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
Deliverable D8.2 Technology innovation system strategy and roadmap

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Abbreviations and Acronyms

Abbreviation / Acronym	Description
AS	Activated Sludge
AD	Anaerobic Digestion
BOD	Biological Oxygen Demand
CAGR	Compound Annual Growth Rate
COD	Chemical Oxygen Demand
CAPEX	Capital Expenditure
DAF	Dissolved Air Flotation
DHA	Docosahexaenoic Acid
F&B	Food & Beverages
FEFAC	European Feed Manufacturers Federation
HRAP	High Rate Algae Pond
JRC	Joint Research Centre
R&D	Research and Demonstration
RO	Reverse Osmosis
TRL	Technology Readiness Level
UF	Ultra-Filtration
WWTP	Wastewater Treatment Plant

Table 1: Abbreviations and Acronyms

1 INTRODUCTION

This report consists in a study to identify the market strategy for the SALTGAE technology, which is based on the cultivation of algae for biomass valorization by using High Rate Algal Ponds (HRAP) technologies and by recycling saline nutrient-rich wastewaters from Food and Beverages industry. The objective of this report is to assess the present technical and market framework in relation to the proposed technology, with the aim to facilitate the innovation and take-off of this new solution in wastewater treatment sector.

In order to identify a roadmap towards the market development of SALTGAE process, the study investigates the state of the art of the proposed solution in the context of wastewater treatment sector and of and algae products market in Europe. The TIS (Technology Innovation System) analysis, performed in D 8.1. has identified the most relevant aspects of the SALTGAE technology in terms of technical innovation, potentials in the present and future market, and relevance among the stakeholders. As a subsequently activity, this report aims at implementing the outcomes from Technology Innovation System report provided by EUBIA, to identify a strategy towards the development of SALTGAE proposed solution in the Wastewater treatment sector. The present document will quantify the position of the proposed technical solution within the present context, assessing the readiness level of different aspects, considered as crucial for technology future development, in order to identify the existing strengths on which basing the strategy for solving most relevant barriers and weaknesses now hindering the commercial uptake.

2 ANALYSIS METHOD ADOPTED IN THE PRESENT REPORT

The studies performed and the results reported in the D8.1 and in the intermediate Techno-economic analysis, allowed to identify four “pillars”. Pillars are defined as the most relevant aspects to consider for studying the phase of development of the SALTGAE technology in the present market and policy framework. The project development pillars are the following:

- Pillar 1: Technology readiness and sustainability
- Pillar 2: Market and Economics
- Pillar 3: Social and cultural approach
- Pillar 4: Policy and Financial framework

Analysis of each pillar performed in this study has the objective to identify both the most **critical factors** which could hinder the development of SALTGAE concept, and the **strong aspects** on which building a structured market penetration strategy. Each of the main aspects, “the pillars”, have been studied after the identification of subordinate influencing parameters. “Drivers” and “Indicators”. Each pillar has been studied through drivers, considered as specific elements influencing the state of development. Each Driver has been analyzed, and then evaluated, thanks to the identification of five indicators. The evaluation of each indicator has been done with the assignment of a vote, from 1 to 5.

2.1 Technology readiness and sustainability

This aspect has been evaluated considering the full technology package of SALTGAE HRAP system. The main aspects influencing the technology attractiveness are the following:

- Research and demonstration activities on microalgae integration in WW treatment sector
- Sustainability of conventional wastewater treatment practices
- Benefits demonstrated by HRAP technology in comparison to present solutions
- Stakeholders involved in the technology optimization and application

2.2 Market and Economics

The present and future market potentials of SALTGAE technology has been analysed according to the results obtained during demo-tests performed at all three sites (KOTO, Archimede and ARAVA). The indicators of market opportunities and barriers have been identified during the development of D8.1 Technology Innovation System Analysis. The main aspects considered to be influencing the market and economics are the following:

- Economic impact of SALTGAE HRAP on F&B wastewater treatment solutions
- HRAP system technology, components and structures
- Market Size and opportunities
- Impact of Algae products obtainable, value and market demand

2.3 Social and cultural approach

Social and cultural context has been identified as an important driver for defining a successful roadmap towards the SALTGAE concept development. This driver has been analysed considering four main aspects:

- Employment impact of proposed solution
- Improving F&B symbiosis industry sectors
- Role of Algae-products in a sustainable society
- Circularity of the proposed model

2.4 Policy and financial Framework

As a final driver considered in this study, policy and financial framework has been identified. The existing supporting policy measures, as well as the barriers against SALTGAE concept development, represent a crucial instrument for evaluating present and future opportunities of this technology. At the same time, policy framework is often influencing the financial instruments available for supporting new industrial initiatives and research activities on this topic.

- SALTGAE in present policy framework
- SALTGAE opportunity in incoming policy framework
- Financing instruments availability

2.5 Drivers' analysis method

The drivers will be themselves object of evaluation through a standardized voting system. Each driver analysis will be performed by separating it in 5 main indicators. Indicators can be imagined as variables with a value. The value represents the "readiness". Each indicator will be valued from 0 to 5, where 0 is very poor and 5 means very strong. The evaluation of the function will be thus reported as a Radar-chart collecting the votes for all 5 indicators. The results obtained will be implemented to identify the most relevant weaknesses and strengths, and thus to identify the best pathway towards the SALTGAE technology business development. Business development Canvas will be produced as a support tool for future business initiatives after the end of the project. The drivers will be object of evaluation through a standardized voting system. Each driver analysis will be performed by separating it in 5 main indicators. Indicators can be imagined as variables with a value. The value represents the "readiness". Each indicator will be valued from 0 to 5, where 0 is very poor and 5 means very strong. The evaluation of the function will be thus reported as a Radar-chart collecting the votes for all 5 indicators. The results obtained will be implemented to identify the most relevant weaknesses and strengths, and thus to identify the best pathway towards the SALTGAE technology business development. Business development canvas will be produced as a support tool for future business initiatives after the end of the project.

3 TECHNOLOGY READINESS AND SUSTAINABILITY

3.1 Research and demonstration activities performed in microalgae integration in WW treatment sector

I 3.1 A - Industrial research activities

The number of Industrial research initiatives carried out during the last 10 years represent a high-level indicator of the actual potentials for the technologies where algae are applied in wastewater treatment. According to the D8.1. outcomes, the private, or partially privately funded projects on this topic demonstrate the interest of the industrial sector in the technology concept and, therefore, they give an idea on the expected growth. At the same time, it must be considered that research activity has the scope of improving companies "sustainable image", but sustainability image itself is considered as an incentive to launch a technological transition. In the case of SALTGAE concept, the number of industrial research and demonstration activities in the algae sector has been assessed considering the identified European projects where industrial organizations are involved, and the existing demonstration plants owned or operated by industrial actors in EU. Despite the large number of positive results reported by research and experimental initiatives, few demonstration plants are currently operating in Europe under the control of wastewater industries or industrial algae end users. The largest plants can be identified in non-EU countries, probably due to EU high costs and strict wastewater treatment regulations. This indicator has been evaluated with a 3, in a scale from 0 to 5.

I 3.1 B - Innovation in research initiatives

Innovation in research initiatives represents another core aspect for assessing the potentials of a technology. In fact, an intensive research activity is often related with a wide range of technical and strategical solutions to adopt for optimizing the process and the technology. In the algae cultivation and water sector treatment, research activity is producing innovative studies every year in different EU countries, more than in other similar sectors, like bioenergy, or biofuels. This indicator has been evaluated with a 5 in a scale from 0 to 5.

I 3.1 C - Technology Readiness level

The TRL assessment has been evaluated starting from the produced results obtained by the SALTGAE project, reported in the table below:

Table 2. TRL of different equipment elements in SALTGAE system

Process	TRL
Dissolved Air Flotation	9
2-step AD	7
Algal ponds	8
Harvesting	8
Pre-treatment before desalination	9
ED	9
Reverse Osmosis	9
Protein extraction	3/4
Piglet feed	5
Platform chemicals	6
Edible coatings	7
3D-printing paste	4/5
Biocomposites	4/5

The Readiness Level table reports the state of development of main technical equipment involved in SALTGAE concept. As visible, the lowest TRL level involves the algae-products, for which there is a low industrial development.

I 3.1 D - International Co-financed projects

The amount of international co-financed projects by public-private funding programmes is a strong indicator to assess the general attractiveness of a proposed solution. Projects focused on microalgae cultivation for wastewater treatment have been identified in the Technology Innovation System Analysis provided by EUBIA in the D 8.1. The list is reported below:

- Phaseplit (FP7-SME-2013, 602007) Project Partner: NOVA Novel Two-phase Acid/Gas Anaerobic Reactor for Industrial Wastewater of F&B SME industries.
- Salinalgue project: designing a sustainable production system of biofuel and by-products from microalgae
- 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.
- 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 to produce 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.
- 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), aims at providing an affordable technical solution for reducing the consumption of drinkable water in the olives washing process.
- 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)
- EnAlgae – Energetic Algae in North West Europe, Interreg IVB programme, 2011 - 2015

In addition to the existing and ongoing projects identified, other regional projects have been financed in different EU countries, strengthening the fact that this topic is still of great interest for public private financing institutions. This indicator has been valued with 4 on 5 in the present study.

I 3.1 E - Research to demonstration experiences

Research to demonstration means the number of research activities, which achieved to effectively upscaling from research status to a real demo-plant operating at higher TRL (es TRL 7-8). The KOTO plant is one of the largely developed in Europe and it represents the excellence in the microalgae application for digestate treatment. However, the amount of operating demo-plants producing algae biomass from wastewater is limited to few demo-sites area, like Algae Park in Wageningen, Algatec in Portugal, Biofat demo-plant and Secil plant. Most of these demo-plants are not operating with wastewater. For this reason, this indicator has been valued with 2 on 5 by the present study

3.1.1 Consideration on driver 3.1.

The research and demonstration activities on the SALTGAE sector show a good development status. The most relevant weakness is represented by the reduced amount of demonstration activities carried out at industrial scale. However, many new international projects are attracting the attention private actors. The interest is growing, and more demonstration scale plants are operating in these years, confirming a positive trend.

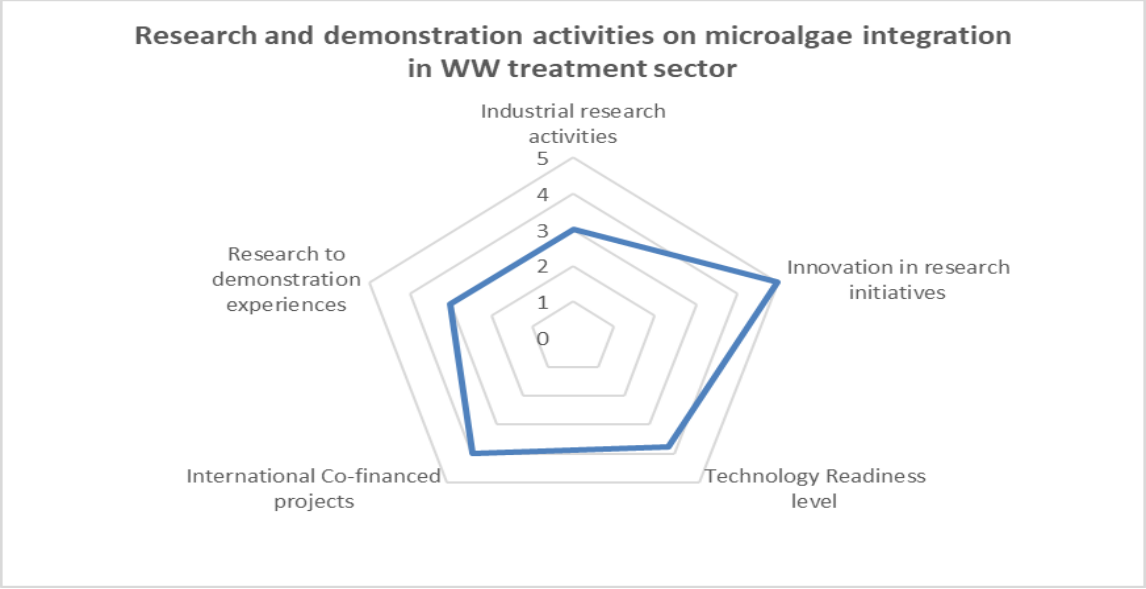


Figure 1. Research and demo activities on microalgae integration in ww treatment sector

3.2 Sustainability of conventional wastewater treatment practices

The opportunity for a novel technology to penetrate the market is strongly related with the need of new solution for the target market sectors to which the technology is addressed. In this case, SALTGAE technology aims to represent an innovative, attractive solution for F&B industry. The most common Wastewater Treatment system in use in the F&B industry is the Activated Sludge system. Activated sludge is the result of a process distributed in three main steps: aeration tank, which serves as bio reactor; a settling tank

("final clarifier") for separation of solids and treated waste water; a return activated sludge (RAS) equipment to transfer settled AS from the clarifier to the influent of the aeration tank These systems have been in use for over 100 years and have proven applicable to most situations. However, they are energy intensive and depending on the mode of downstream energy production, can be responsible for a significant percentage of a company's GHG emissions.

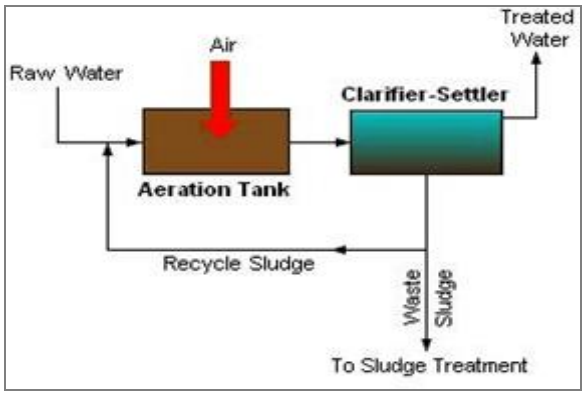


Figure 2. Simplified scheme of Wastewater treatment system

Recently, food and beverage industries has improved the wastewater treatment system by introducing membrane filtration systems, like ultrafiltration, nanofiltration and reverse osmosis. However, these systems require a complex maintenance, with related high costs.

I 3.2 A - Reliability of present technologies

Thanks to the long history of activated sludge system, the most relevant advantage of the conventional technology is that it is fully reliable. F&B industries, like other industrial plants producing effluents, adopt this system. The reliability of the system has been valued with a 4 on 5 score. This value represents an obstacle to the development of SALTGAE solution, as it reflects a strength of the present system.

I 3.2 B - Stakeholders approach to innovation

The approach of SALTGAE stakeholders to innovation has been demonstrated by their direct involvement in this and other research projects. Food and Beverages industries, as well as wastewater treatment companies and water utilities have participated to both international and regional projects to investigate the applicability of microalgae as alternative in wastewater sector. since algae application in different bioeconomy sectors is still at an emerging stage, algae producers and potential off-takers can be defined as innovators. Despite this general approach to innovation, the proposed solution is still not applicated at industrial level. This is mainly due to the difficulties, for wastewater managing industries (water utilities, food industries), to approach new technical solutions without being 100% sure about the performances and about the economic annual balance. For this reason, F&B industry stakeholders' approach to innovation has been valued with a mean value of 3 on 5 by the present study.

I 3.2 C - Obtainable products' quality

Products obtained from F&B wastewater treatment are limited to the reapplication of removed sludge for fertilizing purposes. However, most of the time the sludge obtained after Activation system is still a liquid, too poor in nutrients to be commercialized.

Therefore, the sludge effluents are usually recycled at the top of the plant or disposed. Value of this indicator has been identified with 1 on 5.

I 3.2 D - Water purification efficiency

The removal efficiency of BOD was found to be 94.56% and that of TSS was 93. 72%. The individual units are also performing well, and their removal efficiencies are satisfactory. BOD and TSS removal efficiencies of the primary clarifier are 30.59% and 50.61% respectively. BOD and TSS removal efficiencies of modern activated sludge plant (Aeration tank + Secondary clarifier) are above 90%. In general, despite the energy costs, and the lack of products recovered, the water purification achieved by conventional systems is high, ensuring a safe discarding or partial re-utilization of the depurated water. This indicator has been quantified with 5 on 5.

I 3.2 E - Present circular solutions in conventional WWT plants

Recycling organic elements and depurated water is a common trend which involves all those industry sectors producing relevant amount of effluents. Algae application In WWT sector gives the opportunity to extract a high value material from a problematic waste. In order to evaluate the actual potential of this solution to penetrate the WWT sector, another indicator has been identified to analyse the Sustainability of present WWT practices: the circular solutions available with conventional technologies. In general, circular solutions available depends on the quality and on the market interest in the recovered products. As mentioned above, obtainable products valorisation is a critical aspect, as organic sludge obtained from Activation is almost no-value. On the other side, water after depuration has a rather high quality, which allows local reuse. The indicator has been valued with 3 on 5.

