Feasibility study for the development of a hatchery and pre-fattening fish-farm in el Puerto de Santa Cruz de Tenerife

Descriptive Memory

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1 Acronyms

APSCT: Autoridad Portuaria de Santa Cruz de Tenerife

BOPSCT: Boletín Oficial de la Provincia de Santa Cruz de Tenerife

CSCT: Cabildo de Santa Cruz de Tenerife

FEMP: Fondo Europeo Marítimo y de Pesca

IFOP: Instrumento Financiero de Orientación de la Pesca

PEACAN: Plan Estratégico de la Acuicultura de Canarias 2014-2020

PEPSCT: Plan Especial del Puerto de Santa Cruz de Tenerife

PROAC: Plan Regional de Ordenación de la Acuicultura de Canarias

PUEP: Plan de Utilización de Espacios Portuarios

ROEZEC: Registro Oficial de Entidades ZEC

VPA: Viceconsejería de Pesca y Aguas

ZEC: Zona Especial Canaria

2 Introduction

In the context of the Plan Especial del Puerto de Santa Cruz de Tenerife, in an area called Cueva Bermeja, the development of 112.000 m2 of land reclaimed from the sea is being planned. From this surface, around 80.000 m2 will be construction land (1). This is a real project being studied by the Autoridad Portuaria de Santa Cruz de Tenerife, belonging to the Ministerio de Fomento.

Many business opportunities arise for this land, as it is located in a strategic point for the logistic and industrial sectors (within the port’s area) and will count with extraordinary tax conditions. For this reason, during this project the feasibility of a turbot and sea bass hatchery and pre-fattening fish-farm will be studied.

Figure 1. Location of Santa Cruz de Tenerife.

As mentioned earlier, there are many public incentives helping industrial companies set up at the Canary Islands, as assets are becoming deteriorated after years of use and techniques are not sufficiently efficient to compete on a global scale. This trend in even more present in the fishing industry.

Even though many sectors find the location of the Canary Islands to be a disadvantage for their businesses, we think that the logistic potential of the Islands is huge, as it is a key meeting point between Africa, Europe and America. In fact, Tenerife is just 300 km away from the coast of Africa and 1.500 km away from Huelva, in mainland Spain.

This feasibility study aims at studying the potential of the land plot as a fish farm, a hatchery to be more precise, taking profit of the fact that it is located in the middle of the Atlantic Ocean, surrounded by multiple off-shore fish farms in the Canary Islands as well as in the West coast of Africa.

2.1 State of the Art

There are hundreds of examples of reclaimed land projects all over the world, of much bigger complexity and done many decades ago.

Mumbai City, in the west coast of India, is an Island created after the recurring land reclamation projects around 7 initial small islands (2). Belonging to the Portuguese Empire, by 1845 they were already a big merged landmass. Home to around 10 million people, what seemed like a place not having solid foundations is now one of the main cities in India, thanks to all the engineering works during the 19th century and onwards (3).

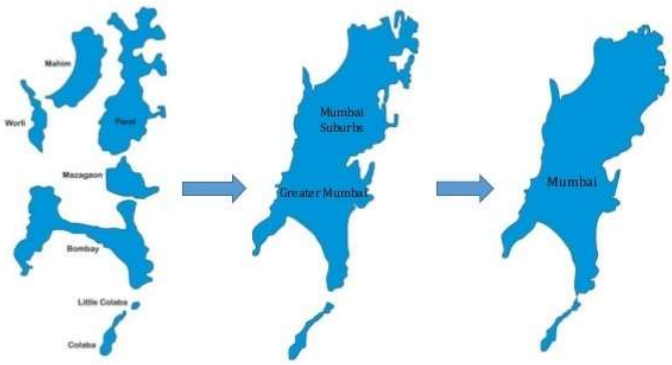

Figure 2. Development of the City of Mumbay.

Other land reclamation projects such as the City of Monaco or the Barceloneta area in Barcelona belong to the long list of similar works done in the past.

Regarding the fish-farm, tens of thousands of them have been developed throughout history. In fact, indigenous tribes from Australia are thought to have grown fish by 6.000 BC, although the first to do it in ponds were the Romans. They bred fish and oysters before 100 CE (4).

