4: Companies for desalination and wastewater treatment from the F&B industry in EU

Manufactures	***Country***
Fluence	Padova, Italy
ProMinent	Heidelberg, Germany
Kurita	Viersen, Germany
Lenntech	Delft, Netherlands
Azud	Alcantarilla, Spain
IDRAFLOT	Zoppola, Italy
AppliTek NV	Nazareth, Belgium
Landustrie	Sneek, Netherlands
Cosun Biobased Products	Breda, Netherlands
NOY	United Kingdom
Enki Water treatment technologies	Basaksehir, Turkey
Amazon Filters	Camberley, United Kingdom
ALLWEILER	Radolfzell, Germany
DESMI	Noerresundby, Denmark
MICRODYN NADIR	Wiesbaden, Germany
GEA Filtration	Ettlingen, Germany
Gebrüder Heyl Analysetechnik	Hildesheim, Germany
Interagua	Figueira da Foz, Portugal
Modern Water	Cambridge, United Kingdom
Myron L Company	Ireland
Evodos	Raamsdonksveer, Netherlands
PALL Manufacturing	Portsmouth, UK
Isap Packaging S.p.A	Verona, Italy

Distributors	***Country***
Esmil Process Systems	High Wycombe, United Kingdom
S.K. Euromarket	Lemesos, Cyprus
ECM ECO Monitoring	Bratislava, Slovakia
Quantitech	Milton Keynes, United Kingdom
Ankersmid Process - Ankersmid Group	Netherlands
Camlab Limited	Over, United Kingdom
Keison International	Essex, United Kingdom
Envco The Environmental Collective	Romania

Service providers	***Country***
Işık Teknolojik Tesisat Sistemleri Ticaret A.Ş.	Atasehir, Turkey
ACWA Services Ltd	Skipton, United Kingdom
Technologies	
Clayton iwt	Penistone, UK
Hydroitalia Colsin Srl	Medicina, Italy
SEUZ Advanced solutions UK	Bristol, UK
Nijhuis Industries	Doetinchem, Netherlands
AWT Technologies Inc. - BIOWORKS group of companies	Netherlands
Engineering service providers	
Desarrollos Ecológicos Industriales S.A.	Hospitalet de Llobregat, Spain

Table 5: Companies working on desalination of wastewater treatment in Europe

Manufacturers	***Country***
LG Sonic	Zoetermeer, Netherlands
Chelsea Technologies Group	West Molesey, UK
MicroLAN B.V.	Waalwijk, Netherlands
Hexa- Cover	Thisted, Denmark
Enexio water technologies GMBH	Huerth, Germany
OTT Hydromet Group	Kempten, Germany
Genesys International Limited	Middlewich, UK
Flottweg SE	Vilsbiburg, Germany
Atlas Seis - Sistemas de Energia para a Industria e Serviços, Lda	S.Domingos de Rana, Portugal
Industrie De Nora S.p.A., De Nora Water Technologies	Milan, Italy
Euratec GmbH	Breddorf, Germany
Stevens Water Monitoring Systems	Bonn, Germany
Biofuture	Dublin, Ireland
FLSmidth	Neusiedl am See, Austria
Modern Water- Monitiring Division	Cambridge, UK
Cleveland Biotech LTD.	Stockton on Tees, UK
SEBA Hydrometrie GmbH & Co. KG	Kaufbeuren, Germany
ENDURAMAXX	Baston, UK
Engineering services	
SWECO	De Bilt, Netherlands
Service provider	
Avista Technologies	Vilanova i La Geltru, SPAIN
Distributors	
Camlab Limited	Over,UK

Market

Algae cultivation in combination of wastewater treatment utilities plays a double functionality as a nutrient media and a waste bioremediation. In addition to the bioremediation value of this technology, cultivated algae product could be valorised and sold to the following markets: transport fuels and energy, chemicals and materials, food and feed, fertilizers, pharmacy and personal care.

Valorisation of biomass

Compared to conventional wastewater treatment, algal-bacterial treatment produces significantly more biomass. Some organisations work on exploitation of such algal biomass, for example: Produmix (Logroño, Spain) is working on using algal biomass as feed ingredient for piglets, Extractis (Dury, France) is working on extraction of high value products, such as beta carotene, Inspiralia (Madrid, Spain) is working on using fractions of algal biomass for coatings and adhesives and algal lipids and protein as components of edible food (fruit) coatings and finally Politecnico Milano (Italy) is using algal biomass as high value fillers or constituents in biocomposites used in 3D printing.

In this project, a number of bio-products will be produced from algal biomass. The biomass will be used as feed for aquaculture, as fertilizers, material fillers and pastes, as resins and edible coatings.

Fertilizers
The development of slow-releasing and environmentally friendly fertilisers based on algae holds significant promise. For example, the nitrogen-fixing algae (like Spirulina) have a long history of use in rice paddy fields. Several producers of algae fertilizers and biostimulants have been identified, e.g. in Spain (Agroplasma S.A. and AlgaEnergy S.A.), Turkey (Mct Tarim), USA (AgroValley Inc.) and India (Soley Biotech).

Bioplastics
Alternatively, algae ingredients can be used as a raw material for the production of bioplastics. Consumer's demand for sustainable packaging, restrictions on landfilling, climate change policies, and changing raw material prices are all driving the market of bioplastics. Today, more and more applications for durable bioplastics are brought to the market, relying on innovation efforts by companies like BASF, DSM, Seaweedm Cereplast and Braskem, which have resulted in the development of high performance bioplastics.

Feed
The use of algae as aquaculture feed is a well-established application. It is estimated that about 30% of the current world algal production is sold for animal feed applications, primarily for aquaculture such as Chlorella, Spirulina, Scenedesmus, Dunaliella. The replacement of soybean meal in compound feed production is a potentially large market for algae. The price of algae is determined by the level of the soybean meal price (Table 6).

Table 6: Animal feed producers

Current Algae Products on market	***Producers***	***Country***
Spirulina	Blue Biotech	Germany
Spirulina	Ocean Nutrition	Canada
Chlorella	Blue Biotech	Germany
Chlorella	Necton	Portugal
Astaxanthin	Blue Biotech	Germany
Astaxanthin	BioReal	Sweden
Biomass for aquaculture	Blue Biotech	Germany
Biomass for aquaculture	Necton	Portugal
Algae paste	Innovative Aqua	Canada
Dunaliella salina	Monzon Biotech	Spain

3.3.2 Networks

The following section lists the official algae networks in EU together with their focal point, some research projects for algae, and the EU relevant public-private partnerships (PPPs) that cover algae cultivation and water and wastewater treatment in EU.

The European Innovation Partnership on Water's online marketplace fosters the collaborations and effective networks needed by providing a 'match-making' tool that gives stakeholders from every aspect of the water sector the opportunity to share ideas and make useful contacts and inform about the latest innovations on the sector.

The EU Water Policy Working group offers an overview of main European water policies and related initiatives, as well as a dialogue between major stakeholders in order to identify main challenges of the EU Water sector and ways of improvement.