3.2.1 Consideration on driver 3.2

The below chart reports the general situation concerning the wastewater treatment practices which are currently adopted by F&B and civil industry. The driver shows that presently adopted technologies, like activated sludge treatment, have a main bottleneck, no products are obtained, no valorisation of organic matter is performed.

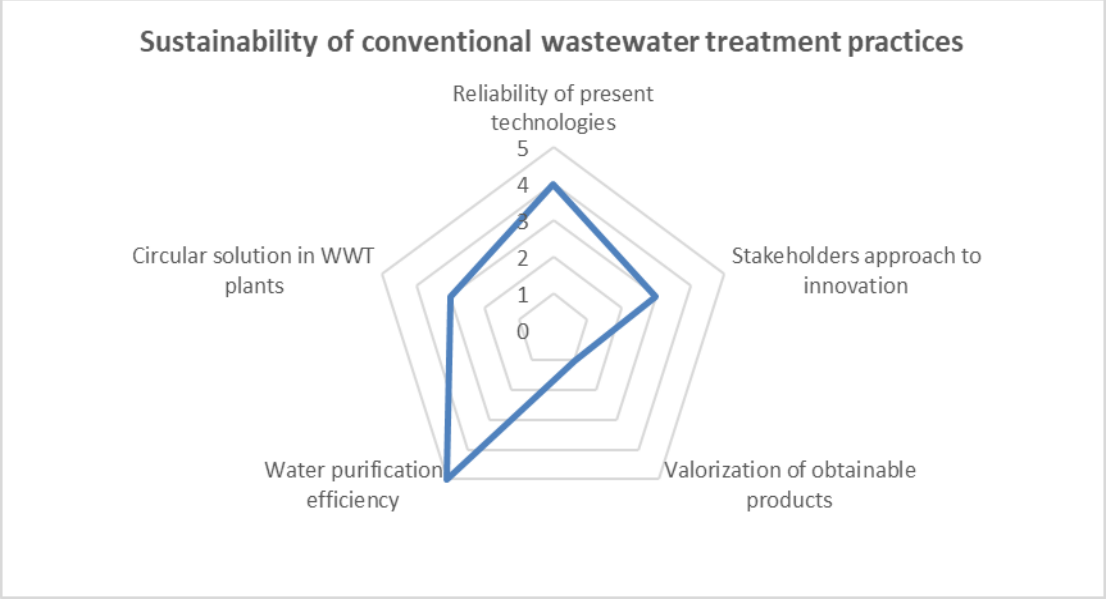


Figure 3. sustainability of conventional wastewater treatment practices

The “radar” area drawn by the 5 valued aspects shows a big strength in the water purification targets achieved by present technologies and identifies, as the main issue, the fact that with this technology, almost no products can be recovered by the organic compounds and nutrients available in wastewater. At the same time, another strength is the reliability. The present technologies are not able to ensure an efficient circular materials and resource recovery, but they sufficiently fulfil the objective they are used for: water purification, avoidance of pollution.

3.3 demonstrated by HRAP technology in comparison to present solutions

I 3.3. A - Energy consumption

Energy inputs were calculated based on energy requirements of 0.35 kWh/m^3 and 2.5 kWh/m^3 for ultrafiltration and centrifugation, respectively, and taking in account the concentrations achieved in each step (UF and centrifugation). The higher Energy input requirement is for *Tetraselmis* sp. At Archimede, due to the low concentration achieved in the first step of UF (only concentration factor of 5, when the other algae were concentrated to 10 or more). The best results have been registered for KOTO consortium, where 0,50 kWh/m3 of water given an algae concentration of 400 g/l. On average, the achieved concentration was around 200 g/l, with an average energy consumption of maximum 0,77 kWh/m3. In summary, given the low concentration on microalgae in wastewater, the microalgae harvesting technologies are ultrafiltration, and centrifugation. The energy consumption for wastewater treatment is reduced by the avoidance of biostabilization/oxidation section. Furthermore, algae equivalent energy recovered turns number from negative to positive energy balance. For this reason, impact of SALTGAE HRAP system on wastewater treatment has been valued with 4 on 5.

I 3.3. B - Products quality

Algae produced by demo plants demonstrated to be suitable for several applications.

- Proteins. The purity is finally reached but the protocol still requires some minor improvements in order to obtain a better yield.
- Animal feed. The small-scale results of including algae (Spirulina or Tetraselmis) in the formulations for piglet feed are very promising. Nowadays, we are developing specific trials that confirm that results in large scale level, analysing completely the nutritional potential of these natural sources of proteins and bioactive compounds.
- Chemicals. We have confirming the most interesting routes for algae oily fraction exploitation as platform chemicals. Due to the initial problems in getting pure useful algae oily fraction from partners, commercial vegetable Linseed oil has been used as chemical model to mimic the oily fraction and remain as reference to include in combination with algae oil.
- Edible coatings. Different algae protein extracts (Spirulina from Arava and Archimede, Tetrasemis and Koto) have been employed in the production of edible coatings. They have been applied on fruits (conference pears) and results confirm the viability to integrate the protein extract from selected algae into edible coating matrix, conferring barrier to gases and enhanced quality performances like the commercial one Decco. This can indicate the potentiality of algae protein extract for this use.
- Filler. Algal biomass can be added as a filler to the geopolymer paste in 1, 3 and 5% w/w. This addition has an apparent positive effect on the printability of the

ceramic paste and the rheology of the fluid resulted in interesting data that will be used to predict the best composition for the scale-up. Scaling up the process will provide new useful data for the selected application, i.e. construction products.

Despite algae quality is influenced by the type of wastewater processed, this study focuses on Food and Beverage sector, where contamination is low. Therefore, algae biomass average quality is considered at high level, also in comparison with competing solutions, which is almost unable to give out relevant quality products: 4 on 5.

I 3.3. C –Environmental sustainability

The primary economic benefit centers on the revenue that can be generated from the sale of the biomass, but this requires scales larger than those explored at the demonstration sites. Archimede is unique case, in that it is not simply a WWT facility, but a biomass production facility, and there is a difference. As mentioned previously, it is difficult to assess the value of the biomass being produced because of uncertainties regarding the type of WW that is being used as a growth medium. From an environmental perspective:

- The SALTGAE solution provides a gold standard example of the Circular Economy concept
- Nutrient reduction is achieved through uptake by the biomass. This avoids the use of high environmental impact chemicals such as ferric chloride for phosphorus removal and avoids energy intensive aeration for ammonia reduction.
- The 2-stage AD produces methane for energy production and CO_2 and nutrient rich digestate for biomass production
- The CO_2 emitted from anaerobic processes (1.0 kg $CO_{2,\ equiv.}$ /kg of COD removed) is reported to be less than half that of aerobic processes (2.4 kg $CO_{2,\ equiv.}$ /kg of COD removed).

Given the additional aspect of microalgae CO2 absorption during growth and biomass production rate from digestate, the environmental sustainability of the process, in comparison with existing solutions, is very high. Thus, the value given to this aspect is 5 on 5.

I 3.3. D - Technology complexity and operating risks

Technology complexity and operating risks is an important driver for assessing the impact of the proposed technology on present WWT plants installed by F&B industry. Despite present oxidation systems, as well as advanced membrane treatment systems are affected by complexity and strong maintenance, algae cultivation represents an integrated step in water treatment process, requiring specialized personnel and additional equipment. For this reason, the adoption of SALTGAE HRAP solution is considered to have not a large benefit on reducing plant maintenance and equipment. The value established for this aspect is 3 on 5.

I 3.3. E - Impact on water purification quality

Water purification achieved by the SALTGAE HRAP system can be compared with present conventional adopted. However, monitoring the strict values of final water quality will need the application of membrane filtration systems, thus it is expected that algae could not fully replace conventional systems.

3.3.1 Consideration on driver 3.3

The below radar-chart shows the results of 5 indicators analyzed above. Technology complexity is the most evident characteristic of SALTGAE process in comparison with existing solutions. This could represent a barrier against the industrial application of this process as a substitute of conventional simple systems

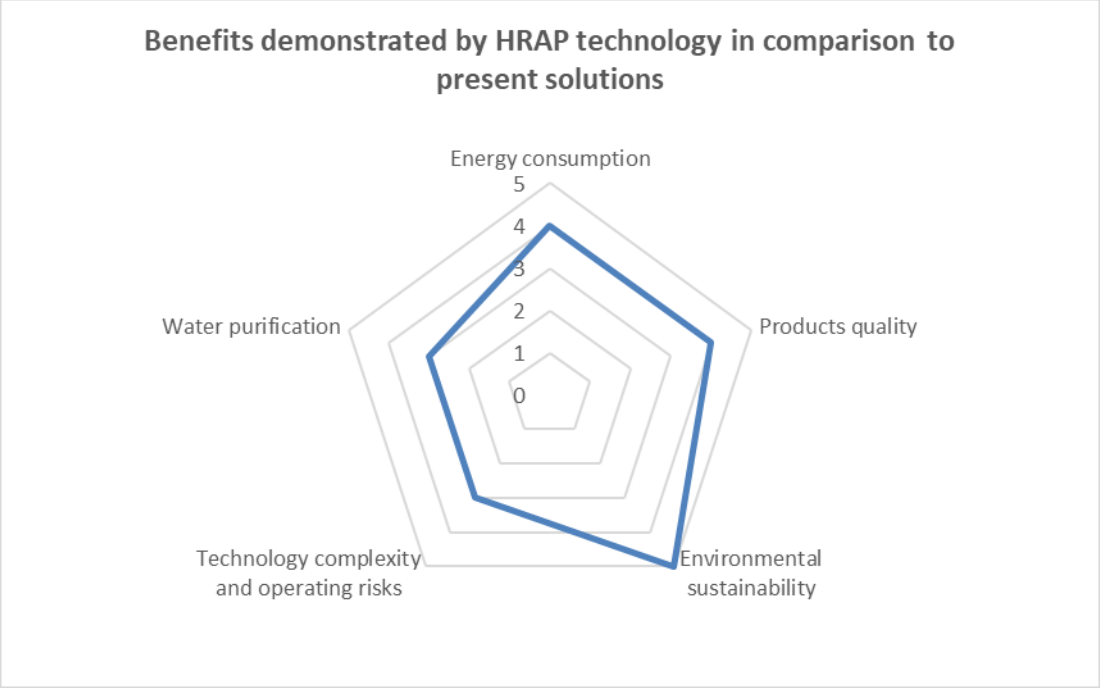


Figure 4. Benefits demonstrated by HRAP technology in comparison to present solutions

3.4 Stakeholders involved in the technology optimization and application

The number of stakeholders active in the technology sector is a strong driver giving the awareness about both the interest behind a technology, and the attractiveness in terms of market potentials. Therefore, this sub-function has been studied considering 5 stakeholders' categories, all of them directly involved in the technology development. This function is targeted to quantify the state of development of the technical solution proposed, thus it is different from the general stakeholders' analysis, which includes actors which are directly and indirectly involved in the proposed technology. The amount and relevance of stakeholders has been assessed giving to each category a "votation", from 1 to 5. The vote determines the availability of stakeholders involved or potentially involved in this sector, translating the number of actors in a readiness assessment for the proposed technology. 0 means no stakeholders available, 5 means many stakeholders easy to identify.

I 3.4. A - WWT Technology providers

According to the Environmental XPRT, a global environmental industry marketplace and information resource, there are more than 90 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 have been identified in D8.1. and listed carefully. In addition to them, many other companies are producing and selling technologies for wastewater treatment, adopting biological, but also membrane filtration, and other solutions available on the market. For this reason, the amount of technology providers in the field of WWT treatment has been valued with 5 on 5.

I 3.4. B - Algae biomass end-users

The evaluation of the number of algae biomass end users has been performed considering the type of algae produced by SALTGAE demo plants (Chlorella, Spirulina, Dunaliella). 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. Other sectors target of SALTGAE projects, are proteins, edible coatings, and chemicals. Potentially, if we consider algae as a general biobased stream usable for industry sectors, we can imagine a large-scale market and a huge number of stakeholders. However, at present, the only existing industry using microalgae at commercial scale is the animal feeding (fish farming, feed additives). For this reason, this indicator has been valued with 3 on 5.

I 3.4. C - Technology End Users

Technology end-users are those F&B industries and, in general industrial sector with high salinity wastewater to treat. The food and drink industry is the EU's biggest manufacturing sector in terms of jobs and value added. It’s also an asset in trade with non-EU countries. The important trade surplus in food and EU food specialties is well appreciated overseas. In the last 10 years, EU food and drink exports have doubled, reaching over EUR 90 Billion and contributing to a positive balance of almost EUR 30 Billion. At the same time, the strict regulation existing in EU for F&B industry sector imposed large industrial actors to fulfil all requirements concerning water recycling and purification. For this reason, the sector is already equipped for WWT and the technology proposed by SALTGAE is a substitute of existing solution. For this reason, despite the large size of this economy, the value for this indicator has been defined at 4 on 5.

I 3.4. D - Research institutes

According to Deliverable 8.1., there are about +300 research groups on microalgae in EU and +90 in other European countries (including Turkey, and Eastern Europe) each research group has 10-20 persons and there are several dozens of isolated researchers. Approximately, more than 10.000 persons are doing research on microalgae in Europe. R&D activities are covering the key elements of the value chain for increasing the sustainability of technology. In Europe, there are 57 master programs 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. There are 14 studies programs specialized to water and wastewater treatment. 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 labor 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 programs on algae to educate the next generation of skilled algal technicians to fill new job openings and to support algal commercialization. The number of research centers, and the number of activities carried out on algae at research and demonstration level represent a strength of this sector. For this reason, the value for this indicator is 5 on 5.

I 3.4. E - Algae production technology providers

This indicator was evaluated with 1 on 5. Algae sector is still considered an emerging sector. Cultivation of algae have reached an industrial development level only in few cases where fresh water was used for intensive microalgae cultivation. The knowledge on algae cultivation systems is a strong basis for the development of dedicated algae cultivation technologies adopting wastewater as growing media. However, the sector is still approaching the commercial development. Therefore, providers are still lacking in the market.

3.4.1 Consideration on driver 3.4

The below radar-chart shows the results of 5 indicators analyzed above. The Microalgae cultivation sector is represented by few actors. This aspect is due to the emerging stage of microalgae cultivation industry.

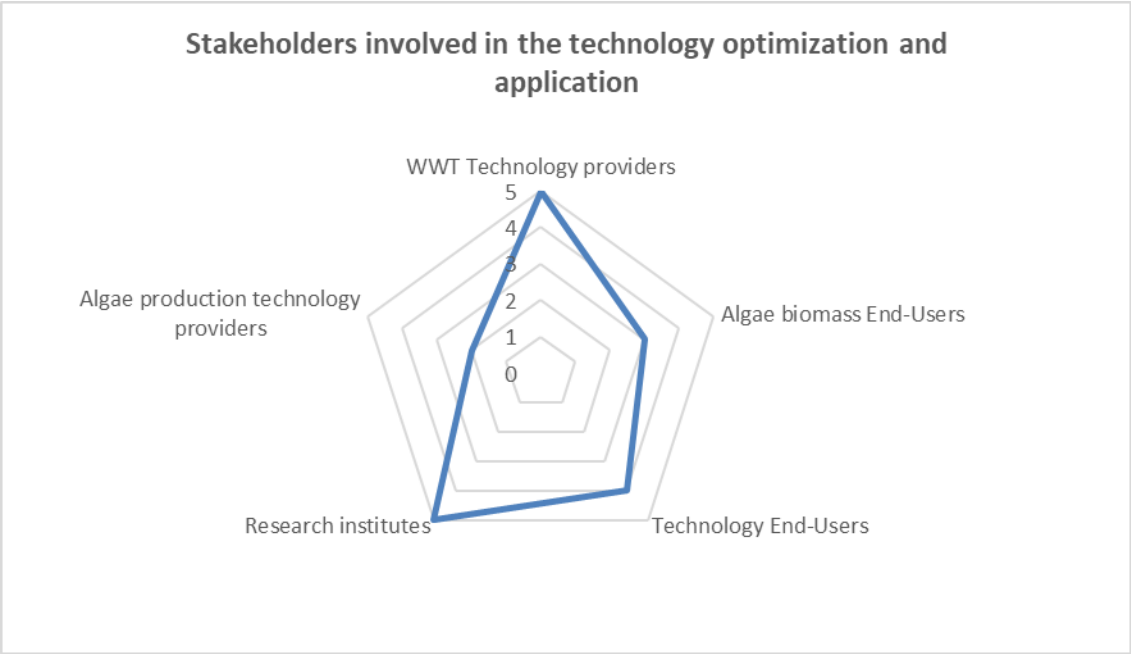


Figure 5. Stakeholders involved in the technology optimization and application

4 MARKET AND ECONOMICS

4.1 Economic impact of SALTGAE HRAP on F&B wastewater treatment solutions

I 4.1. A - Impact on Wastewater treatment energy consumption

According to SALTGAE demo-scale results, the ultrafiltration followed by centrifugation enabled high biomass concentration with energy input inferior to 0.77 kWh/m^3, with variable results depending on the microalgae, as shown in Table below.