However, fish farming still finds many problems, such as the great amount of waste generated by intense sea aquaculture, which is not always washed away by sea currents, or the huge energy costs needed by on-land fish farms. There are several technical barriers that stop on-land fish farming to meet the required efficiency to be used on a big scale, even though we have seen in the past few years some great projects that are for sure a big step in the development of the state of the art. They are necessary in order to put into practise (and economically sustain) the big amount of R&D that this field still needs.

Just as an example, the Kuterra inland fish farm in British Columbia, Canada, produces 250 yearly tons of salmon by what they call a completely sustainable process. Water is recycled in a way that no waste is rejected to the exterior; instead, this waste is converted into fertilizer. Feed given to fish is also specifically chosen so that they grow as fast and as much and possible while keeping all biological and nutritive properties. This kind of facilities is not common, as they tend to be old-fashioned and use obsolete processes and equipment, which makes them little efficient and not always profitable.

Figure 3. Kuterra salmon inland fish farm.

Other inland and offshore facilities also offer good production numbers, although there is still a big need in the industrial of rethinking processes in order to become less harmful to the environment and to the fish themselves, all while increasing productivity ratios and nutritive properties.

2.2 Motivation

Real conditions for the future land plot will be very good. In one hand, from a logistics strategy point of view, the Canary Islands are a key meeting point between Africa, America and West Europe. Furthermore, Tenerife and Gran Canaria are the two main islands in the Canaries, with the largest ports by far. Being located in the Port of Santa Cruz means having total access to sea transport channels as well as operational and tax benefits, as it will be within a Free Trade Zone.

The Port of Santa Cruz de Tenerife greatly contributes to the Island's economy. It is capable of berthing big touristic cruising ships and ferry boats (1.222.540 total passengers in 2014 (5)), as well as several merchants at a time.

The industrial development of the Islands is important for the sustainable growth of the population and its economy. On one hand, the current scenario shows that the economy of the Canary Islands depends mostly on tourism, a very cyclical sector and already saturated, with low margins, although it is starting to recover during the last couple of years. The need for diversification is obvious, and the area of the Puerto de Santa Cruz de Tenerife currently offers big opportunities for industrial development.

Regarding the fishing sector, its state is even worse than the average. Many reports show the decrease of profitability for most actors in the industry. Businesses have traditionally been family size, not able to cover big investment needs, which combined with the isolation of the population and difficulty to keep up to date with technology, has ended up with a very obsolete fishing fleet and methods.

2.3 Objectives

The main objective of this project is to study the technical and economic feasibility of a hatchery and pre-fattening fish farm to be developed on the Reclaimed Land. This fish farm will be covered by a warehouse, which will be specifically designed to suit the operational needs while keeping costs as low as possible. In addition, as the reclaiming works and the fish farm erection need a very large investment, the economic feasibility of the project will be studied, taking into account potential sales and the main operational costs.

The warehouse should be designed with the latest technology. An adapted fit out combined with several energy efficiency elements will help reducing operational costs. This is a second objective that should be treated separately from the first one.

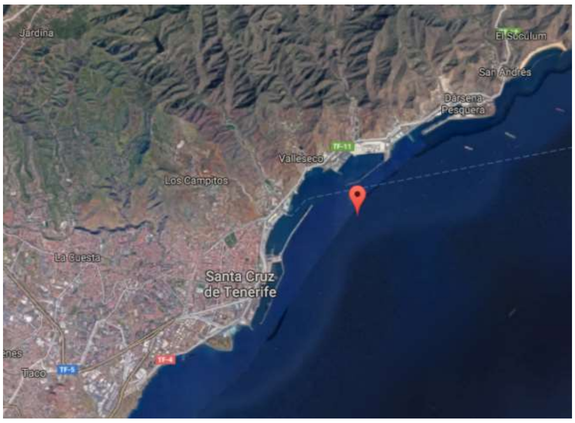

Figure 4. View of the Harbour of Santa Cruz de Tenerife.