European network for algal-bioproducts (EUALGAE) is a Science and Technology Network financed by the European COST programme. It is created to stimulate interaction among research groups across Europe, to foster cooperation between academia and industry for utilization of algal biomass for sustainable fuels and fine chemical products.

ALGAEADRIA (Italy, Croatia, Montenegro and Albania) cooperates between institutions, research centres in the marine biotoxins of the Adriatic Sea by utilisation of algae for WWT.

Global Water Initiative (GWI) promotes good wastewater management practices and works towards having wastewater viewed as a potentially valuable resource instead of as a waste product. The GWI platform comprised of UN agencies, international organizations, governments, scientists, private sectors and major groups and stakeholders to provide the foundations for partnerships to initiate effective and sustained programmes addressing wastewater management.

The European Water Association (EWA) deals with the management and improvement of the water environment. It is one of the major professional associations in Europe that covers the whole water sector. EWA consists of about 23 European national associations. EWA thus represents about 55,000 professional individuals working in the broad field of water management.

International Water Association (IWA) develops research and projects focused on solutions for water and wastewater management, organises events about the latest science, technology and best practice to the water sector; works to place water on the global political agenda and to influence best practice in regulation and policy making.

European Water Trade Association (EWTA) provides a contact for the European Point-of-Entry (POE) or Point-of-Use (POU) water treatment industry to recognise and act upon the opportunities for promotion of the POU/POE through websites, press coverage, conferences, government lobbying, etc. It also presents potential challenges in the form of legislation, standardisation, product certification, media publicity.

Table 7: Algae specific networks

Algae specific networks	*Location*
Algal Information Network (AIN)	http://www.algae-network.eu/
European network for algal-bioproducts (EUALGAE)	http://eualgae.eu/
Sociedad Española de Ficología (SEF)	Spain
Federation Spiruliniers de France	France
Forum Italiano sulle Tecnologie Microalgali	Palermo, Italy

Table 8: EU & International associations and lobbying organization

EU & International associations and lobbying organization	*Location*
ANOVA	Napoli, Italy
Cluster Bayern	Augsburg, Germany
Prana Sustainable Water	Gland, Switzerland
Norwegian Water	Hamar, Norway
Marine Biological Association	Plymouth, UK
The Czech Water Association	Brno, Czech Republic
Constructed Wetland Association	Rugeley, United Kingdom
Danish Water and Wastewater Association	Skanderborg, Denmark
SWIG	London, United Kingdom
Italian National Agency for New Technology, Energy and Sustaina Economic Development	Rome, Italy
European Biogas Association	Brussels, Belgium.
Optima Renovables S.L	Terrassa, Spain

European Algae Biomass Association	Italy
European Biofuels Board	Belgium
European Environmental Board	Belgium
International Energy Agency	France
International Renewable Energy Association	Dubai
European Energy Research Alliance	Belgium
European Biomass Research Network	Belgium
European Desalination Association	Italy
Bio-based Industries Consortium	Belgium

Algae support initiative – European projects applying algae for WWT

- The AQUAFUELS project aimed to product of algae biomass for the creation of biofuels with European Union funding. Following this project, EABA, the European Algae Biomass Association was created
- Salinalgue project: designing a sustainable production system of biofuel and by-products from microalgae.
- InteSusAl, British project by the Centre for Process Information, showed the possibility to obtain biofuels from algae in a sustainable way.
- All-Gas, by Aqualia, Spain, which objective was to demonstrate the possibility of use of municipal wastewater for the production of bio-fuels based on low-cost microalgae cultures.
- Sustainable Polymers from Algae Sugars and Hydrocarbons (SPLASH) worked on optimization of biomass production to develop products from microalgae.
- Partner: iBET An Integrated Membrane Process for Oily Wastewater Treatment, Water Reuse and Valuable By-Products Recovery.
- ALBAQUA (Combined ALgal and Bacterial wastewater treatment for high environmental QUAlity effluents), the potential of algae for the paper industry and related industrial sectors was investigated – subcontractor to Institute of Pulp & Paper.
- The project “Integration of microalgae depuration system in aquaculture for water quality enhance (IMPULSE)” aims at implementing an innovative method based on microalgae for the treatment of wastewater, water reuse and recycle to reduce the amount of clean water used in fish farms and the amount of waste discharged into the environment.
- ALGATEC II - Optimisation of the biotechnological recycling solution for olive washing water (FP7-SME), www.algatec2.eu, aims at providing an affordable technical solution for reducing the consumption of drinkable water in the olives washing process.
- EU Project FP7-SME-2013-602007: “Phaseplit” Novel Two-phase Acid/Gas Anaerobic Reactor for Industrial Wastewater of Food & Drink SME industries. (2014-2016) http://cordis.europa.eu/project/rcn/191142_en.html
- EU Project FP7-PEOPLE-2012-ITN-607492: “Mermaid” Microbial Resource Management and Engineering solutions for the Urban Water Cycle. (2013-2017) http://www.mermaid-itn.eu/
- EU Project CIP-Eco-innovation-2013-63038: “Artica4nr” A multivariable advanced control solution for sustainable operation of nutrient removal urban WWTPs. (2014-2016) http://artica4nr.eu/

Public- Private Partnership

Climate KIC consists of dynamic companies, the best academic institutions and the public sector. Their mission is to create opportunities for innovators to address climate change and shape the world's next economy. Climate KIC has an algae incubator theme in the Netherlands.

Bio-Based Industries (BBI) PPP, Horizon 2020 consists of the EU and the Bio-based Industries Consortium. Operating under Horizon 2020. The Joint Undertaking on Bio-based Industries (BBI) is a public-private partnership aiming at increasing investment in the development of a sustainable bio-based industry sector in Europe.

3.3.3 Institutions

The following paragraph gives us a view on the current EU legislation framework and it also examines social perceptions, social awareness and beliefs. This section lists the most important regulations, influencing the scoped algae cultivation technology take off, the most important overarching strategies for bio-economy, the main regulations covering spatial planning, environmental permitting and algae products standards. In the end, social acceptance around business creation, algae cultivation and algae products in Europe is discussed.

Regulatory bodies

The main regulatory bodies are government bodies of each member state working nationwide on regulating research and innovation, actors in charge of implementing regulation for spatial planning, environmental permits, as well as for implementing algae product standards.

The European policy makers are highly interested concerning protection and preservation of water resources. This interest is highlighted in the number of legislation, policies and directives that have been put forward in the last 30 years, covering almost any aspect concerning protection and preservation of water resources. The main overall objective of EU water policy is to ensure access to good quality water in sufficient quantity for all Europeans, and to ensure the good status of all water bodies across Europe. In the followings, the legislation framework of the EU for water and wastewater effluents is summarized.