Table 3. Energy consumption and cell concentration obtained from different SALTGAE demo plants

	Final cell concentration (g/L)	Energy input (kWh/m3)
Spirulina from Arava	90	0.49
KOTO microalgae consortium	419	0.50
Spirulina at Archimede	150	0.54
Tetraselmis at Archimede	250	0.77
Nannochloropsis at Archimede	250	0.56

Despite the optimal results obtained in terms of energy consumption per treated water, the benefit given by SALTGAE concept to the global energy consumption of WWT section is not of high impact for the economics. In comparison with conventional Wastewater treatment, SALTGAE HRAP system demonstrates to have an improving effect. The value estimated for this indicator is 3 on 5.

I 4.1. B - Personnel costs of new solution

According to the estimations performed in WP7, a demo plant operating with SALTGAE system is estimated to employ the following personnel

- 3 worker types required – Supervisor, biologist and semi-skilled worker
- At least 1 non-skilled worker working full time on the system, considering workload
- Biologist could be subcontracted for very small systems
- Plant manager can act in a supervisory capacity for the WWT system, allocating a percentage of time

The present employment condition of Archimede demo-site can help giving an example on expected personnel costs:

- Present Archimede personnel cost: 81,5 €/m3
- Expected value for personnel in industrial scale plant: 61,16 €/m3

These values could be even downscaled, however, the need of specialized personnel will in any case represent an additional cost for F&B industries. This can represent one of the main shortcomings of the proposed technology, which could be balanced only by the high value (end revenues) of obtained algae biomass. For this reason, the value of this indicator is 1 on 5.

I 4.1. C - Waste sludge disposal costs

A great advantage of SALTGAE system is that waste sludge will be avoided thanks to the purification performed with algae growth. For this reason, HRAP technology can guarantee the avoidance of waste sludge by F&B wastewater treatment plants, with a direct impact on companies' cost saving. This indicator has been valued with 5 on 5.

I 4.1. D - Equipment maintenance costs

Equipment maintenance is directly related with personnel costs. The integration of algae cultivation ponds in WWT plants will have a direct impact on plant management. Algae harvesting and collection will be monitored, and maintenance activities could be needed periodically to change membranes, clean ponds, adjust water parameters. For this reason, the proposed solution is estimated to have higher maintenance costs in comparison with existing technologies. Therefore, the indicator value is 2 on 5.

I 4.1. E - Value of purified water

According to the tests performed by SALTGAE partners demonstrated effective COD reduction by algae cultivation in wastewater, and a valuable performance in nutrients absorption. Additionally, algae harvesting with membranes allows to obtain a good quality water for different reuse. At the same time, water output quality can be achieved without microalgae cultivation, but just thanks to the application of COD reduction system and membranes filtration units. For this reason, SALTGAE system has been neutral concerning the water output purification quality, and the value identified for this indicator is 2,5 on 5.

4.1.1 Considerations on driver 4.1

The below radar-chart shows the results of 5 indicators analyzed above. Personnel cost will be higher in comparison with existing solution. This aspect is representing a strong bottleneck towards the technology business development.

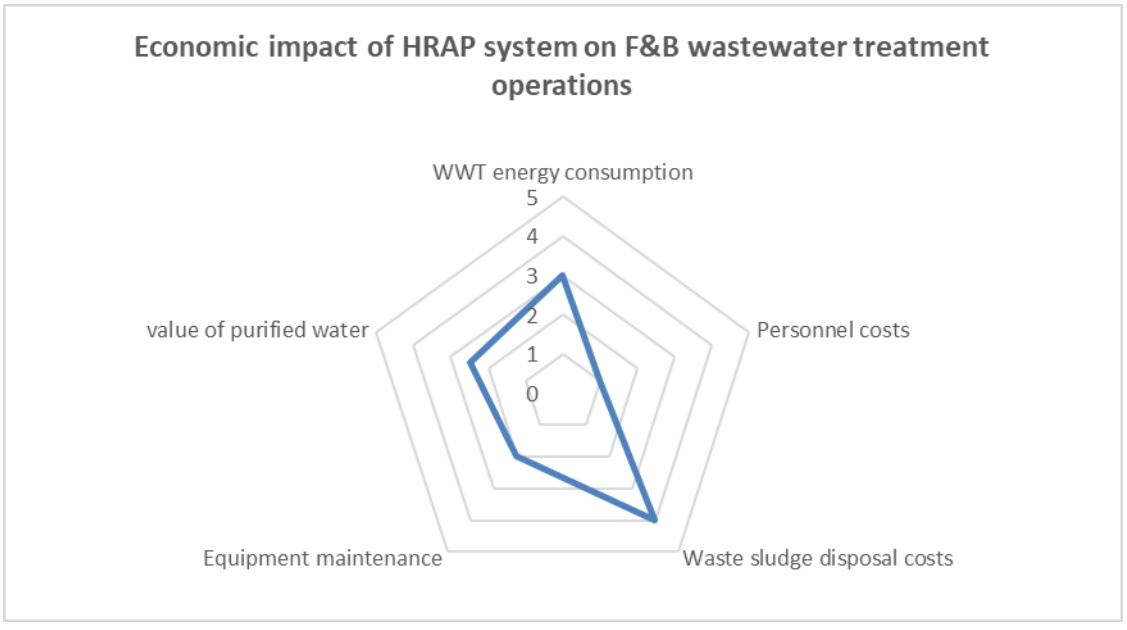


Figure 6. Economic impact on HRAP system on F&B wastewater treatment operations

4.2 HRAP system technology, components and structures

I 4.2. A - Possibility of HRAP integration in existing WWT system

The solution developed by SALTAGE project involves and integrates different water treatment technologies. In particular, the cleaning steps can be summarized as follows.

i. Separation of think suspended solids
ii. Valorisation of sludge BOD by means of anaerobic digestion
iii. Algae biomass cultivation on saline digested water
iv. Separation of algae biomass by membrane filtration systems, reducing water salinity

Apart from Step iii, where microalgae are involved, the other cleaning steps are well known technologies in the wastewater treatment sector. First step is usually present in all WWT plants, for removal of thick solids. Anaerobic digestion proposed by HRAP system is not considered a conventional AD unit, but in case of a WWT plants presenting existing anaerobic digesters, an integration and adaptation of the HRAP system could be evaluated. Membranes filtration system are well known solutions for saline wastewater treatment plants. For this reason, partial re-utilization of existing units in a new HRAP system is considered feasible. However, membrane separation units' performances, capacity, and tolerance are usually strictly dimensioned for wastewater characteristics. Therefore, the reutilization for separating algae in HRAP system will need to be redesigned and adapted. The identified value for this Indicator is 4 on 5.

I 4.2. B - Attractiveness of HRAP investment compared to conventional solutions

The complexity of HRAP system involves a wide range of advanced technologies which contribute to increase the investment for a single plant. The below table reports the Capex estimated for HRAP system having a processing capacity of $10m^3/h$. The reported values must be integrated with the cost of ponds.

Table 4. Capital Expenditure estimated for different SALTGAE HRAP components

Process step	Capacity	CAPEX	Unit
Pre-treatment	$10m^3/h$	430.000	€
AD	$10m^3/h$	750.000	€
Dryer	$10m^3/h$	130.000	€
Centrifuge	$10m^3/h$	250.000	€
Membranes	$10m^3/h$	600.000	€
Total		**2.160.000**	**€**

The advanced technologies needed for high level pretreatment, biogas production and desalination, and the additional step represented by the algae ponds contributes to increase the investment for this technology in comparison with conventional solutions currently adopted by F&B industry. The value for this indicator is 2 on 5.

I 4.2. C - Savings on wastewater treatment plant surface required

The proposed solution replaces the biological treatment system. However, surface required is requested for ponds, and Anaerobic Digesters. The presence of different units requires passages and space for maintenance, which contribute to increase the space required for this type of plant. For this reason, the value for this indicator is 2 on 5.

I 4.2. D - Investment cost reduction expected in future

The increase of investment costs due to the technology complexity could be reduced in the future thanks to different factors.

- Commercialization of the technology will develop a new components' manufacturing industries, with related costs reduction for equipment
- In future, new materials usable for harvesting units and AD systems, representing most of plant costs, could be developed contributing to reduce plant costs.
- Ponds CAPEX is related to the plant scale. A large-scale commercialization is expected to make the full HRAP solution competitive with conventional ones.

Therefore, the value for indicator is assessed at 4 on 5.

I 4.2. E - Equipment plant life cycle duration

The plant life cycle has been estimated considering the readiness level of proposed technical equipment involved in HRAP. The most relevant aspect influencing the equipment reliability is the uncertainty concerning algae ponds and performances of membranes separation units as algae harvesting system. The lack of demonstrated long time runs performed with the adopted equipment bring uncertainty on plant components life cycle. Therefore, this indicator has been valued with 3 on 5.

4.2.1 Consideration on driver 4.2

The below radar-chart shows the results of 5 indicators analyzed above. As visible, a strong aspect is represented by the expected CAPEX reduction in the next future. On the contrary, investment costs are considered critical for a fast market penetration in the short time.

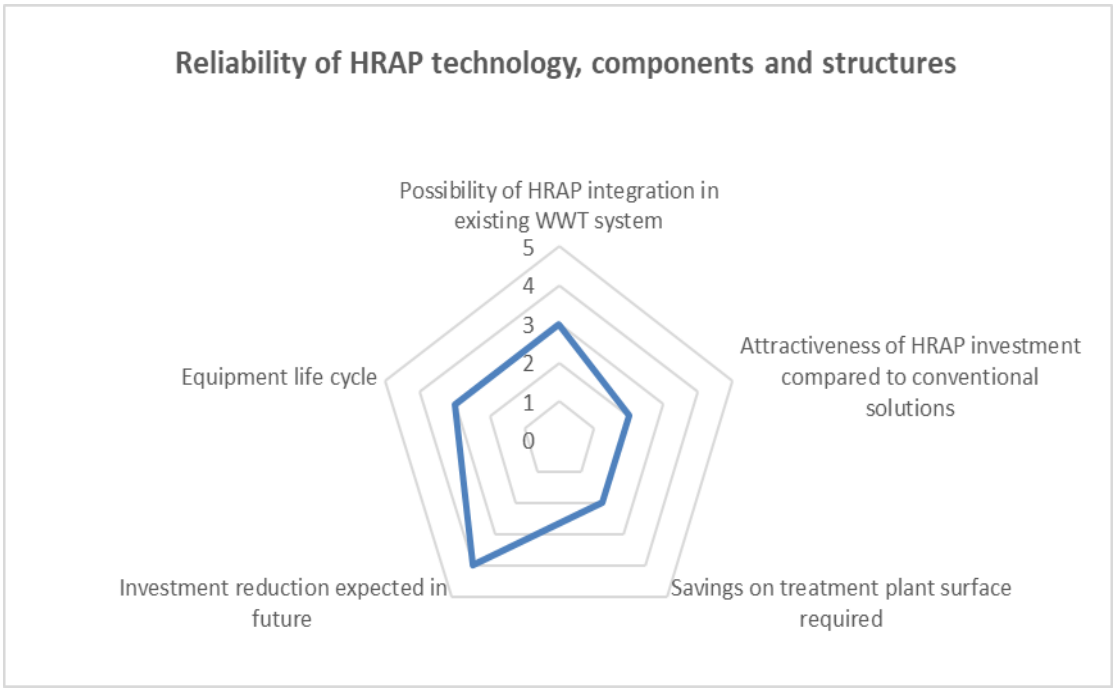


Figure 7. Reliability of HRAP technology, components and structures

4.3 Market Size and opportunities

I 4.3. A – Market size and trends for Wastewater treatment technologies

In 2018, the global water and wastewater treatment equipment market size was valued at 25.01 billion € and is estimated to expand at a CAGR of 3.68% by 2025 (https://www.grandviewresearch.com). More in details, in 2016, Frost and Sullivan estimated involved market like design and engineering, and reagents adopted by treatment plants, developing a high value market assessment outlook.

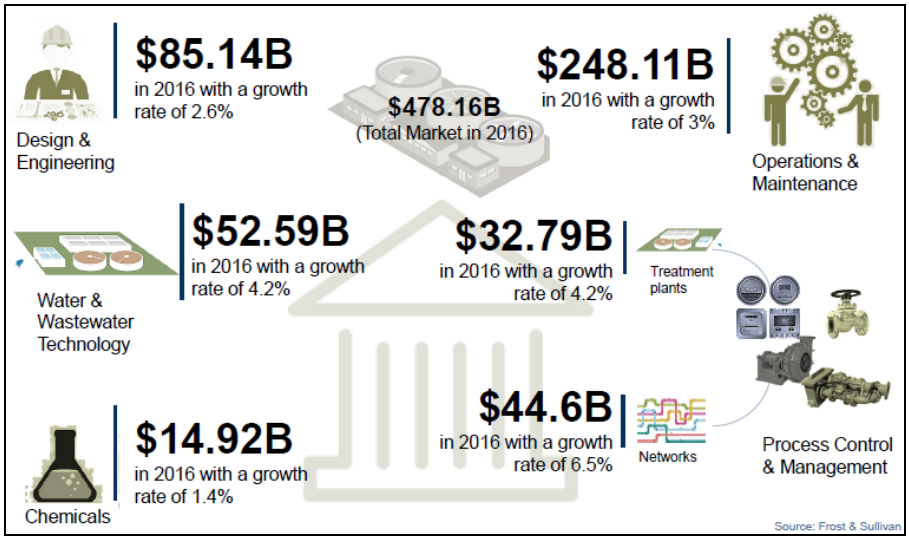


Figure 8. Wastewater sector global market size in 2016. Source: Frost and Sullivan

The expected investments in these equipment and facilities is projected to drive the market. Increasing demand for clean water, given by the demographic growth and the related industrialization, with rapid urbanization of emerging countries is resulting in a marked rise in the adoption of the equipment. Increasing requirements for minimized global water footprint and optimum quality yields in emerging economies (Asia Pacific), are anticipated to drive the market.

In Europe, the number of wastewater treatment plants has increased steadily over the past 20 years, while their technical standard improved, the release reported, and the market for municipal wastewater treatment plants will continue to grow in the long term. The EU Urban Wastewater Treatment Directive and the EU Water Framework Directive still provide the strongest market stimuli, especially in Eastern and Southern Europe, noted the release. At the same time, the maintenance and renewals activities, as well as measures for reducing operational costs (primarily in terms of energy and reagents) are increasing in Central and Northern Europe.

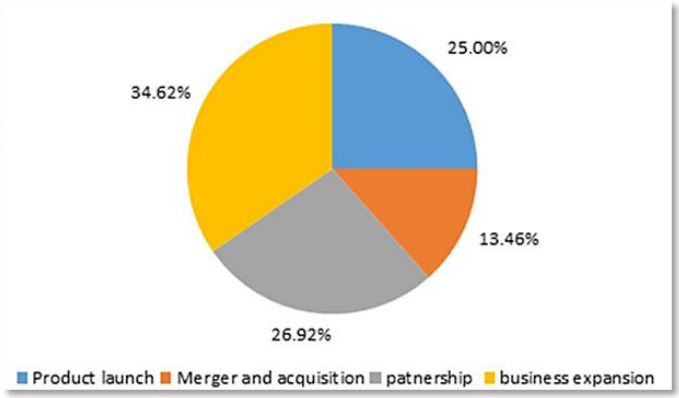


Figure 9. Winning strategies in wastewater treatment technology development at global scale

In general, despite differences have been identified in terms of growth rate and market size, the volumes and opportunities expected for water treatment sector are very promising. For this reason, the value given to this indicator is 5 on 5.

I 4.3. B – Present Market volumes for algae biomass

According to JRC report on microalgae market edited in 2014, although the global production volumes and market size of micro-algae in general are still relatively small, they have been characterised by high and increasing growth rates, from 1,000 tonnes dry weight in 1999 to 9,000 tonnes dry weight in 2011. Over 75 per cent of this production was for the dietary supplements market, including algae-based high-value food additives and ingredients, such as DHA. EABA (European Algae Biomass Association) presented in 2016 its report on algae market In Europe. According to the association, "with more than 400 companies operating in the sector, and a total turnover estimated in 2015 to be overcoming 750 M€ per year, the total microalgae biomass production (on dry weight) is evaluated as 500 dry tons per year".