Table 9: Legislation framework for water and wastewater

TITLE OF DIRECTIVE	*OVERVIEW*
2000/60/EC Water framework directive	It is a framework for the Community action in the field of water policy with a series of prescribed steps that should be undertaken by all EU members to achieve the objective which is the "good status" for ground and surface waters in the EU. The ecological and chemical status of surface waters are assessed in terms of: biological quality, hydromorphological quality, and physicochemical quality.
96/676/EC Nitrates directive	It aims to reduce and prevent water pollution caused by nitrates from agricultural sources. It obliges MS to designate vulnerable zones of all known areas in MS whose waters are or are likely to be affected by nitrate pollution. Vulnerable zones are defined as those waters, which contain a nitrates concentration of more than 50 mg/l or are susceptible to contain such nitrates concentration if measures are not taken. The measures for action of the nitrates directive are also listed in the Water Framework Directive (Annex

	VI) and the Groundwater Directive (Annex IV, part B).
91/271/EC Urban wastewater treatment directive	It aims to protect the environment from the adverse effects of discharges of urban wastewater and wastewater from certain industrial sectors, and concerns the collection, treatment and discharge of: domestic wastewater, mixture of wastewater, and wastewater from certain industrial sectors. The Directive requires: Collection and treatment of wastewater in all agglomerations of > 2000 p.e., pre-authorization of all discharges of the aforementioned wastewater streams, monitoring of the performance, controls of sewage sludge disposal and re-use, and wastewater reuse.
2010/75/EU Industrial emissions directive	This is the main EU instrument regulating pollutant emissions from industrial installations including wastewater. The IED aims to achieve a high level of protection of human health and the environment taken as a whole by reducing harmful industrial emissions across the EU, in particular through better application of Best Available Techniques. Around 50,000 installations undertaking the industrial activities listed in Annex I of the IED are required to operate in accordance with a permit.
99/31/EC Landfill directive	It seeks to prevent or reduce the negative effects of landfill waste on the environment, including groundwater. For each site the groundwater, geological, and hydrogeological conditions in the area must be identified. The sites must be designed, so as to prevent groundwater from entering landfill waste, collect and treat contaminated water and leachate, and prevent the pollution of soils, groundwater or surface water by using the appropriate technical precautions such as geological barriers and bottom liners.

EU Policies and regulation on food/feed products derived from algae

There are two EU regulations that affect production and commercialization of food/feed products derived from algae: Regulation (EC) No 178/2002 on Food Safety (EC, 2002) and Regulation (EC) No. 258/ 97 on Novel Food (EC, 1997). The Novel Food Regulation illustrates the requirements for the authorization procedure of new food and feed products in the EU, including the ones from algae, which represents the first fundamental step for their commercialization. Applicants for the authorization have to prove that the new products are as safe to animal and human health as the traditional ones and provide scientific evidence. EU has a competitive disadvantage in the field of food/ feed products derived from algae due to restrictive requirements of the regulation, and therefore has limited chances to become global market leader due to the regulatory environment.

3.3.4 External factors influencing the TIS of SaltGae

The innovative wastewater treatment is affected by some external factors to the TIS, but relevant to our compounds of system. These factors include:

3.3.4.1 EU regulatory framework and objectives

Biofuels

Renewable Energy Directive (RED) 2009/28/EC: It regulates the use of renewable energy in the EU transport sector. The RED determines that by 2020 member states must meet at least 10% of the national energy demand in transport through renewable energy sources, including biofuels.

Of importance to algal biofuel production, therefore, is ensuring that fuel products do actually achieve these targets, contributing on the same time to the reduction of GHG emissions.

RED II is the Recast of the RED. In January 2018, the text was approved by the EP plenary session where the main objectives are: EU should boost energy efficiency by 35% by 2030, Renewable energy sources should account for 35% of total consumption. The institutions are now carrying on the trialogue and discussing the text after the approval of the Council on the Energy Union in December 2017. RED II proposes a sub-target of 3.6% blending for advanced biofuels coming from the feedstocks listed in RED Annex IX, Part A, by 2030, starting with a sub-mandate for 0.5% blending in 2021. The feedstocks that can be used to achieve this sub-mandate are algae, biowaste from households and industry, agriculture residues, industrial residues, forestry residues, and energy crops. This sub-mandate for advanced feedstocks should help to promote emerging technologies for biofuel production, such as cellulose hydrolysis and pyrolysis. This framework underlines the lack of national targets and directive discussion. This could bring to the increase of gap and discrepancy on the fulfilment of objectives in terms of energy efficiency and renewable energies from one country to another, e.g. prohibition to produce food from algae comity.

Food and Feed

- Regulation (EC) 767/2009: It regulates for the marketing of feed materials and compound feed.
- Regulation (EC) 1831/2003: It regulates for the authorisation, supervision and labelling of feed additives.
- Regulation 183/2005: This Regulation is requiring registration and approval of all feedstuff operators, is the critical measure within the EU's overall 'Hygiene Package'. Regulation 710/ 2009: on organic aquaculture animal and seaweed production.
- Regulation (EC) No 1907/2006 Regulation on Registration, Evaluation, Authorisation and Restriction of Chemical (REACH): lists restricted chemicals in products that are marketed in the EU. In order to market, there is a need to make sure that products do not contain hazardous substances as defined by REACH.

Bioplastics

There is currently no EU-wide legislative framework to support the use of renewable raw materials for plastic solutions. On January 2018, the EC launched the first Strategy on Plastics aiming to protect the environment from plastic pollution, in particular to reduce single-use plastic, restrict the use of microplastics, and ensure that all plastic packaging is reusable or recyclable in a cost-effective manner by 2030. The EC will launch the work on the revision of the Packaging and Packaging Waste Directive and prepare guidelines on separate collection and sorting of waste to be issued in 2019.

The EU has, however, started to acknowledge the important role of bioplastics to drive the transition to a circular economy and in decoupling economic growth from the depletion of fossil resources. A number of strategies and policy initiatives are currently underway that are relevant for the success of the bioplastics industry in EU to unfold its full environmental, economic, and social potential, including: Europe 2020/Innovation Union, Lead Markets Initiative for Bio-based Products, Resource Efficiency Strategy, Key Enabling Technologies, Horizon 2020, Bioeconomy Strategy and Circular Economy Package. The Circular Economy Package (2015) by the EC, outlines that the waste should be regarded as a valuable resource. Bioplastics can play an essential role in the transition to a circular economy and linking it to the bioeconomy. Therefore, the Circular Economy Package needs to address a range of economic sectors and introduce concrete provisions to stimulate the bioeconomy and use of bio-based materials and introduce additional economic measures to promote the market penetration of bio-based products, including Green Public Procurement and an EU-wide Eco-label, both of which consider a certain bio-based content of products, as well as the creation of a level-playing-field regarding access to bio-based feedstock in the EU.

3.3.4.2 Cultural aspects influencing algae business development

The EU is open and free to innovation, industrial development, and investment. Identification of any institutional aspects which may potentially influence the deployment of algae cultivation technologies among MS is difficult and depends heavily on country.

With regards to social acceptance to using algae for product development, there is relatively low social awareness on the potential benefits and risks of algae cultivation and utilisation in consumer products. This is associated with the limited expansion of algae products in the EU market. However, environmental bioremediation is an industrial application that would be acclaimed by the community under certain circumstances. For a project case that incorporates installation of HRAP and recycling nutrient-rich industrial wastewater, the social acceptance is expected to be medium to high. The main resistance from consumers would be expected to come from using greenfields for industrial algae activities, due to the high population density and the perceptions about how recreational rural areas should look like, and from using the algae cultivated in wastewater products for feed, even if algae have been approved by HACCP regulation. Generally, the use of recycled wastewater for biofuels, fertilizers, materials more likely would not face consumer's resistance.

Prices

Table 10: Overview of synthetic counterparts of algae based materials and chemicals, and outlook for algae in these markets.

Product	Substitutes	Biomarket share size, global	Value substitutes
Biofertilizers	synthetic fertilisers	USD 440 million	EUR 0.2-0.5/kg
Biopesticides	Synthetic pesticides	USD 2.1 billion	USD 5/acre
Bioplastics	Fossil based plastics	1 710kton	EUR 1.147kg

Table 11: Overview of feed markets and substitutes for algae products used as feed.

Product	Substitutes	Market size EU	Value substitutes
Aquaculture	Fishmeal, fish oil	1,9 million ton	EUR 55-500/ kg
Livestock feed	Soybean	22,65 million ton	USD 300/ton
Feed additives	Botanicals, antibiotics	5,2 billion	

4 FUNCTIONAL ANALYSIS

Functional analysis is focused on the identification of the main factors that influencing the development, responsible of the present market status of the SaltGae technology. The analysis is articulated in 8 functions:

1) Market formation; 2) Legitimation 3) Knowledge development 4) Knowledge exchange 5) Resource Mobilization 6) Influence of the direction of the search 7) Entrepreneurial experimentation and production 8) Development of external economies.

4.1 Definition of the development phase

Technologies pass through different phase of development along their life. Phases are determined based on assessing the readiness level, the availability of necessary infrastructure and the market saturation. The figure 8 illustrates 5 different stages of development of technology innovation. Depending on the current phase of the technology, not all functions are equally influential in further development of the scoped technology.

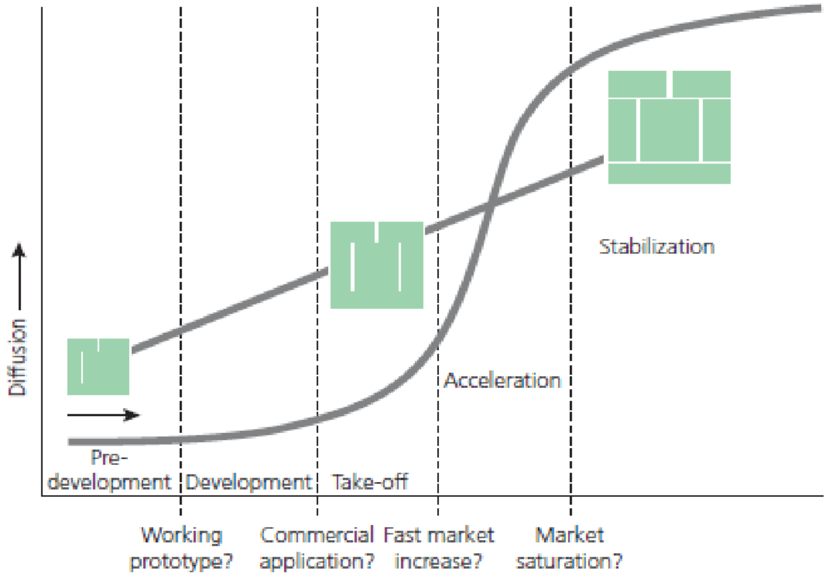


Figure 8: **Classification of the different phases of development**

The build up of the innovation system occurs over time throughout the phases which results that the fulfillment of the system functions is cumulative. Therefore, all system functions need to be fulfilled in order to support the build up of the TIS in question.

The SaltGae system is in the pre-development phase. In this phase, a prototype is produced and there is the first evidence that the new technology works. For the pre-development phase, the knowledge development is the most critical system function. This system function may be negatively influenced by a poor performance of other system functions, such as knowledge exchange, influence of the direction of the search and resource mobilization. These 4 functions deserve most attention in the analysis for the pre-development phase. The other system functions are expected to be less influential, however they may influence the system function and may be critical. Therefore, all systems will need to be analysed in this phase.

The TIS functions are considered to provide the underlying system structure that determines the evolution of the technology used in the SaltGae project. These functions are performed by the actors in the TIS. The functions are assessed by looking at the actions of relevant actors. The list of functions was taken from Fig. 1: The scheme of analysis (adapted from Oltander and Perez Vico, 2005). This analysis aims at ascertaining to what extent the functions are currently filled in that TIS, i.e. to analyse how the TIS is behaving in terms of a set of key processes. In the following, it will be explained each of these functions for the SaltGae Project.

4.2 Market formation

The analysis has shown that some important function elements are in place already. For example, there is an articulated demand associated with the supply chains of the technology (industrial side streams and wastewater), projects associating algae cultivation, PPP and government industry contracts for key enabling technologies where in fact algae are included, product standards for algal products like food, feed, or chemicals that drive parallel market formation.

Within Europe it is estimated that >445.9 million m3 of saline wastewater is generated each year within F&B industry sectors having a combined market value of >€63.7 billion. Taking a 15 year depreciation rate we can estimate a total potential annual EU market for the SaltGae system of €1.04 billion. The potential global market is estimated to be ~4 times this market valued at €4.16 billion. The projects aim to bring the new technology to market within a three-year period with target €122.85 million business growth over a five-year period, equivalent to the sale of ~70 SaltGae systems.

Assuming a total potential EU market of 8,893 SaltGae systems generating on average ~18.7 tonnes algae biomass per system annually, it can be calculated a total potential algae biomass of 166,298 tonnes from utilisation of the SaltGae solution within EU. This will create valuable new sources of bio-based feedstocks for value extracts, animal feeds, biochemicals and bio-based material additives worth in the region of €350.69 million. Initial target markets for the SaltGae technology include Southern Europe (Spain, France & Italy), Slovenia and Israel. These markets were selected due to the strong food processing sectors that are more susceptible to new technologies; the greatest need for improved water treatment and recycling; and because of regions with the ideal environment for algae growth. Secondary markets with include Central and remaining Southern European regions. Tertiary markets will include Eastern and Northern European and selected international markets (Asia, USA, Australia, Brazil, etc…) who have favourable frameworks that will drive adoption of the technology. The five-year sales plan targets a cumulative €122.85 million business growth in the first five years demonstrating a >15 fold return on EC investment.

The SaltGae solution has a modular design enabling flexible configuration and use in different geographic regions and climatic conditions due to the diverse climate across Europe. As already mentioned, high salinity wastewater treatment represents an issue more in the Southern European countries since the main industries working in tannery, diary are mostly located in the South. The solution will select and utilise algae species that achieve optimum growth in each climatic region taking into consideration the wastewater composition and potential product streams. The technology configuration will also be optimised to ensure commercial viability.