	MICROALGAE <M€>	753 M€ > 60 COMPANIES (= TOP 20% THAT REPRESENT 80%) WITH RELEVANT MICROALGAE RELATED SALES
France	> 100	**Roquette**, Fermentalg, Greensea, Algosource, Microphyt, …
Norway	2	MicroAlgae, AS, Algaetech, Algalif, …
Spain	10	Fitoplancton Marino, Exeleria, Algaenergy, ASN, …
Ireland	1	Algae Health Ltd, …
UK	3	AlgaeFeed, AlgaeCytes, Xanthella, Supreme Biotech, Algenuity,…
Netherlands	> 350	**DSM** Martek, Feyecon, Photanol, LGem, AlgaeCom, …
Portugal	5	AlgaFarm, BuggyPower, Necton, Algicel, …
Italy	5	Archimede, F&M, Microlife, Algamundi, …
Denmark	1	AgroTech, …
Germany	> 100	**BASF** Cognis, Phytolutions, Subitec, Salata, Astaxa, GICON, MIAL, MINT, Bluebiotech, …
Belgium	1	Proviron, Orineo, …
Israel	> 20	Algatechnologies, NBT, Frutarom, Transalgae,…
Sweden	5	Astareal, Simris, …
Switzerland	> 100	Lonza, Antenna, …
Austria	2	Ecoduna, SAT,…

+7 SPECIES *Crypthecodinium, Ulkenia, Chlorella, Haematococcus, Nannochloropsis, Odontella, Arthrospira (Spirulina) + aquaculture*

20

Figure 10. European algae market and turnover in 2015. Source: EABA

At global level, looking at different algae biomass types, the dried Spirulina has the largest market, with more than 12,000 tons produced every year (at about 30 US$/kg), of which about 70% is produced in China, India and Taiwan. Worldwide, Chlorella producers cultivate an estimated 5,000 tons per year. The market volume of other microalgae is followed by D. salina (about 3,000 tn for carotene), a. flosaquae (1,500 tn for food), H. pluvialis (700 tn for astaxanthin), C. cohnii (500 tn DHA), Shizochytrium (20 tn of DHA).

According to the European Commission's Annual Economic Report on EU Blue Economy, the EU algae biomass sector in 2018 jumped to a value of EUR 1.69 billion, including research and development, equipment production and jobs in the larger supply chain that depend on output from the algae sector. Specific market volume per country are reported by the above table, provided by EABA in 2016. Market development for algae-based products can be stated as an emerging market, where a modest production is now available in EU.

The limit is given by lack of regulation, and high production costs. Different estimation has been provided by JRC and EABA concerning microalgae biomass available on the market. However, even considering the most optimistic vision of 9,000 dry tons/ year, it comes out that most of the microalgae turnover is represented by research and demonstration activities. In fact, with a production of 9,000 tons of microalgae on dry basis per year, and an estimated cost of 30 €/kg (spirulina for food sector), the turnover generated by algae products in EU should not overcome 270 M€. For this reason, the value to this indicator is 2 on 5.

I 4.3. C – Market growth and trends for algae biomass

Rise in global population and increase in demand for food and customization of functional food product are the factors expected to boost the growth of the algae products market. In addition, application of algae as protein source for production of livestock for aquaculture species such as fish for their cultivation support the market growth. However, consumption of algae-based prescription drug products, such as sun chlorella, microalgae, spirulina caused gastrointestinal, abdominal, and nausea health problem, is expected to hamper the market growth during the forecast period. According to a 2018 report by “Report Linker”, reported by Forbes, on the global algae market, the algae products market is projected to grow to $5.2 billion by 2023, at a CAGR of 5,4%. The report also notes that during this same time, 2018 to 2023, algae protein and the nutritional and dietary supplement segment is projected to have the highest growth rate. According to the report, the demand for algae-based food and beverage products is growing. Ice cream and food additives manufacturers are starting to add algae to their products to increase the nutritional value and the sustainability of the product. Many stakeholders, including algae biomass end users and consumers, but also umbrella associations, agree the positive trend concerning algae market. In particular, the expected success of algae biomass within the future EU bioeconomy is related to the food sector, where different algae species have already been exploited successfully. However, the difficulty in estimating the effective and actual growth of microalgae biomass does not allow to identify the potential growth. For this reason, a value of 3 on 5 has been agreed for this indicator.

I 4.3. D – Market volumes and trends for SALTGAE products

SALTGAE project focused on using microalgae for producing the following end market products:

- Proteins (food)
- Animal feed
- Chemicals and fillers
- Edible coatings

A market assessment summary has been provided for each of the above products.

Proteins (food). Microalgae are a source of high quality, essential proteins, bioactive polysaccharides and pigments with therapeutic potential. The protein content of some microalgae species, including Chlorella, Spirulina, Scenedesmus, Dunaliella, Micractinium, Oscillatoria, Chlamydomonas, and Euglena, accounts for more than 50% of the dry weight. In comparison to conventional plant-sourced nutrients, microalgae offer the advantage of fermentative production and comparative simplicity of extraction of these valuable components. The current use of algae in food is predominantly the use as capsules sold as health food. The capsules containing algal powder are sold as remedy to a wide variety of illnesses. Algae are also used as ingredient in pasta, drinks, snacks, candy and gum. The species of micro algae that are currently used as food or food

ingredient are restricted: only Spirulina (Arthrospira), Chlorella and Dunaliella are used. Despite the positive nutritional composition, dried micro-algae use as direct food have not gained significance as food or food ingredient. The reason for this minimal use in food is several obstacles. The first is related to the “taste properties” of dried algae biomass. The powder-like consistency, the green colour and the fishy smell of the algae biomass are the most significant obstacles. The high production cost is the final obstacle. Protein is one of the main nutrients that will be in short supply in the future. Alternative protein sources and production methods are required to fulfil the demand of consumers and to meet predicted global protein requirements. Algae are generally regarded as a viable protein source, with EAA composition meeting FAO requirements and they are often on par with other protein sources, such as soybean and egg.

Several businesses have been set up for the sale of algal products, which produce protein- and lipid-rich algal flour. According to “mordorintelligence”, the global algae protein market is expected to register a CAGR of 6.5% during the forecast period (2018-2023), owing to the growing demand for plant-based protein alternatives, the positive effects of the algae proteins on the immune system, and their attributes that improve the nutrient content of the food. Europe leads the market for algae proteins, owing to high research in the growth of algae and cheaper methods of preparation of the protein from algae. In the APAC region, India and China have been dominating the market, owing to increasing consumer awareness regarding the health benefits of algae protein.

Animal feed. In 2016, the global animal feed production was about 1 billion tons, for around 400 billion dollars of market turnover. The high protein content of algae can also be beneficial for use as animal feed, including aquaculture, farm animals, and pets. An estimated 30% of global algal production is estimated to be used for animal feed, with 50% of Spirulina biomass in particular used as feed supplement due to its excellent nutritional profile. Several species of microalgae including Spirulina, Chlorella, and Schizochytrium sp, and seaweed can be incorporated as protein sources into the diets of poultry, pigs, cattle, sheep, and rabbits. Most of the research on the incorporation of algae as animal feed has been carried out with poultry, likely due to their promising prospects for improved commerciality. Tasco® is an example of a proprietary seaweed meal derived from A. nodosum, produced by Acadian Seaplants in Nova Scotia, Canada, which has demonstrated beneficial properties when included in animal feed.

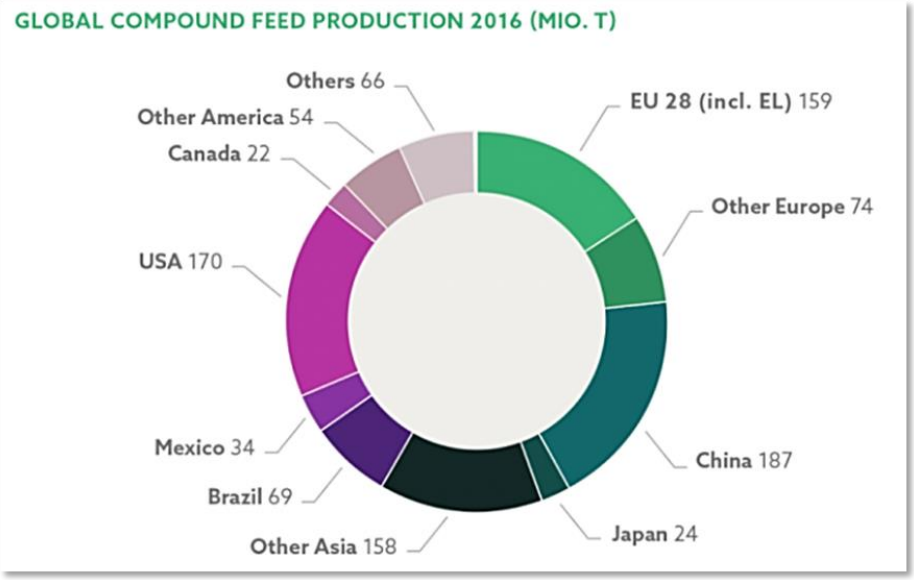


Figure 11. Global compound feed production in 2016 (MTons). Source: FEFAC

The United Nations Food and Agriculture Organization (FAO) estimates that by 2050 the demand for food will grow by 60% and that between 2010 and 2050 production of animal proteins is expected to grow by around 1.7% per year, with meat production projected to rise by nearly 70%, aquaculture by 90% and dairy by 55%.

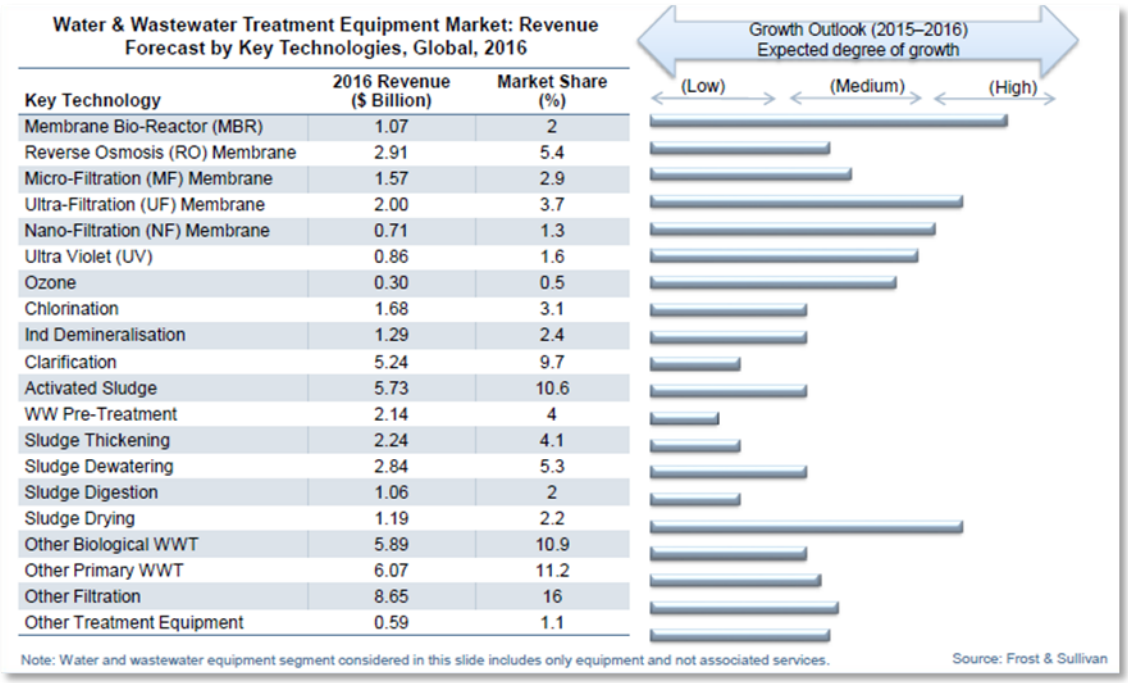
Chemicals and fillers. As mentioned in above paragraphs, the global algae products market is classified based on application into food & dietary supplements, animal feed, chemicals (adhesives, resins, etc..), edible coatings and fillers (plastic materials). The food & beverage segment dominated the market with the largest share in 2017, and is expected to exhibit significant growth during the forecast period. A reduced market size is expected for biobased polymers like fillers or chemicals in comparison with food sector. However, the raising appeal of biobased material is driving the growth of market like bio-resins and adhesives, which are expected to grow rapidly and post a CAGR of more than 16% from 2017 to 2023. The same can be stated for fillers to be replacing fossil based polymers. The increasing interest in biobased plastics and more sustainable building blocks, even in the 3D printers sector, presents an opportunity for algae-derived products.

Edible coatings. Packaging accounts for approximately one-third of the world's garbage. Increasing awareness about environmental problems related to disposal of solid waste and reducing the amount of waste generated are major reasons why food manufacturers are focussing on packages that can be recycled, in order to reduce the amount of wasteAccording to future market insight, the revenue generated from the global edible films and coatings market is estimated to be valued at US$ 2,139.1 Mn by the end of 2017 and is expected to increase at a CAGR of 4.5% over the forecast period. Global edible films and coatings market is expected to be valued at US$ 3,336.7 Mn by the end of 2027.

Summary of values. The general value estimated for the present and expected market value for SALTGAE products can be assessed considering that, by far, the most interesting sectors are food and feed, while chemicals and fillers represent interseting but not currently approachable market sectors. Unfortunately, application of microalgae obtained on wastewater in food sector is not easy due to the contamination of metals which can occur during treatment process. However, F&B sectors present water streams with not high concentrations. For this reason, the value for this indicator has been decided as 3 on 5.

I 4.3. E – SALTGAE opportunity versus competitors

Microalgae producers in ASIA represents the most critical competitors for SALTGAE technology in the end products commercialization. In fact, the low operational costs and manpower available in Asian countries, in addition to favourable climate conditions, allow these regions to reduce the microalgae price and, thus, representing the main producers worldwide. Regarding competitors of SALTGAE as wastewater treatment technology, the size of the sector and the growing interest of companies to avoid sludge disposal costs and increase their sustainability is opening the doors to many technical solutions. As visible by table below, in 2016 the fragmentation of adopted technologies (with domination of activated sludge system), was already at high level.



Water & Wastewater Treatment Equipment Market: Revenue Forecast by Key Technologies, Global, 2016

Key Technology	2016 Revenue ($ Billion)	Market Share (%)
Membrane Bio-Reactor (MBR)	1.07	2
Reverse Osmosis (RO) Membrane	2.91	5.4
Micro-Filtration (MF) Membrane	1.57	2.9
Ultra-Filtration (UF) Membrane	2.00	3.7
Nano-Filtration (NF) Membrane	0.71	1.3
Ultra Violet (UV)	0.86	1.6
Ozone	0.30	0.5
Chlorination	1.68	3.1
Ind Demineralisation	1.29	2.4
Clarification	5.24	9.7
Activated Sludge	5.73	10.6
WW Pre-Treatment	2.14	4
Sludge Thickening	2.24	4.1
Sludge Dewatering	2.84	5.3
Sludge Digestion	1.06	2
Sludge Drying	1.19	2.2
Other Biological WWT	5.89	10.9
Other Primary WWT	6.07	11.2
Other Filtration	8.65	16
Other Treatment Equipment	0.59	1.1

Figure 12. Wastewater treatment equipment market: Revenue forecast by key technologies. Source: Frost & Sullivan

The pathway for SALTGAE process to penetrate the sector is complicated and not easy in the short term. For this reason, the value of indicator 4.3. E is 2 on 5.

4.3.1 Considerations on driver 4.3

The below radar-chart shows the results of 5 indicators analyzed above. Competitors in algae biomass production are mainly identified in non-european producers, which are low-cost algae biomass producer, mainly thanks to the low personnel and permission costs.

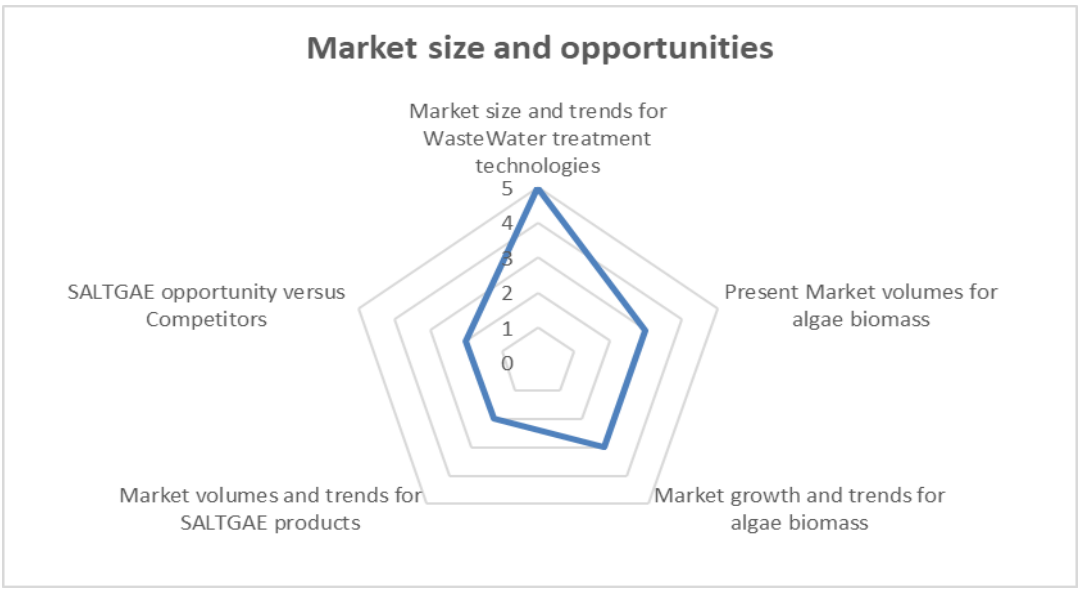


Figure 13. Market size and opportunities.