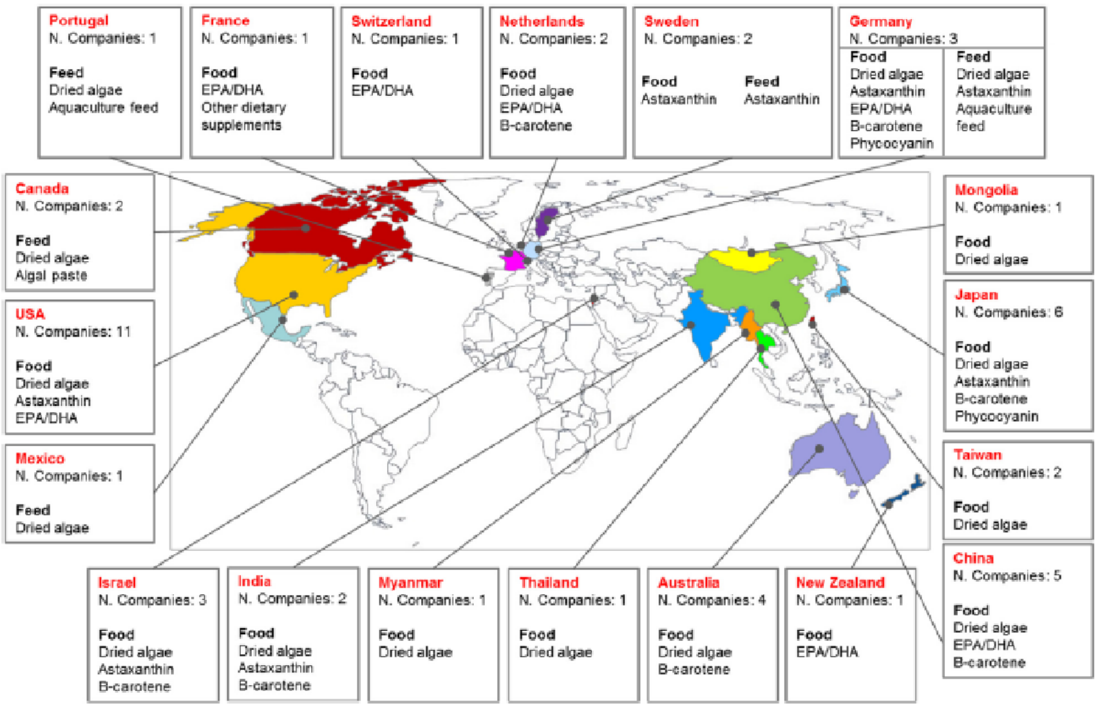
Competitiveness on algae market

The chemical, pharmaceutical, cosmetical and energy industries are exploring the potential of algae, however it is the nutrition sector that seems to potentially benefit more from algae technologies (Pulz & Gross, 2004). Algae application in Italy, according to results of the case study, demonstrated a competition in use of it in various industries, mainly in Cosmetics (ALGAE), pharmaceutical (BIOPLANTEC), energy, mostly for biofuels (TEREGROUP), food as nutritional component (ALGHITALY), and agriculture for fertilizers, animal food (Algain Energy srl).

Food and Feed products from algae

A number of conditions are still to be met to exploit the production and commercial potential of algae products in the EU. From a regulatory point of view, the European regulations on novel food and novel food ingredients, on food safety, and on nutrition and food health claims affect the marketing of micro-algae products. The safety of the products must be assessed before their launching on the markets, but restrictive regulatory requirements can delay the pace of commercialization. In particular, the EU food safety regulation requires the assessment of toxins, allergens or other harmful compounds potentially produced by the algae (EC, 2002).

The main exporter of algae to the EU was Chile, with an annual average of 13 million dollars/year of algal products, followed by Indonesia and the US. The most important EU exporters in 2010 and 2012 were Ireland, France and the Netherlands, but with values of one order of magnitude lower with respect to China. The most important countries importing algal products from the EU were the US, Australia and South Africa. Other existing data on algae-based food/feed products and nutrients are mostly owned by private companies and are mainly world estimates, with little details on market information at product level. In the figure adapted from M. Vigani et al. / Trends in Food Science & Technology 42 (2015) illustrates the global distribution of algae.



(Source: Vigani et al., 2015)

Figure 9: Geographical distribution of major companies operating in the Food and Feed production from algae sector

The large-scale industrial production of proteins and carbohydrates from algae for the agri-food sector would require higher production volumes and a dramatic reduction of production costs to be competitive with agricultural commodities.

EU strengths in the field of algae market formation are:

Science and technology base: algae applications for food and fuel is its strong position in algae science and technology. Europe is very active in this field and has good engineering and training skills.

Public R&D funding: high priority in R&D funding policies in this field of a number of MS and of the EC. The EC has a focused a thematic area in this field in its Framework Programmes and active sustainability policies that support scientific and technological developments in this field.

Industrial and logistical position: an outstanding tradition in high-quality agricultural production and a strong food and feed industry with multinationals operating on a global scale. Europe has good physical infrastructure, such as large seaports capable of handling large volumes of commodities. Europe also benefits from a high level of human capital, a workforce with adequate engineering and technical skills to work in algae.

EU weakness in the field of algae research and production for food and feed:

- Geographical position: main weakness with is relatively suboptimal climate with high levels of rainfall, low levels of sun hours and sun intensity, low temperatures for most countries outside southern Europe. For this reason, Europe has a lack of surface area for the production of micro-algae.
- Structural financial-economic disadvantages: high labour costs, lack of venture capital and seed capital available for start-up companies and low entrepreneurial activity among researchers and engineers in this field. Due to the focus on public research, there is relatively less focus on up-scaling and optimising production. Moreover, large companies hardly invest in R&D in this field.
- High land costs. Regulation: EU lacks a consumer history with algae, in contrast with Asia or the USA, which makes effective marketing of algae-based products more difficult in EU.

Since algal wastewater treatment are not properly commercialised across Europe, market formation for algal biofuel is in a nascent stage. However, a major market formation barrier is the size of the enterprises operating and producing knowledge for the scoped technology or other algae cultivation technologies that could benefit the scoped technology. However, as mentioned earlier, there are no large-scale facilities associated with the scoped technology so far, that would enable integration of businesses across the value chain.

4.3 Legitimation

The Functional analysis has shown that among the factors influencing the legitimation for the scoped technology, the enacted policies and strategies supporting algae cultivation from waste are of critical importance. The EU have created an integrated regulatory system around planning permission and environmental permitting procedure that smoothens new business creation.

Each demonstration site had to comply with the regulatory authorisations and prerequisite legislative obligations for construction and operation of the demonstration site. On Demo Site 1-Slovenia, KOTO had to inform Environmental Agency (ARSO) about the technology of the pilot plant, as well as give an estimation of environmental impacts. As the Slovenian site included anaerobic digestion pilot facility, the company had to consider also explosion safety. No building permits were required as the reactors were built as facilities for research and demonstration purposes.