4.4 Impact of Algae products obtainable,

4.5 value and market demand

I 4.4. A - Algae biomass relevance on plant economics

The impact of algae biomass on plant economics is relevant as it represents the core added value of the proposed solution. According to the tests performed by SALTGAE demo tests, different algae species will ensure a reliable yield. According to performed tests, algae biomass produced from different wastewater could be in a range of 0,1-0,15g/l. the below table assumes a water treatment capacity of around 10m^3/h

Table 5. Production rate obtained by SALTGAE tests per algae type

Algae type	Industry	Yield *(g/L day)*	Hourly prod *(g/h)*	Daily prod. *(g/day)*	Annual prod. *(kg/a)*
Dunaliella	tannery	0,14	1.400	33.600	11.088
Tetraselmis	cheese	0,15	1.500	36.000	11.880
Chlorella	Fish	0,10	1.000	24.000	7.920

According to IEA, the market price of algal biomass for bulk chemicals and food commodities is below 2 €/kg, which makes it imperative to drop costs below this level to be competitive in the market. With this value, and the expected production of around 10,000 kg/y, the incomes from algae biomass would be around 20-30,000 €/y. Despite this represents not a large income if compared to the plant capex, the on-site refining activity could achieve the production of high-quality products (food and feed, chemicals), of which gross market value is around 100 €/kg. In summary, algae biomass represents a strong driver for plant economics, as it will be the main revenue together with Biogas production. However, there are uncertainties concerning the expected real cost of algae biomass in a large-scale market, also depending on the reuse, and the reliability of algae refining technologies for upgraded added value products extraction. For this reason, the identified value is 4 on 5.

I 4.4. B - Stability of algae biomass production rate

Stability of algae biomass production rate is one of the key aspects to validate the commercial readiness level of a technology. Despite advanced monitoring systems and the growth in a controlled indoor ambient, the production rate of algae biomass can have a variation related to different operating conditions. Additionally, stability can be validated only after a proven long-term production (thousand hours). For this reason, this indicator is valued with 2 on 5.

I 4.4. C - Market demand for algae biomass produced volumes

According to the market assessment reported In TIS report D8.1, it can be calculated a total potential algae biomass of 166,298 tonnes from utilisation of the SALTGAE solution is available 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. The algae biomass volumes produced by SALTGAE systems will perfectly fit in the expected EU algae biomass market. At the same time, due to the uncertainty concerning competitor systems in algae production sector and future development in wastewater treatment, the value decided for this indicator is 4 on 5.

I 4.4. D - Final competitiveness of algae biomass produced

The fact that algae biomass will be produced as a waste-derived product, represents an opportunity in terms of product competitiveness. The SALTGAE system will benefit of a reduced number of reagents to be used for algae cultivation, as it will be focused on extracting them from wastewater and from AD. Moreover, despite the reduced yield, the system will be part of an integrated industrial wastewater treatment, of which algae biomass will represent only a part of all revenues. For this reason. The final competitiveness of the obtained algae biomass has been valued with 4 on 5.

I 4.4. E - Market demand for expected algae biomass quality

Quality is a barrier concerning the SALTGAE system produced algae biomass. In fact, the difference between microalgae dedicated cultivation systems and SALTGAE system is that the SALTGAE concept starts from a wastewater. The main target of a wastewater treatment plant will be that of depurating the water effluents, while algae quality optimization could not be optimized. Products to be achieved from produced biomass are:

- Proteins.
- Animal feed.
- Chemicals.
- Edible coatings
- Filler

According to SALTGAE tests, microalgae quality will be technically suitable for ensuring the production of above mentioned products, with limits on the process yield. For this reason, this indicator has been valued with 3 on 5.

4.5.1 Considerations on driver 4.4

The below radar-chart shows the results of 5 indicators analyzed above. Stability of algae biomass production rate is still considered a bottleneck of Saltgae process as algae-biomass producing solution. In fact, according to the tests performed so far, the production volumes are influenced by the wastewater characteristics and by the operational steps. Specific evaluation must be developed case by case.

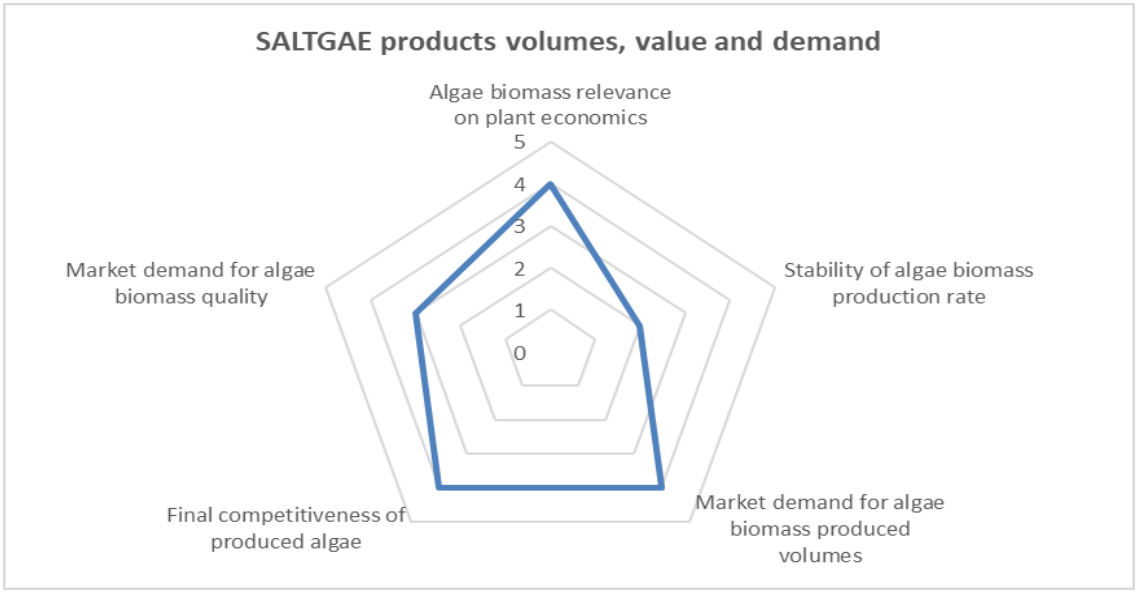


Figure 14. SALTGAE products volumes, value and demand.

5 SOCIO-CULTURAL OPPORTUNITY

5.1 Employment impact of proposed solution

I 5.1. A - Generation of new direct jobs

As investigated in the economic assessment drivers, SALTGAE system will ensure a strong impact in terms of direct employment. According to estimates, 3 worker types will be required for each plant: Supervisor, biologist and semi-skilled worker

- At least 1 non-skilled worker working full time on the system, will be needed considering workload
- A Biologist could be subcontracted for very small systems
- A Plant manager could act in a supervisory capacity for the WWT system, allocating a percentage of time

As an example: a plant of about 10000 square meters will require 6 new employees. For this reason, indicator on new direct jobs has been valued with 4 on 5.

I 5.1. B - Generation of new indirect jobs

The great impact of algae sector on EU bioeconomy is mainly related to the wide range of advanced quality products to be extracted from algae biomass. The production of tons of dry algae biomass from wastewater sector will have the opportunity to generate new indirect jobs. All these jobs will be related to the processes for extracting advanced products from algae biomass harvested, creating new specific and attractive market sector. The value given to this indicator is 5 on 5

I 5.1. C - Formation of new experts (specialized workers) category

As reported in D8.1, in Europe, there are 57 master programs 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.

Literature estimation

	Employee type		
Scale	Plant Supervisor	Biologist	Unskilled Worker
m^2	No.		
40000	1	1	7
30000	1	1	6
20000	1	1	5
10000	1	1	4
5000	1	1	3
2500	1	1	2
1250	1	1	1
625	0.5	0.5	1
312.5	0.25	0.25	1

Figure 15. Employment for SALTGAE HRAP system

According to TIS interviews, the current situation is no ideal because of complexity of it which requires of work labor 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. The development of commercial SALTGAE concept will allow to start new industrial research activities and new courses for the formation of a new category of specialized experts in algae use for wastewater treatment. Future impact of SALTAGE in a new expert category is valued with 5 on 5.

I 5.1. D - Formation of new companies on algae biomass refining

According to TIS, there are few companies working on algae refining for advanced products:

- 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.
- FUNDITEC (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.
- 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.

The commercial development of SALTGAE system will be strongly related to the formation of new companies exploiting algae produced biomass. Therefore, Indicator value is 5 on 5.

I 5.1. E - Replicability of the proposed model

The replicability of SALTGAE system is not always easy to evaluate. In fact, different algae species and different solutions must be designed considering the wastewater quality, the amount of effluents, and the specific aspects concerning wastewater produced by single plants. For this reason, SALTGAE developed and investigated different solutions for different water categories (high BOD, low BOD). However, despite SALTGAE concept replicability is wide, the real project and technology is strongly variable depending on a wide range of factors (region, industry type, algae used, capacity, etc..). for this reason, the value for this indicator has been assessed at 3 on 5.

5.1.1 Consideration on driver 5.1

The below radar-chart shows the results of 5 indicators analyzed above. Indirect job generation is still an uncertain point, as it will be related to the impact on algae biomass market volumes and on the creation of new value chain steps.

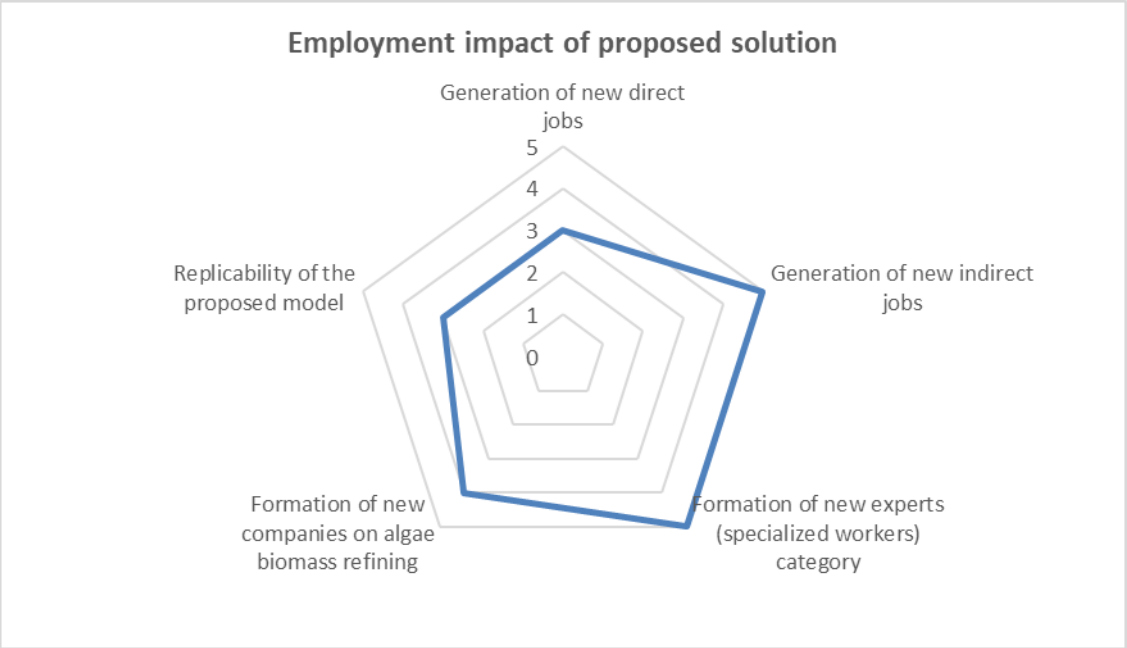


Figure 16. Employment impact of proposed solution

5.2 Improving F&B symbiosis industry sectors

I 5.2. A - New industry sectors involved in SALTGAE model

SALTGAE model is not strongly related to the development of other sectors different from F&B and algae refining. The range of industry sectors involved in the SALTGAE concept can be identified as:

- Water separation technology providers
- Anaerobic digestion plants providers
- Algae biomass users
- F&B industries
- Water users

The innovative industry sector involved in the systems are all related to the manufacturing of algae cultivation ponds, and algae biomass refining. All other technologies involved are well known in the wastewater treatment sectors. For this reason, value has been agreed to be 3 on 5.

I 5.2. B - Market size of final algae product

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 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. Value of algae products market size is maximum (5 on 5) considering the high rate market growth.

I 5.2. C - Recyclability of depurated water

Recyclability of depurated water has been valued in comparison with present depuration level achieved. According to project results, no improvements will be achieved in comparison with conventional wastewater treatment. For this reason, the value is 3 on 5.

I 5.2. D - Number of actors in the proposed value chain

As above mentioned, the actors involved in the future SALTGAE value chain, excluding technology providers, will be:

- F&B industries
- Algae biomass producers
- Algae biomass end-users
    - Chemical industry
    - Food and feed industry
    - Biomaterials industry sector
    - Pharmaceutical sector

Considering that further developments are expected in the identification of most effective algae streams for water treatment, specific end using sector will be identified in the future, representing a fixed part of the value chain. The wideness of the SALTGAE system value chain has been quantified with 3 on 5.

I 5.2. E - Improvement of side - industries sustainability

One of the main benefits of SALTGAE system is represented by the impact of the technology on the sustainability improvement for industries involved in the value chain. The proposed concept will improve the sustainability of F&B industries, reducing the CO2 emission of wastewater stabilization process. At the same time, algae biomass will be used to replace materials with higher environmental impact, in food and feed, agriculture, or chemical sector. For this reason, the impact of SALTGAE system on value chain industries sustainability has been valued with 4 on 5 points.

5.2.1 Consideration on driver 5.2

The below radar-chart shows the results of 5 indicators analyzed above. Saltgae model is estimated to push algae biomass refinery sector, transforming Wastewater treatment sector in a biomass producing industry. Other sectors are far from being influenced by the algae volumes produced by this technology in Europe and worldwide

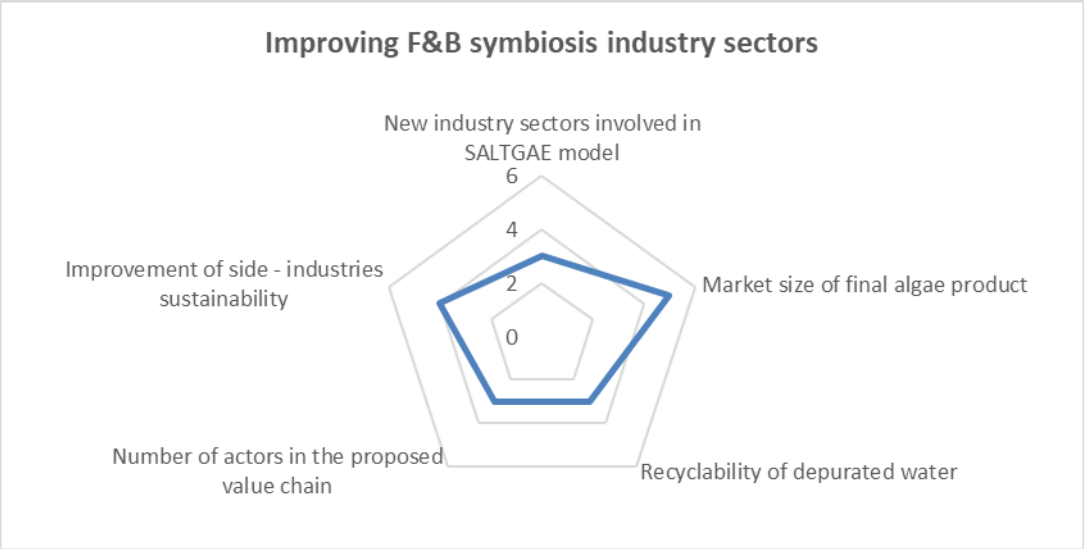


Figure 17. Improving F&B symbiosis industry sectors

5.3 Role of Algae-products in a sustainable society

I 5.3. A - Algae role in sustainable cosmetic industry

In cosmetic industry microalgae have been already used since a long time. At the same time, only specific algae species are usable by this sector, which have not yet tested for wastewater treatment by SALTGAE project. For this reason, also considering the present use of algae biomass at industrial scale and the simple penetration strategy for this sector the role of algae, and SALTGAE biomass in cosmetic sector has been quantified a 3 on 5.