As one of the product streams includes animal feed, it is essential to ensure safety of animals during animal trials. Hence, in order to mitigate risks of potential contamination with heavy metals or harmful toxins, SaltGae will in this case utilise algae derived from whey or aquaculture wastewater. The project is considering only algae species used in food and feed applications, such as Spirulina, recognised as safe by the US Food and Drink Administration. Trials are undertaken in safety and compliance with Directive 2010/63/EU on the protection of animals used for scientific purposes. New feed compound must be assessed by the European Food Safety Authority. The new SaltGae products that will be commercialised and introduced on the market, will be assessed by the European Food Safety Authority and comply with the following directives: EC Regulation on Food Safety (EC 178/2002); EC Regulation on Novel Foods and Novel Food Ingredients (EC 258/97); and EC Regulations on Nutritional and Health claims made on foods (EC 1924/2006).

Analysis showed that legitimation of algae has many barriers, mainly due to the early stage of the development of the scoped technology. The main source for social resistance is expected to come from using "wastewater" for feed products. The fact that the project use saline wastewaters for algae production decreases the legitimacy of the concept. Advocacy coalitions for algae are available in EU level, there are associations for bio-industries, renewable energy, and anaerobic digestion, but not for valorisation of algal biomass by products. Large enterprises that could increase legitimation to the scoped technology or other algae cultivation technologies are not very active yet. This creates an obstacle because large enterprises can unlock resource mobilisation, and improve knowledge development and exchange, market formation, and bold entrepreneurship experimentation.

4.4 Knowledge development

The Functional analysis has shown that there is a good level of research activity in academic environments with universities and research centres doing studies relevant to the scoped technology, and commercial initiatives most of which are performing also R&D activities. R&D activities are covering the key elements of the value chain for increasing the sustainability of technology

Table 12: Research and development institutes

Research and development institutes	***Country***
Training and Demonstration Centre for Decentralized Sewage Treatment	Leipzig, Germany
Universita Libre de Bruxelles	Belgium
University of Antwerp	Belgium
Center of New Water Technologies Foundation	arrion de los Cespedes, Spain
Institute for Sanitary Engineering, Water Quality and Solid Wa Management	Stuttgart, Germany
IKT – Institute for Underground Infrastructure	Gelsenkirchen, Germany
Research Institute for Water and Waste Management	Aachen, Germany
POLTEGOR-INSTITUTE	Wroclaw, Poland
Gebze Institute of Technology	Kocaeli, Turkey
Institute for energy and environmental research	Heidelberg, Germany
Instituto de Biologia Experimental e Tecnológica	Oeiras, Portugal
University of Greenwich	London,UK
University of Almeria	Almeria, Spain
Università degli Studi di Firenze	Florence, Italy

In Europe, there are 57 masters program in Environmental engineering. Environmental engineering is an academic area of study that trains students to mitigate or remove the waste and pollution produced by manufacturing and other harmful business industries. Then, individuals are able to work on recycling systems, water sanitation and waste disposal solutions. There are 14 studies programmes specialized to water and wastewater treatment (www.masterstudies.com). In the interview with our expert, it was discussed the knowledge development needed for sustainable skills for WWT. According to him, the current situation is no ideal because of complexity of it which requires of work labour with a different academic background, from mechanical engineering to marketing studies. Also, there is a lack of a postdoctoral researcher conducting research after the completion of their doctoral studies in this sector due to high prices for education. There are many training programmes on algae to educate the next generation of skilled algal technicians to fill new job openings and to support algal commercialization.

If we take Italy as a case study, we notice that the recent education trends in Italy are in subjects such as: biotechnology, environmental protection, and chemical engineering. Excellent italian research centre are: Archimede Research, A.&A. Fratelli Parodi s.p.a, Politecnico di Milano, University of Milan Bicocca, University of Padova, University of Pisa, CNR (Consoglio Nazionale delle Ricerche), University of Florence, CREAR, Università degli Studi di Roma la Sapienza, TEREGROUP, Fondazione Parco Tecnologico Padano. While, the majority of italian skilled students are completing their studies at organisations such as WUR, iBET or enrolling to national university studies on Land management, Environmental Engineering, Biological Sciences and Biotechnology.

The analysis showed that knowledge is developed only in small-to-medium scale facilities, since there are not many accessible facilities at large scale. Knowledge development at large scale facilities is fundamental to solve practical challenges of the technology and furthermore to describe accurately the techno-economic, environmental and social benefits and the costs of the scoped technology. Under current circumstances there are very limited options for knowledge development at medium scale and not any options at large scale, and this affects both the academic and industrial sector. Knowledge has not only to be developed but also needs to be well-maintained. Because, to a large extent, knowledge development R&D activities take place in academia, expertise and competencies are developed mainly during periodic R&D projects. One implication of that is that once a project is finished and not renewed, gained expertise and competence might be diluted or lost.

4.5 Knowledge exchange

The analysis has shown that universities and industries are partners in many large European R&D projects where they exchange knowledge in process, technology, and value chain development. The EC R&D funding schemes strongly encourage inclusion of industrial partners in the R&D project consortia, both enabling knowledge exchange and technology transfer. There are formal algae networks in Europe, mentioned in Networks section. Analysis showed that knowledge gained during R&D projects is disseminated via peer-reviewed publications, conferences, theses, patents etc. However, these resources are not easily accessible. This failure in disseminating projects outcomes creates a barrier to further innovation and use of the innovation. There are no official network platforms capturing the interests of the entire value chain connecting algae related expertise, which means there is no network bringing together industrial wastewater handling actors with algae cultivation actors, and valorisation of biomass. Companies that have expertise in developing, designing and building commercial algae cultivation projects across borders, are advantageous into gaining knowledge and have a unique opportunity to bring this knowledge across EU.

4.6 Resource Mobilization

The Functional analysis has shown that to a very good extent for this stage of development the Resource Mobilisation is working well especially in terms of 1) government financial support for R&D innovation and demonstration of technology, 2) established financial incentives associated to biomass valorisation, 3) an extensive knowledge and technology-base for technical and agricultural studies placed in some universities, 4) regulations for handling wastewater from F&B industries. Some of funding bodies:

- *European Investment Bank supports investments* for ensuring of reliable provision of sustainable and affordable water and wastewater-related services both in quantity and quality, and promote the increase in energy efficiency measures and recovery mechanisms. For wastewater lending comprises facilities for treatment and disposal of residual waste, and increasingly, infrastructure aimed at increasing the levels of materials and bio-waste recycling, where the latter can also enable generation of renewable energy from bio-gas. This integrated approach - water for energy and at energy for water - aims to ensure that both water and energy resources are developed sustainably and that water and energy services are produced and consumed efficiently.
- *European Commission*: Horizon 2020 research and innovation programme- Water
- *Fondazione Cariplo*: research projects in 5 areas, two of them are Agribusiness and Environment and Technology
- *Centro Euro-Mediterraneo sui Cambiamenti Climatici*
- *Fondazione Cassa di Risparmio di Modena*
- *BBI*. Horizon 2020 European Union Funding for Research & Innovation. Bio-Based Industries Joint Undertaking.
- *COST*. The European Cooperation in Science and Technology.