I 5.3. B - Algae impact on food and feed sector

Food and feed sector seem the most promising in terms of volumes, range of algae species, and market demand. Despite some barriers are hindering the use of algae biomass from WWT in feed sector, the promising market has been valued with 4 on 5.

I 5.3. C - Algae relevance for agriculture sector sustainability

Agriculture, and in general plant growth sector is interested in microalgae as a valuable source of nutrients. The production of high-quality fertilizers with microalgae is easily demonstrated by the existing products. In addition, microalgae cultivated on wastewater will valorize the nutrients of the sludge, which are usually wasted. For this reason, this indicator has been valued with 4 on 5.

I 5.3. D - General interest on algae biomass for bioplastics sector

Algae biomass is considered suitable for bioplastics production, thanks to the purity and the large amount of lipids and sugars. At the same time, the algae production costs and the plastics market size represents obstacles for the application of this high quality biomass in the polymers industry. Many projects are ongoing and some of them demonstrated the suitability of different algae streams for producing polymers. However, due to the low quantity of algae produced by average size SALTGAE WasteWater treatment plant, bioplastic sector is of reduced perspective compared to the other end uses. For this reason, 2 of 5 is the value of this indicator.

I 5.3. E - Sustainability of algae as biomass source

Sustainability is one of the most relevant aspects making SALTGAE process a real attractive strategy for improving the sustainability of both food industry and bioeconomy. Thanks to the demonstrated CO2 absorption, and to the role of algae biomass as depuration element, SALTGAE contribution to the creation of a sustainable society has been valued with 5 on 5.

5.3.1 Consideration on driver 5.3

The chart below summarizes the results reported by different indicators. On summary, driver 5.3 shows what is also common in algae sector. A strong interest is emerging for algae use in food and feed sector and, in general as a sustainable feedstock.

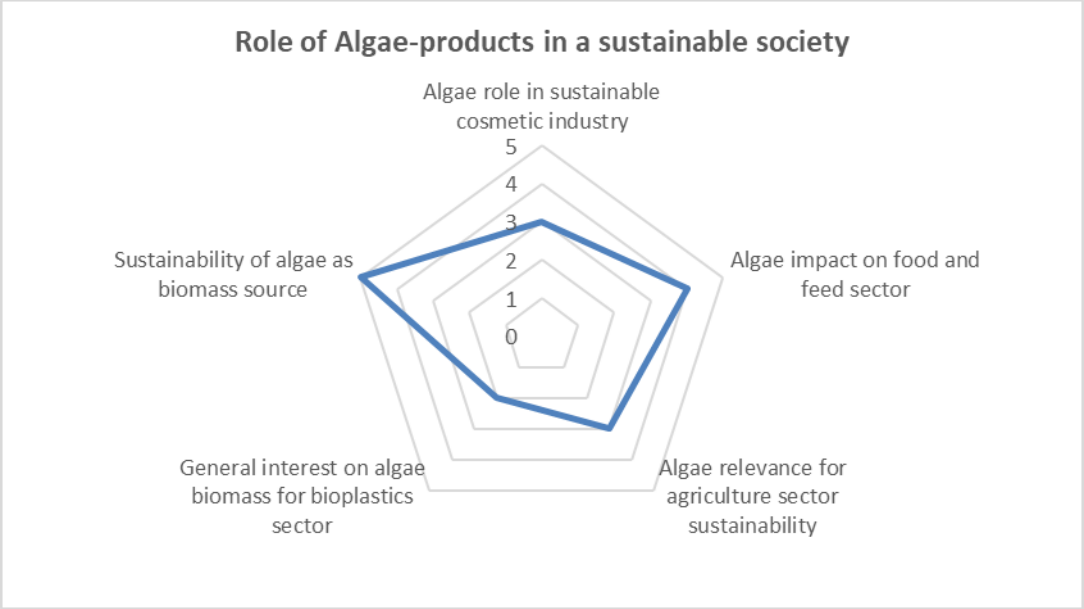


Figure 18. Role of Algae-products in a sustainable society

5.4 Impact on local circular economy

I 5.4. A - Feasibility of reusing algae biomass for new products

The microalgae obtained from SALTGAE process will have the main target of water depuration and CO2 absorption. The obtained algae biomass will represent a valid feedstock for a wide range of application and end uses (food, feed, materials, fertilizers), however, specific composition depend on the waste-water treated and on the specific salinity condition, which will have an impact on final biomass application. The reutilization of algae will be ensured by the interest demonstrated by the market on this type of biomass; however, some limits are existing, in particular concerning use for food and feed sector

I 5.4. B - Opportunity of recycling depurated water in F&B industry

The reutilization of depurated water directly in F&B sector is at present not a simple solution. Strict conditions must be respected by F&B companies for using in internal processes. Therefore, disposal or recycling by third parties are expected as final water usage practices. For this reason, the value given to this indicator is 3 on 5.

I 5.4. C - Contribution to critical raw materials savings

Algae extraction from F&B wastewater could allow to recover organic carbon, and some nutrients contained in the sludge. However, no critical raw materials are directly saved by the application of algae biomass as feedstock. Magnesium and Phosphorus could represent two CRM recovered by algae cultivation in wastewater, but quantities expected in this sector are reduced. This indicator has been valued with 2 on 5.

I 5.4. D - Impact on water consumption reduction

Despite direct water reutilization is not easy for food industries, depurated water could reach suitable quality for cleaning and irrigation practices. Advanced filtration systems adopted to harvest algae biomass could allow a strong COD reduction to make water available and reduce the consumption of fresh water for some processes. Water reutilization related to SALTGAE process has been considered with 4 o 5.

I 5.4. E - Replicability of proposed model

The SALTGAE model has been studied and developed to be applicable to a wide range of F&B sectors. The project demonstrated efficacy for chees, fish, tannery and other industry sectors. At the same time, the SALTGAE concept could be applied to different F&B industries after specific analysis of wastewater, in order to be adapted and optimized. Some binding conditions could be identified, hindering the process applicability, like concentration of solids, salinity, and contaminants affecting final algae quality.

5.4.1 Consideration on driver 5.4

The below radar-chart shows the results of 5 indicators analyzed above. As visible, the obtained biomass will represent an example of circular economy strategy for extracting a product (algae biomass), from a waste (wastewater). Despite the circularity of the proposed model, it is expected that SALTGAE process won't have a strong impact on the creation of local circular economy, thus with local reuse of produced algae.

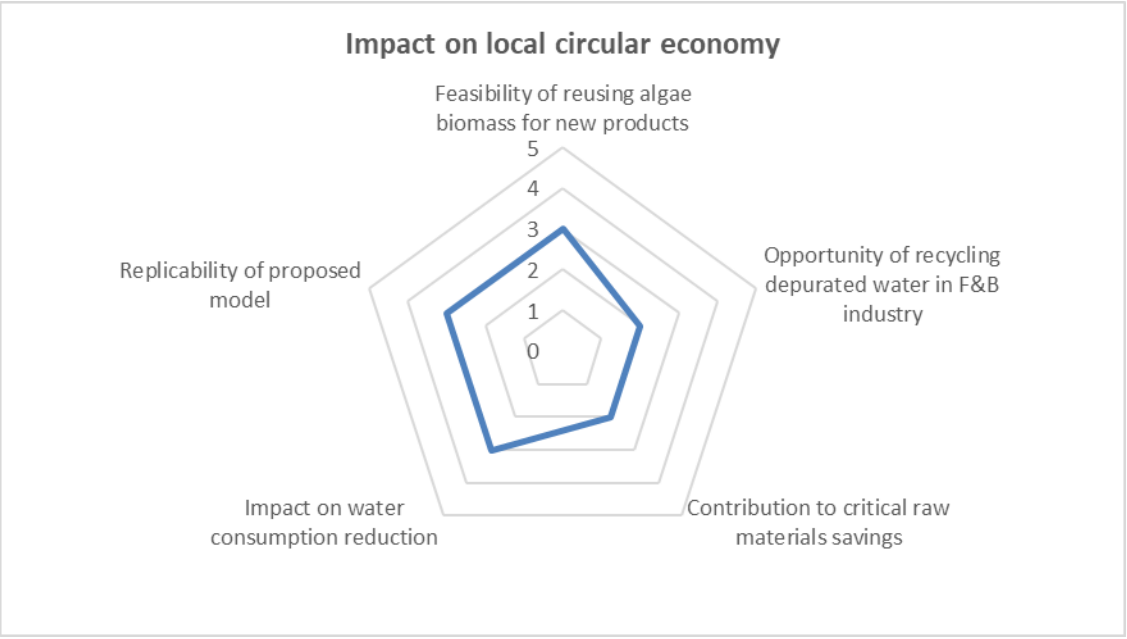


Figure 19. Impact on local circular economy

6 POLICY AND FINANCIAL FRAMEWORK

6.1 SALTGAE in present policy framework

I 6.1. A - Legislation on algae products in food and feed sector

According to EUBIA report on policy and regulation concerning SALTGAE model, the European regulation on algae use for food and feed products is still at an early stage, mainly concerning algae cultivation on wastewater. The table reported by EUBIA identifies all policy measures:

Table 6. EU policy measures concerning food and feed sector

TITLE OF DIRECTIVE	OVERVIEW
Regulation (EC) No 178/2002 on Food Safety	The Regulation lays down the general principles and requirements of food law, establishes the European Food Safety Authority and lays down procedures in matters of food safety. The principal aim of this Regulation is to protect human health and consumers' interests in relation to food.
Regulation (EC) No 183/2005 feed hygiene	The principal aim of this Regulation is to protect human health and consumers' interests in relation to food. It applies to all stages of production, processing and distribution of food and feed.
Regulation (EC) 1831/2003 on additives for use in animal nutrition	This Regulation sets procedures for authorizing the placing on the market and use of feed additives. The Regulation lays down rules governing the supervision and labelling of feed additives and premixtures in order to provide the basis for the assurance of a high level of protection of human health, animal health and welfare, environment and users' and consumers' interests in relation to feed additives.
EU Regulation 2015/2283 on Novel Foods	The Regulation establishes authorisation procedure for Novel Foods, establishes a list of authorised Novel Foods and safety evaluation criteria and improves conditions so that food businesses can easily bring new and innovative foods to the EU market, while maintaining a high level of food safety for European consumers.

According to the EU regulation, algae application in food sector is considered of high value for the global economy, with a great future opportunity. However, microalgae cultivated on wastewater, even if coming from food and beverage sector, represent a biomass obtained from a waste material. Therefore, this biomass can't be used today for food or feed products. For this reason, the value to this indicator is 2 on 5.

I 6.1. B - Legislation on SALTGAE products in non-food sector

Differently from food and feed sector, European regulation supports the utilization of algae for a wide range of end products. Algae are mentioned in the EU energy directive (RED) of 2009, and in revised directive (RED II) published on 2018. The importance and the sustainability of algae as renewable source of energy is recognized also, biomethane is promoted as a high value bio product. However, energy and transport sector are the sole with specific target and incentives promoted at EU and National levels. Other sectors, like

bioplastics and biomaterials, biodegradable and biobased, are supported both at EU level and with specific national regulations (Italy, Spain). Cosmetics and pharmaceuticals are not specifically supported. Value to this indicator, also according to EUBIA report on policy measures, has been valued with 4 on 5.

I 6.1. C - Authorization simplicity for proposed plant

Authorization procedures and related complexity depend mainly on the EU country where the SALTGAE system will be proposed. When new wastewater treatment plants are proposed by industries, EU member states follow different practices based on local regulation. In the case of SALTGAE system, the technology is expected to be installed as integrated process within an existing wastewater treatment system. This could reduce authorization complexity and time-step. The SALTGAE main components, excluding microalgae cultivation reactors, are common equipment adopted in wastewater treatment industry. Therefore, the only novelty will be represented by the algae product and harvesting system. Given the lack of examples, no previous cases can be reported other than Koto. For this reason, a value of 3 on 5 has been defined for this indicator.

I 6.1. D - Availability of Standards for algae biomass from Wastewater

No specific standards are still available for microalgae obtained from wastewater treatment plants. Being the algae biomass a product to be commercialized, a REACH certificate will be required per each wastewater treatment unit adopting SALTGAE system- REACH will define the safety of the obtained bioproduct. Algae biomass recovered from wastewater will have to respect limits established for other feedstocks depending on the final industrial end use. In this case, algae will represent an intermediate product to be refined and processed for further products extraction. Theoretically, the lack of specific standards is not representing a strong barrier to the SALTGAE system development, as the project considers the algae biomass as an intermediate material for additional processes. Only for food and feed sector, the lack of standard could represent a binding issue. Thus, value established is 3 on 5.

I 6.1. E - Supporting measures available for proposed plant

No evidence is available concerning existing SALTGAE systems installation, if excluding SALTGAE project demo sites. However, legislation in terms of wastewater treatment, algae recovery and biomethane production is supporting the proposed solution. The project countries and the European Commission policy measures are demonstrating the advantage of the proposed strategy:

2000/60/EC Water framework directive;
96/676/EC Nitrates directive;
91/271/EC Urban wastewater treatment directive
86/278/EEC Directive on the protection of the environment, and in particular of the soil

- Avoiding water pollution caused by nitrates in specific critical areas
- Promoting the high-quality depuration of water for reducing surface water consumption
- Reduce pollution due to wastewater sludge disposal and uncontrolled discharge
- Avoid untreated sewage sludge use in agriculture

EU Energy directive (National energy schemes in all EU countries)

- Promoting the recovery of biogas and biomethane from organic waste
- Promoting the use of sustainable biomass to be ILUC-free (avoiding indirect land use change) for biofuels and bioproducts

- Fostering bioeconomy and circular bioeconomy within EU circular economy package

The European and national measures supporting both water treatment and algae biomass use in different sectors represent a great opportunity for SALTGAE system. For this reason, the value for indicator 6.1 – A, is 4 on 5.

6.1.1 Consideration on driver 6.1

The below radar-chart shows the results of 5 indicators analyzed above. It is clear that, the lack of possibility of producing food products from waste treatment systems is currently the most relevant barrier at political level in Europe

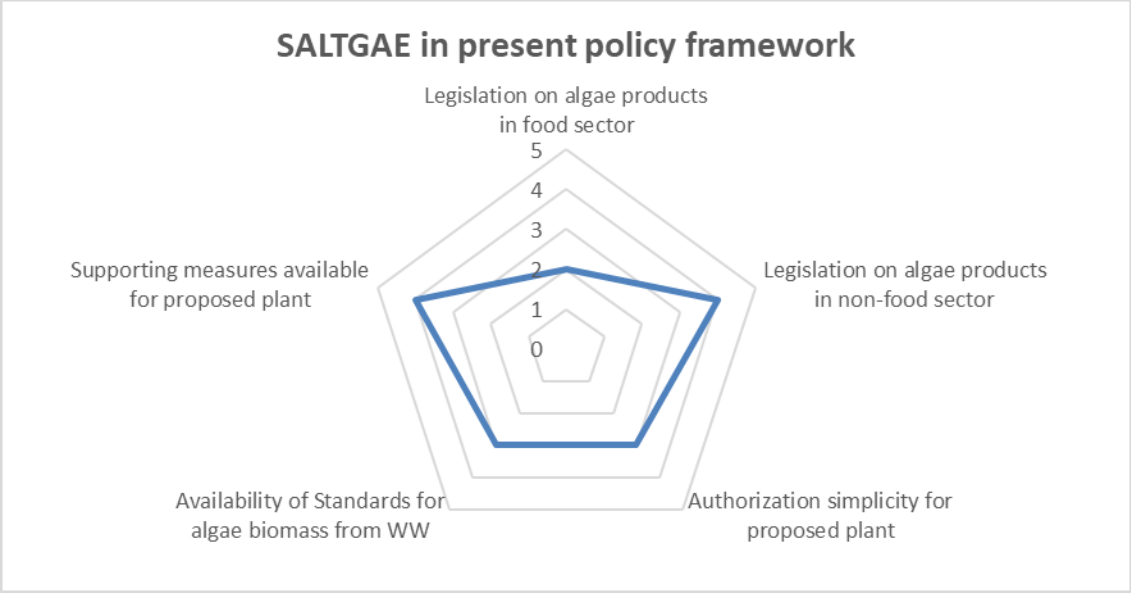


Figure 20. Saltgae in present policy framework

6.2 Availability of financing instruments and opportunities

I 6.2. A - Availability of national funds for upgrading WWT plants

National funds for wastewater treatment plants are currently lacking in most of EU countries. On the contrary, wastewater sludge disposal costs are increasing due to the increasing amount of material produced, and to the strict regulations required by the EC directives. Civil wastewater treatment plants are often able to install new machineries for reducing their sludge production and recovery materials, but algae are not included in these measures. For F&B sector, no incentives are available other than fiscal benefits for improving plants efficiency and sustainability. Value: 3 on 5

I 6.2. B - Incentives on algae-based non-energy products

Incentives on algae-based products relates only to energy, like transportation fuels or additives. Other supporting incentives are not available in EU countries. Value: 2 on 5

I 6.2. C - Regional funds for wastewater treatment capacity

Regional funds for these types of plants relates to regional co-financed projects available for sustainable solutions at demonstration scale, that regions guarantee thanks to EU funds available for environmental sustainability development programmes. The funds are obtainable only under the submission of financing request and it must be including innovation aspects. No specific funds for wastewater sector have been identified. Value: 2 on 5

I 6.2. D - Availability of private funds on algae-based products

Algae products are attracting the interest of both companies and private investors, which demonstrated to be interested in the application of algae biomass for mainly three sectors:

- Food and feed
- Fertilizers
- Pharmaceuticals

The private funds are working with innovative industries and researchers to identify economically viable solutions for the exploitation of algae potentials as sustainable, high quality organic feedstock to be applicated at large scale in the future EU bioeconomy. At the same time, the investment practices are still at an early stage due to the lack of supporting scheme and the reduced number of real scale production plants. Future opportunities are expected in the future. Value: 3 on 5

I 6.2. E - Funds available from private water utilities

Wastewater treatment companies, including civil wastewater treatment and food and beverage industries, are looking and investigating on new solutions for both avoiding sewage sludge production and recovery of valuable products from their residual streams. This growing interest is mainly due to two factors: the incoming supporting programmes for waste-derived products. The high disposal costs for sewage sludge caused by the EU directive, which is pushing for a gradual avoidance of sludge direct landfilling, or application in agriculture. The high treatment cost for produced sludge and the need of turning the waste treatment process in a more profitable practice is pushing F&B and WWT companies to invest in new technologies fulfilling the market and policy needs. This can be considered one of the most relevant strengths for SALTGAE concept. Value: 4 on 5

6.2.1 Consideration on Indicator 6.2

The wastewater treatment sector presents valuable financing opportunities thanks to the interest of private industries, interested in reducing wastewater disposal costs. From the other side, a reduced financial support from institution is registered, if compared with other environmental actions.

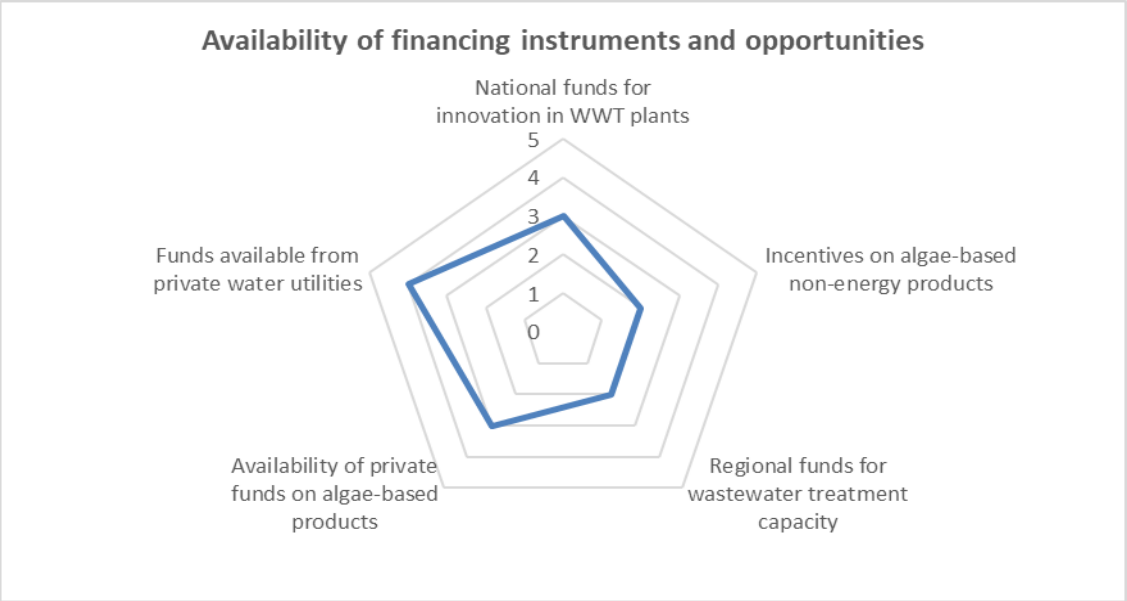


Figure 21. Availability of financing instruments and opportunities

6.3 SALTGAE opportunity in incoming policy and financial framework

I 6.3. A - Future impact of EU policy on SALTGAE products

EU circular economy package published so far did not present a specific action plan for wastewater. However, the emergency concerning sewage sludge and the need of promoting water and organic elements recovery is driving the creation of technology platform and working groups to assess the best solutions for recovery of critical elements (nutrients, organic carbon, etc…) from residual substrates. SALTGAE could have a benefit from this general approach to green technologies in the future. Despite SALTGAE concept is still at pre-industrial development stage, the production of algae biomass as a by-product of wastewater treatment plant could unlock its potential as substitute of petroleum products, like polymers and coating industry sector. Despite policy measures are considered relevant for SALTGAE model development, the influencing level of EU policy in SALTGAE technology deployment has been valued with 3 on 5.

I 6.3. B - Financing opportunity for innovative wastewater treatment solutions

In parallel; with the formation of working groups and technology platform by the European Commission and National governments, new financial opportunities could be available in the next future to allow innovative solution to penetrate the market and to support industries in a green transition, replacing old wastewater treatment units with innovative, efficient integrated plants ensuring the development of a blue, sustainable economy. The results expected by R&D projects, like demonstration of reliable technologies ready for commercialization, could represent an additional incentive for institution to promote financing instrument and facilitate the technologies commercialization. Value for this indicator is 2 on 5.

I 6.3. C - Expected novelties in EU food regulation

The need of reducing environmental impact of intensive livestocks (fisheries, cattle and pig livestocks) with more sustainable source of proteins, thus reducing land use due to intensive cereals plantation, is in favour for algae market growth. Despite algae obtained from wastewater are currently out from the admitted protein sources for feed and food

sectors, the EU is now working hard on this topic and, in the next future, a more specific regulation concerning limit and safety measures is expected, thus regulating the sector and unlocking the potential of microalgae for food and feed production. The expected amendment to the present food and feed regulation could be positive for SALTGAE products market penetration. The value to this indicator is 4 on 5.

I 6.3. D - Expected supporting measures for biobased products

Biobased products supporting measures could be represented by national initiatives for taxating CO2 emitted by fossil-based products manufacturing (including plastics and other materials), the application of CO_2 equivalent tax to these sectors could be a strong support to algae-based products. In summary, the evaluation of new supporting measures opportunities having a real impact on SALTGAE products has been estimated with 3 on 5.

I 6.3. E - Future Investment opportunity for biobased industry sector

Future investment opportunities are expected to grow in parallel with the incoming supporting policy measures and thanks to the reliability of innovative technologies. The raising need of replacing fossil based products is pushing investment funds and companies towards clean energy and renewable biological products. However, the persisting economic crisis is reducing both the risks margin for private investors and the availability of bank loans for new experimental practices. Future better economic conditions, coupled with general trend towards biobased materials, could make biobased industry sector an attractive business for companies investors. The value of this indicator is 4 on 5

6.3.1 Consideration on driver 6.3

Financing opportunities are not representing a strong support for the short-term future of SALTGAE technology development. There is a common trend in reducing investment risks and the lack of confidence in the industrial application of innovative systems for waste treatment procedures. New policy measures, new investment in biobased products and in algae biomass, will probably come first.

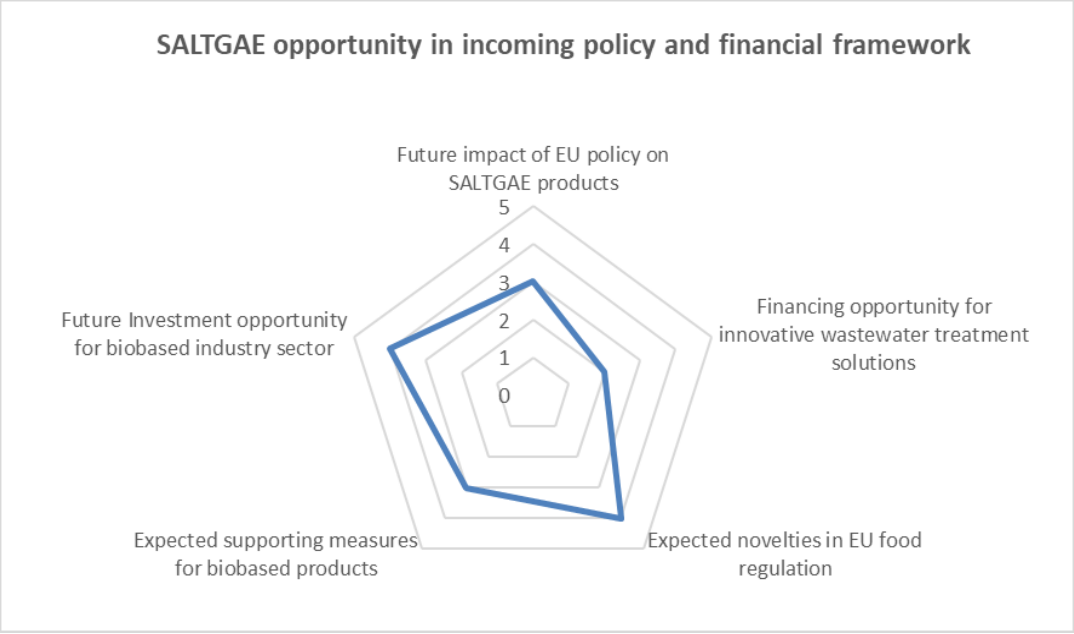


Figure 22. Saltgae opportunity in incoming policy and financial framework

7 RESULTS ASSESSMENT

7.1 Assessment of Pillar 1: Technology readiness and sustainability

Technology readiness and sustainability pillar has been analyzed in four different drivers. Radar chart defined by Driver: “Research and Demonstration activities” shows the largest area, indicating a strength in the technology development status. Another positive aspect is represented by the reduced sustainability, and the lack of any product extracted from the wastewater (excluding biogas), characterizing the conventional practices[1] (driver 2). A further positive aspect is represented by the reduced energy technology energy consumption, in relation with the quality of the obtained product, which could have a market value over 10 €/kg. At a contrary, a relevant weakness is represented by the stakeholders’ availability, which shows smallest radar chart area, with algae production technology providers as the worst indicator. This aspect is important as it is indicating an emerging technology; which is not yet ready to be considered “commercial”.

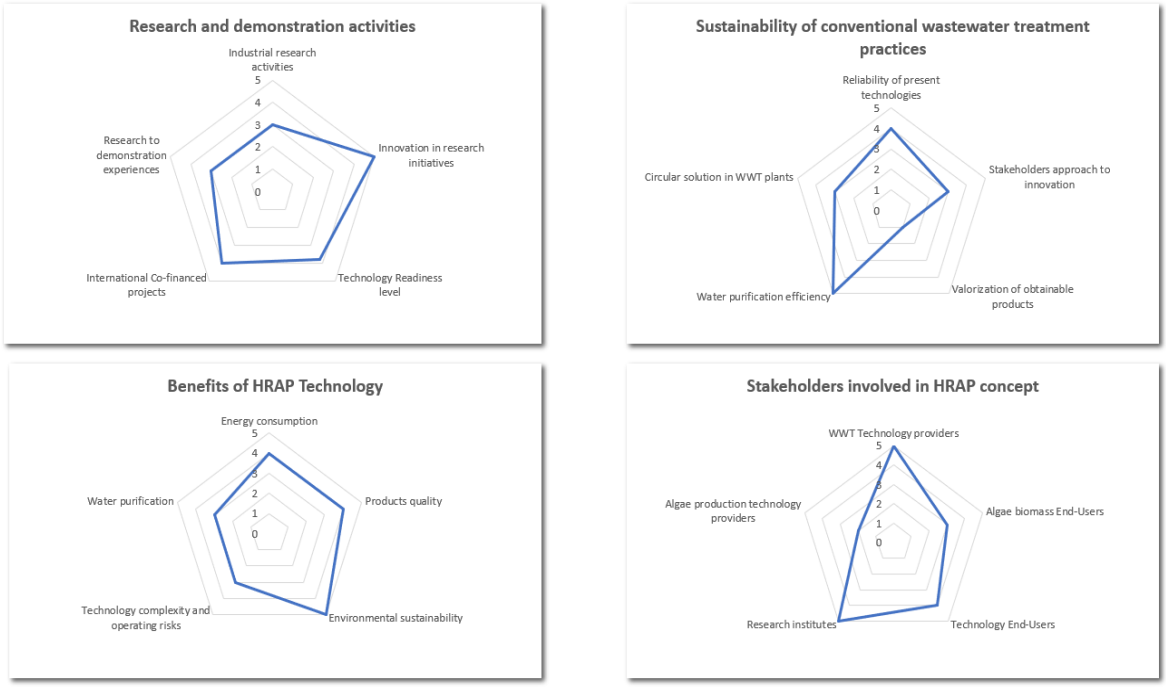


Figure 23. Summary of Pillars 1 indicators' assessment study

7.1.1 Conclusion on Pillar 1

On average, the Pillar 1 shows a positive framework, mainly thanks to the large amount of high level research and demonstration activities carried out worldwide. The good framework is also supported by the demonstrated environmental sustainability of the proposed model in comparison with existing conventional solutions. The lack of stakeholders, and of industrial initiatives in comparison with the wastewater market size is representing the real bottleneck for this Pillar.

[1] Conventional practices include: Activated Sludge, Membrane filtration, Biological treatment, chemical-physical treatment. Anaerobic digestion can be integrated in some of the above mentioned solutions.

7.2 Assessment of Pillar 2: Market and Economics

The four drivers involved in Pillar 2 analysis include:

- Economic benefits of HRAP technology on F&B wastewater treatment
- Reliability of HRAP technology, components, and structures
- Market size and opportunity
- SALTGAE products volumes, value and market demand

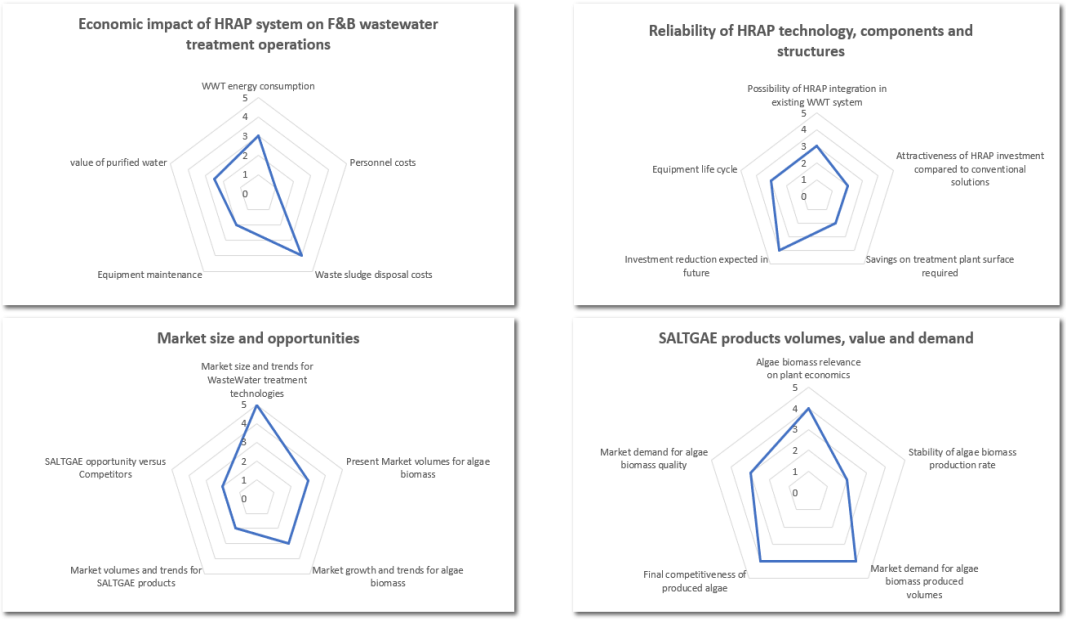


Figure 24. Summary of Pillars 2 indicators' assessment study

The economic analysis of SALTGAE system has been developed as an estimation of commercial future plants to be installed according to the project research outcomes. As visible from the radar charts, the average value of the four drivers is lower than for pillar 1. In particular, Driver 1 (economic benefits) and Driver 2 (reliability of HRAP system) of this pillar show reduced strengths. The most relevant barrier, as visible from the first radar chart, is that SALTGAE system include a wide range of technologies and process step (1step treatments, digestion, algae ponds, membrane filtration), which make wastewater treatment plants more complex in comparison with adopted solutions. This has an impact on personnel cost, and equipment maintenance, which will affect plant OPEX. Value of purified water is an additional uncertainty point concerning the impact of SALTGAE process no F&B wastewater treatment. In fact, microalgae growth is responsible of purification, reducing COD and salinity, absorbing metals. However, level of water purity can't be efficiently controlled with only algae cultivation but need to be adapted according to local legislation limits. Positive aspects concerning market and economics are that wastewater treatment sector is growing and new technologies are under investigation by utilities and industries. In addition, the produced algae will be competitive on the market thanks to their integration in a wastewater process, in comparison with cultivation in freshwater media.