4.7 Influence on the direction of search

The analysis has shown that there are European and national strategies supporting green growth and innovation in the bio-based economy, as well as policy incentives clearly supporting R&D and innovation with algae cultivation and also water treatment.
The expectations and the visions of the various stakeholders associated with the algae technologies, wastewater, and valorisation of algal biomass value chains are not well aligned. The ineffective dissemination of the evidence related to the technology readiness, and the associated costs and GHG savings of the scoped technology creates a barrier obstructing the formulation of objective expectations and visions for the innovative technology. There are many R&D activities with regards to developing algae biotechnological platforms and processes for different products. However, there are currently many algae biotechnological platforms that in parallel have attracted the attention of researchers (human resource) who are also supported by public-funded research (financial resource.) This phenomenon effectively causes new knowledge to be diluted as R&D efforts are not focused on a selection of platforms across research groups, and therefore knowledge development rate slows down. These influences involve visions, expectations and beliefs in growth potential, actors perception on knowledge and technologies, regulations and policy, articulation of demand, technical bottlenecks, market and current business crisis, etc.

4.8 Entrepreneurial experimentations and production

The Functional analysis has shown that technologies like the one scoped here, that combine wastewater treatment with algae cultivation, are popular in Europe among commercial initiatives. There are large enterprises that are engaging in R&D and innovation upstream and downstream algae projects. The Function analysis gives evidence that entrepreneurial experimentation and production suffers from lack of processing facilities at demonstration scale accessible to SMEs.

For developing knowledge in entrepreneurial experimentation and production, the accessibility to large scale facilities is fundamental in testing and proving technologies and learning by doing. Currently demonstration-scale facilities include algae cultivation technologies and the complementary technologies for conditioning recycled nutrients and feeding to algae cultivation from industrial wastewater. The analysis also shows that valorisation of algal biomass and co-products development is practiced. Main industrial actors cultivate algae mainly for production of food and feed products or for waste bioremediation. Currently there are no industries producing co-products, e.g. fertilizers, bio-composites but there are some commercial initiatives that are involved in R&D and innovation activities for algal applications.

4.9 Development of external economies

Parallel developed technologies or markets can affect the development of the new technology both directly and indirectly, in terms of competencies and expertise, technology development, infrastructure, policy unlocking etc. The impacts can affect all previous examined functions of the scoped technology. The development of parallel algae markets and cultivation technologies will have radical impacts in the development of the scoped technology, in terms of e.g. knowledge development, entrepreneurship experimentation, market development and integration, and legitimation. Competences would include engineering, biology, entrepreneurship, life-cycle analysis, and macroeconomics. The development of parallel markets or cultivation technologies will benefit the development of scoped technology since both technologies or markets will all be empowered to lobby for unlocking resource mobilisation, knowledge exchange, value chain integration, and legitimation.

5 BARRIERS AND BLOCKING MECHANISMS

The SaltGae project addresses a number of cross-cutting challenges facing the water sector. The main challenges of implementation of water and wastewater treatment technologies could be gather in 5 groups: user perception, governance, finance and regulation, commercial barriers and technology challenges.

5.1 User perception and lack of familiarity.

Factors that may influence public acceptance of water reuse are:

1. Trust in the authorities, scientific findings and knowledge of issues related to recycled water.
2. Issue of choice: the benefits of using the recycled water outweigh all other options.
3. Emotional variable such as disgust.
4. Anticipated regret.
5. Risk perceptions of using recycled water.

The traditional approach of implementing new water reuse by means of a “decide, announce and defence” policy has now been commonly acknowledged as ineffective. The new strategies proposed for implementing water reuse projects is to involve the community prior to the conception of any reuse projects (Recycled Water Task Force, 2003). Community empowerment is the key to this early public involvement process. In the planning of the project, every issue raised by the community should then be considered. This process is time consuming but provides an opportunity for informing the public and allowing any misconceptions people may have about their water supply to be clarified. Through a programme of education and demonstration of the SaltGae solution and technologies, the project will contribute on educating user stakeholders concerning the potential value of wastewater and how it may benefit them, thereby facilitating a change in user perception from 'a cost to be minimised' to 'a resource to be valorised'.

5.2 Fragmentation in Governance

Divergent interests, multi-level governance structures and risk aversion in public administration can pose challenges to the effective implementation of policies and technologies. European policies are important and necessary in order to ensure junction among the Member States. Having a knowledge on EU water related policies is important for understanding the policy objectives, benefits and identify future challenges. A high-level policy such as the Water Framework Directive (WFD) can be inconsistently implemented. For example, Member States can have different levels of sector integration and interpret policies – and the language used – in a variety of ways. They might also prefer to fit existing country-level institutions to new policy requirements rather than create new, specially designed organisations which, while not inconsistent with the WFD, might lead to inconsistent implementation, even within the same watershed. Southern et al. (2011) suggest some innovative approaches to improving the functioning of such authorities, including developing national resource databases and policy mechanisms that transcend property and institutional boundaries. The lack of legislative uniformity among the MS is a huge challenge. The published report on water reuse by the Water Supply and Sanitation Technology Platform notes that 'Although investors and water utilities are becoming increasingly enthusiastic about water reuse … the capability of Europe's water sector to deliver reuse projects is being compromised by a lack of suitable regulation, skills and public understanding'. This report also notes that 'with appropriate investment in people, knowledge, and technology, Europe could be a global leader in this rapidly developing market.' and highlights the 'huge eco-innovation potential in terms of technologies and services around water recycling in industry, agriculture and urban water systems' (EC, 2016).

The lack of legislative uniformity among the MS is a huge challenge. For example, the discussion on waste recycling in EU is imposing only targets at EU level that needed to be transposed at national levels. The waste framework is composed by 4 directives tackling the issues of: waste; packaging waste; landfill of waste; end-of-life vehicles and waste batteries. After long discussions, the EU institutions managed to find a common text which was widely adopted.

5.3 Finance and regulation

Barriers to the diffusion of innovation include the widespread reluctance of water utilities to trial new technologies. This is partly because of their heavy investment in existing, long-lasting technologies, with maintenance or renovation of this equipment claiming a large portion of current budgets (EIP Water, 2014). Other barriers include a high cost of installing new technologies, a particular problem for small or medium enterprises (SMEs) considering development of closed-loop industrial treatments. Water systems need to maintain regulatory compliance to ensure the safety of water and to maintain the confidence of the public.

Multiple regulatory-related barriers have been identified: regulatory policy fragmentation, complex regulatory requirements, unnecessary regulatory restrictions, absence of regulatory incentives, geographical fragmentation of the regulations. These barriers can make it difficult to approve new technologies. The way in which specifications are written can limit the appropriateness of new technologies. Specifications are written to ensure that an appropriate technology is chosen to address issues, and occasionally, specifications favour long-established technologies. These types of narrowly written specifications have been identified as a barrier to public works innovation in the United Kingdom (Uyarra et al. 2014).