7.2.1 Conclusions on Pillar 2

On average, the Pillar 2 shows a value lower than 3, which can be compared to a not-sufficient vote. The reason is mainly given to the fact that economics are still not favorable for the present technology in comparison with existing one, and that algae product sale is still a source of uncertainty for approaching this solution. In general, investment reduction and algae biomass market standardization will have a positive impact on the market penetration potentials of SALTGAE technology in the future.

7.3 Assessment of Pillar 3: Social and cultural framework

Pillar 3: social and cultural framework, is the most favorable to the development of proposed SALTGAE model. This pillar has been studied considering 4 drivers:

- Employment impact
- Impact on F&B industrial symbiosis
- Algae for sustainable society
- Local Circular economy impact

The final result of this Pillar is positive thanks to mainly two aspects: the sustainability of algae, and the impact on increasing job opportunities at local and even large scale.

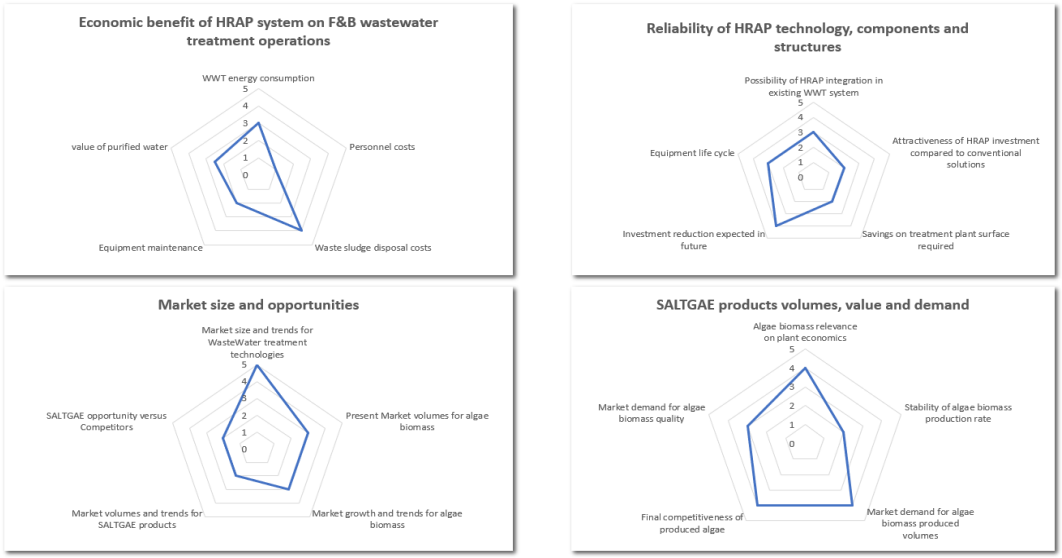


Figure 25. Summary of Pillar 3 indicators' assessment study

The deployment of SALTGAE model will bring to the formation of a new experts' category, supporting new specialization among operators and also high skilled personnel, formed for being expert of algae cultivation and water treatment methods. This aspect will generate new job opportunities and academic courses. Furthermore, algae biomass commercialization will bring to the formation of a new value chain, specialized on the valorization of microalgae biomass obtained from wastewater treatment sector, with positive impact on sustainable society development.

Additionally, this solution will facilitate the integration of F&B industries with other industry sectors, improving sustainability and impact on local community. The less positive driver is the one on circularity. Circularity is considered reutilization of algae biomass and depurated water for local purposes, or even for direct industrial reuse. Unfortunately, the contamination of algae biomass and the strict regulation concerning food industry is not currently supporting a safe reutilization of SALTGAE products. The only reused product can be the heat obtained from biogas combustion.

7.3.1 Conclusion on Pillar 3

The social and environmental benefits of SALTGAE process are indeed the most promising aspect on which counting for a future market development. The SALTGAE approach will have strong benefits for citizens life quality, increasing job opportunities, introducing a sustainable, renewable bio-based source, avoiding sludge disposal and promoting a high value blue economy. Giving a monetary value to these benefits could contribute to the fast development of the proposed model.

7.4 Assessment of Pillar 4: Policy and Finance

The fourth pillar is concerning Policy and financial framework, identifying 3 drivers:

- SALTGAE opportunity in present policy framework
- Availability of financing instruments
- Incoming policy and financial framework

Objective of this study was to transform the policy assessment study performed by TIS, giving a value to the SALTGAE possibility in the present policy and financial framework, and to evaluate the future emerging opportunities.

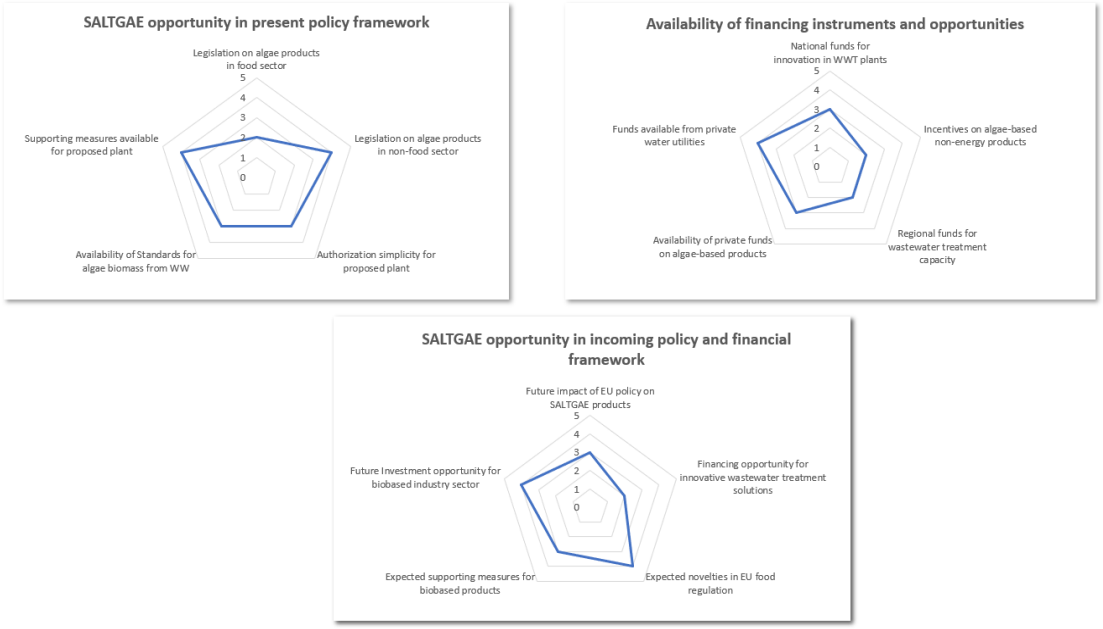


Figure 26. Summary of pillar 4 indicators' assessment study

The driver 1 of this pillar, the one on policy framework, shows a general positive context. EU and national policy measures are supporting biobased products as renewable sustainable materials. Additionally, there is a common trend in pushing water utilities to move towards efficient, advanced water treatment solutions. However, the driver includes an indicator which has been isolated for its relevance, the application of algae in food sector. According to the EU and national food sector regulations, algae obtained from wastewater are often not directly usable for food products. The main bottleneck of financial framework is represented by the lack of funds and supporting incentives for algae non-energy products, nor for innovation in wastewater treatment. Including these types of technologies among the supported technologies for water utilities and industry will help SALTGAE model reducing the gap with conventional solutions.

7.4.1 Conclusions on Pillar 4

The same regulation concerning algae is representing a big bottleneck and a big opportunity for the future at the same time. National authorities and international bodies are working to open food and feed sector to microalgae biomass, as well as insects, cultivated on biowaste streams. Contamination will of course limit the application but open the market for those products fulfilling the criteria. This is probably the most promising expectation concerning future regulation. Financial opportunity could be increased by the market trend and the growing interest, by private funds and industries, in approaching solution able to transform biowaste in a resource for the bioeconomy sector.

8 PROPOSED MARKET PENETRATION STRATEGY

The analysis of the four pillars allows to draw a picture on the general position of SALTGAE model in a theoretical pathway towards a commercial development status. The analysis has shown critical aspects and opportunities of the proposed model for each pillar identified.

8.1 Identification of positive aspects

The market penetration strategy should start from the most relevant strengths identified, to be set as the basis for any further business development activity be performed in the future. The drivers reporting a higher value have been therefore listed selected:

Table 7. Positive aspects identified in 4 evaluation pillars

Research and demonstration activities on microalgae integration in WW treatment sector
Benefits demonstrated by HRAP technology in comparison to present solutions
Market Size and Opportunity
Employment impact of proposed solution
Improving F&B symbiosis industry sectors
SALTGAE opportunity in incoming policy and financial framework

It must be underlined that one of the first strong points of the proposed solution is represented by the wideness of research and demonstration activities performed worldwide, and the benefits it could bring to industries with wastewater to treat, improving their social and environmental sustainability.

Another important aspect is represented by the market size. Despite algae sector is still full of uncertainties for investors and companies, the growth is ongoing, and the size is increasing year by year. Moreover, the integration of algae cultivation within wastewater treatment plants will have a great impact in terms of employment and industrial symbiosis, as F&B companies, as well as other WWT companies will become producers of a high-quality algae biomass, and depurated water, to be recycled onsite.

8.2 Identification of weak aspects

At the same time, together with strengths, weak aspects must be identified and evaluated:

Table 8. Negative aspects identified among 4 evaluation pillars

Economic impact of SALTGAE HRAP on F&B wastewater treatment operations
SALTGAE HRAP investment costs
Availability of financing instruments and opportunities
SALTGAE Opportunity in present policy framework

First important aspect to identify is that, despite SALTGAE benefits for F&B industries has been identified as a strength, it becomes a weak aspect in terms of economic savings. Even with the sale of algae biomass extracted, and the revenues from biogas produced, it will be difficult for project to represent a reduction in the economic expenses of wastewater treatment plants. The reason is the increasing number of employees, the control and maintenance activities, and the energy consumption. Economic impact is also affected by the investment cost, which is estimated to be higher than conventional adopted practices, due to the installation of algae ponds, digesters, and membrane filtration units. Other two barriers have been identified in the present policy and financial framework. From legal point of view, until there will not be a clear and open regulation concerning the usability of wastewater algae biomass for food products or for feed production, the largest market sector for microalgae in EU and worldwide, will be out of limit for SALTGAE product. In addition, the competitiveness of the proposed model needs to be supported by financial supporting measures, which will be able to valorise its main feature, the environmental and social benefit.

8.3 Business Model Canvas

The Business Model Canvas has been used to summarize the business model analysed in this study, fragmenting the issues in different business segments. The space of the table under some segments have been fully filled in, but other spaces remained almost empty, or generic, due to the lack of information and commercial status development (customers). The list of segments is the following.

- Key partners
- Key activities
- Key resources
- Value proposition
- Customers relationship
- customer segments
- channels
- cost structure
- revenues streams

Table 9. Business Model Canvas

<table>
<tr>
<td rowspan="2">Key Partners
Algae technology providers
Wastewater treatment companies
• Civil Water utilities as technology end users and investors
• F&B companies as technology end users and investors
Water end users
• recycling of depurated water
Biogas plant technology providers
Membrane filtration systems providers
• partner in design specific membranes for algae
Policy makers
Financing institutions
Umbrella associations
Research institutes and environmental protection agencies.</td>
<td>Key Activities
• Participation to new food regulation working group for results exploitation
• Investigation on specific microalgae composition requirements for end users according to market needs
• Demonstration scale of products synthesis from obtained algae biomass
• Products REACH certificates development
• Fostering market value of produced algae as main revenue stream</td>
<td rowspan="2">Value Proposition
• The SALTGAE model change waste sector into a business opportunity for F&B and wastewater treatment industries
• The solution improves food sector sustainability and safety
• We contribute to increase job opportunities
• We create new sector for high level manufacturing industry in EU
• We contribute to the development of global algae products commercialization, improving sustainability of all algae end users’
○ reducing impact of fish farming and agriculture
○ reducing fossil fuels consumption for chemical and plastic sector</td>
<td>Customer Relationships
• Technology end users need guarantee of technology performances in terms of safety, reliability, efficiency
• Algae biomass end users will ask for homogeneous, clean biomass suitable for post-processing
• All customers will ask agreements concerning supply and quality of the proposed system
• All customers will ask for awareness, and assistance</td>
<td rowspan="2">Customer Segments

Identified customers are:
Algae biomass end users
<u>Fertilizers producers.</u> they have already demonstrated interest in using algae for high value fertilizers for gardening and horticulture)
<u>Food and feed producers</u>
The alternative production of proteins derived from algae is a core market segment for SALTGAE concept. The extracts obtained from algae could be used for food, additives, and feed for fish, and animal livestock
<u>Chemicals and plastic industry</u>
This is a still emerging market, but with great potentials for the application of biomass derived polymers
<u>Wastewater producers</u>
Wastewater treatment companies are the end users of the whole proposed technology package, which has been designed for this specific sector.</td>
</tr>
<tr>
<td>Key Resources
• resources for industrial scale production volumes achievement
• Initiatives for promotion of microalgae products
• Resources for demonstrative activity to main end users of technology and products
• Financial resources for revenue streams market penetration</td>
<td>Channels
• The awareness of customers concerning SALTGAE opportunity is good thanks to many initiatives developed on this topic so far.
• The most effective channel is represented by conferences, workshops, training activities organized during different specific events with different stakeholders’ categories</td>
</tr>
<tr>
<td colspan="3">Cost Structure
○ The investment costs are the most relevant in the whole business model. The solution require investment in the order of M€.
○ Resources are not required for the process, the most important is related to the labour costs
○ The most expensive activity for promoting the technology is represented by products certification, analysis, registration and testing.</td>
<td colspan="3">Revenue Streams
○ High quality of algae and suitability for post-processing is a core aspect
○ The biogas produced is an additional by-product
○ Payment is in €/dry ton or $/dry ton
○ The algae sale will represent the 80% of all revenues of the plant</td>
</tr>
</table>

9 CONCLUSION

According to the outcomes of the presented study, the SALTGAE concept can be positioned in a pre-industrial development level. The high interest by the wastewater treatment sector in new technologies, and the positive approach of biobased industry towards in algae biomass as renewable bioresource can represent a pushing factor for starting a market penetration strategy towards commercial deployment the SALTGAE model. These two aspects should be the “reason for starting the battle”. After identifying the reasons, a strategy is needed to develop a winning battle for SATGAE commercialization. The strengths of the proposed model are those aspects able to convince stakeholders. Different strengths are influencing different stakeholders’ categories. The SALTGAE market penetration strategy should count on:

- ✓ its environmental sustainability and its impact on employment to convince policy makers supporting the concept, including promoting supporting regulation, incentive programmes, and fostering algae use.
- ✓ Its impact on turning wastewater treatment from a cost (sludge disposal) to a promising business based on bioenergy and high value biomass production, with no disposal issues, with attractive payback time in the short term.
- ✓ The increasing market value of algae biomass for attracting potential investors, favouring financial agreements between wastewater companies and algae biomass traders.

After identifying the values on which counting for winning the battle, the remaining step is made of activities. After the end of the project, there is the need of implementing the demonstration activities performed during the last three years. Objective is to identify, among others, the most promising case studies, and focus extracting a relevant quantity of algae-based products (hundred Kgs - ton) to be tested and promoted. In addition, policy action must be performed, in order to bring project results to the national and European authorities. Finally, demonstration sites should be optimized with technical integrations identified during the project, and all aspect concerning operational costs should be actualized based on real industrial scale trials, performed on a single flagship plant.

Considering business model to be developed, the potential solution could be in the creation of a headquarter company, based on selected demo-site identified as most advanced from industrial point of view. The new company could be working at European level, performing mainly research, demonstration and optimization activities in terms of technology and products. It will also act as mother company, official technology provider of other side companies, smaller, aimed at introducing the technology in different countries, where regulatory framework and market demand are different. This solution could facilitate the collection of funds, the promotion of technology concept, and the involvement of European stakeholders

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