- **Lack of supportive political and funding landscape**

It is important to identify, prioritise and engage with national and European agencies in regard to influence policy, future legislation/regulation and funding programmes. This would make available new funding opportunities for further development and commercialisation of the SaltGae technologies.

- **Lack of water standards**

Water efficiency standards will be integrated into the SALTAGE solution and cross cutting activities. However, there are currently no EU-wide standards for the reuse of water. As a result, different MS has different specifications and any company marketing a new technology may find the costs of certifying it for multiple countries to be prohibitive (EIP Water, 2014).

5.4 Commercial barriers

- **Absence of positive commercial perception of reclaimed products.**

By demonstrating the performance and quality standards of the resulting product streams (water, animal feed, resins, high/medium value extracts, additives, fertilisers) and the commercial/ financial benefits possible through utilisation of such resources; SaltGae will facilitate a positive transition in consumer/industry perception of reclaimed products and recycled water.

- **Lack of identification and engagement of potential bio-economy markets and organizations.**

Bringing bio-economy products to market and contributing to the development of a sustainable bio-economy, involves using new and often untested production technologies, and then bringing these replacement products to markets of which relatively little is known of their receptivity. This route sets out a value chain that is both complex, high risk and with relatively uncertain market projections. Europe has a number of well-established traditional bio-based industries, and it is already one of the largest and most important components of the European economy.

5.5 Technology challenges

Some of the key challenges that are associated with algae-based WWT include:

1. Land Requirement 2. Light Requirements 3. Temperature 4. Rainfall
5. Mixing 6. Harvesting 7. Contamination 8. Maintenance
9. Other Challenges associated with pond systems used for algae-based wastewater treatment are:
   (a) Scum Control: Scum is a common characteristic usually present in the spring when the water warms and the biological activity resumes. Scum can promote a blue-green algae growth which can give rise to disagreeable odors.
   (b) Odor Control: Odors are associated with overloading and poor housekeeping.
   (c) Weed Control: Weeds are mostly objectionable because they can promote mosquito breeding and scum accumulation.
   (d) Mosquito and Insect Control
   (e) Oxygen Depletion
   (f) Evaporation losses may occur in hot, dry climates, which significantly reduce the amounts of treated wastewater available for agricultural reuse (Oilgae, 2014).

- **Lack of interoperability**

With respect to software, the term interoperability is used to describe the capability of different programs to exchange data via a common set of exchange formats, to read and write the same file formats, and to use the same protocols. The lack of interoperability can be a consequence of a lack of attention to standardization during the design of a program. In Europe, there are 9 software companies and vendors for wastewater treatment (BITcontrol, Germany; LEMTECH, Poland; WRC plc, UK; ANOVA, Italy; Envi Dan, Denmark; INVENT Umwelt and Verfahrenstechnik, Germany; Water Innovate, UK; UAB Ekologiniai projektai, Lithuania; KISTERS, Germany). As part of the SaltGae solution we will integrate an advanced process monitoring and control system to enable automation of key activities and remote monitoring. Such technology provides a platform for interoperability between water information systems, particularly with regards to discharge and environmental monitoring.

6 CONCLUSIONS

When it comes to water, it is obvious that innovation matters: there is tremendous potential to meet the urgent need for change with new combinations of new and old technologies, and by improving recycling and re-use systems. However, it is clear that innovation should not be confined to technological measures alone and finding the best technology does not pose the most significant challenge, although resources need to be made available at a local scale to determine those which are most appropriate. The main issues lie in the coordination and decision making between interest groups, and in the gap between the development of innovative technologies, and their rollout on a scale that will improve water use. Grants, financial incentives and pricing strategies can all help. However, experiments with economic instruments should not obscure the fact that management of large bodies of water needs strong collaboration between many parties on multiple layers.

The main challenges of implementation of water and wastewater treatment technologies identified in this report, could be gather in 5 clusters: governance, user perception, commercial barriers, finance and regulation, and technology.

- Barriers in governance section are: fragmentation of stakeholders; poor communication or alignment of policy, legislation and regulation; low priority on the political agenda; incomplete understanding of the innovation barriers and fragmentation of institutions and responsibilities.
- Main obstacle in user perception of wastewater is a low social acceptance of recovered resources. There is a negative consumer/industry perception of reclaimed product streams and recycled water.
- Commercial barriers are due to lack of incentives for full-scale implementation and validation of innovative solutions, for SMEs to respond to market opportunities or access to sources of funding and lack of public awareness and private involvement.
- Next challenges in the finance and regulation sections consist on insufficient overall financial flows into the sector, risk averse nature of the sector, poor alignment of pricing methodologies and incentives, weak profitability arising from inadequate cost recovery, and lack of awareness of the economic value of water.
- Regarding the technological barriers, it is worth noticing the increased complexity of water treatment processes creating difficulties to user take-up, the high cost and competitiveness of new technologies, lack of knowledge of new technologies and its capabilities upon making investment decisions.

Many of these barriers are the result of fragmentation, poor communication, limited knowledge and lack of a common vision and strategy both across vertical and horizontal value chains. These barriers are common to novel technologies implemented across the water and wastewater treatment sectors. The new assets are specific to the local geography, economy and society, and the WWT have to be modify to the target hydrological context. Transaction cost economics suggests that asset specificity implies substantial sunk costs, an event that in regulated utilities opens the way toward governmental opportunism. Interaction with local governments and sector regulatory authorities is a distinctive trait of most water process innovations. This process innovation has to be adapted to the existing infrastructural capital and production processes. Third, the internal and external stakeholders of wastewater utilities are numerous and diverse, public and private owners, managers, employees, suppliers, customers, local water using vs. polluting industries, citizens and politicians. The benefits and costs related to the adoption of new WWT technologies accumulate in different proportions to these players.

Benefits of SaltGae project

The most important social and economic benefit of the project consists on the efficient treatment of saline wastewaters. This means less energy consumption, less greenhouse gas emissions, better effluent quality and new products produced from the resulting biomass. Initial focus of wastewater treatment was sanitation, then it shifted to effluent quality to prevent pollution and eutrophication, now it is shifting to cyclic economy. A modern good quality municipal wastewater treatment plant providing effluent to the EU environmental standards and implementing most of the modern measures to recycle energy still emits between 20 and 40 kg of CO_2 equivalent of GHG per population equivalent yearly. This is equivalent to burning some 10 to 2 l of gasoline per person yearly solely for treating his or her wastewater. Rough estimates of emissions for treatment of industrial wastewater are 5 to 30 times higher (depends heavily on the geography). This means that each EU citizen burns some 100 l of gasoline to prevent his water consumption to deteriorate water quality in nature. Using technologies developed in SaltGae project, the aim is to lower these numbers significantly in our target market of F&B industry. In these markets, there are not many alternative technologies, so they are the best candidate for introduction of such novel circular technologies, but very similar (even simpler) technologies can be used for more common wastewater treatment.

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