Once established the constructive, operational, and regulatory aspects of the warehouse an insight into the Project Planning, Budget and Schedule will be done. The final objective of this Master Thesis is to define the global situation and action plan for the Project to be implemented in as much detail as possible.

2.4 Methodology

In a first phase we will study the civil works to be done, mostly marine works, for the Reclaimed Land Project. There is a published Basic Project done by Acciona. We will analyze it and understand its results in order to be able to plan the second and third phases. The urban, technical and environmental restrictions of the future land will be considered, in order to be as close to reality as possible. To do this we will have to take into consideration the Plan Especial del Puerto de Santa Cruz de Tenerife, published in the Boletín Oficial de la Provincia de Santa Cruz de Tenerife on the November 28th 2014 (6).

The second phase will consist on the Basic Design of a fish farm on the reclaimed plot. Constructive and operational conditions of the facilities will be established. The resulting building should also fulfil all required norms and standards.

The warehouse will incorporate State of the Art constructive and operational features, such as an optimized design to increase efficiency within the facilities or energy efficiency measures that substantially reduce Operational Costs. A lean approach will be used in order to reduce all waste within the process and facilities. This will enable us to implement a fully optimized production system in terms of time, space, quality, etc, and to design the facilities that will host it fully adapted to its needs.

As mentioned earlier, we will take an insight into the Project Management of the fish farm to be built. A budget, overall time schedule and license roadmap will be defined using Group IPS' methodology.

2.5 Used Resources

To tackle this Project a wide variety of resources will be needed. A starting point will be the *Plan Especial del Puerto de Santa Cruz de Tenerife*. It will have to be analysed, as constructive and use restrictions for the Land are defined in this document. Other technical codes will be taken into account, such as the *Código Técnico de la Edificación* or the Eurocodes. The *Código de Urbanismo de las Islas Canarias* will be used in order to define an Urbanization Plan for the Plot that will be used as a hypothesis for the second phase of the Project. Technical aspects of the Land will be extracted from the Basic Project *PROYECTO DE SEGUNDA FASE DE DEFENSA DE RELLENOS DEL DIQUE DEL ESTE, DESDE EL QUIEBRO DE 1º Y 2º ALINEACIÓN HASTA EL ESPIGÓN DE CUEVA BERMEJA*, developed by Acciona.

Research will be done by means of the Internet, were all needed information can be found. Public Institutions' websites will be firstly consulted, as this is probably the most reliable information source.

The fish farming process will be studied using internet resources as well as taking into account the opinion of experts in the matter: biology teachers and researchers from the Universidad de las Palmas de Gran Canaria, specialized in the matter. In addition, technical doubts (such as the best type of pump to be used) will be solved by fish farming specialized companies.

Regarding the warehouse concept design, internal Group IPS and ICAI's resources will be used. The building's design will be done following what's been learnt in *Construcciones Industriales*. In addition, specific design measures will be included once the final requirements are established.

As per the Project Management aspects of the Master Thesis, Group IPS methodology will be used, including some of the document templates.

3 Background

3.1 Plan Especial del Puerto de Santa Cruz de Tenerife

The Plan Especial del Puerto de Santa Cruz de Tenerife was published in the Boletín Oficial de la Provincia de Santa Cruz de Tenerife on November 28th 2014. Its main objective is to set a detailed planning for the land in the area of the port by determining the compatible uses that can be given to the land as well as the constructive conditions imposed by this Plan.

Furthermore, it also establishes the conditions for the implementation of the land management and its urban norms and restrictions regarding the construction areas within the port by the Authorities or by any other individual in an Administrative Lease format.

The PEPSCT was developed in the context of the *Plan de Utilización de los Espacios Portuarios* (PUEP) published in the BOE on July 31st 2006. It covers in detail the whole land zone of the port except for the functional areas of the Litoral de Valleseco and San Andrés, which are ruled by a complementary plan. The land to be reclaimed from the sea in Cueva Bermeja is also included into the plan's scope. It entered into force 15 days after being published and will regulate the area until a further modification is approved.

3.1.1 Cueva Bermeja within the Plan Especial

The Plan Especial divides the area into different functional areas, being the one in Cueva Bermeja the one of our interest for the development of our warehouse. As per the *Plan Especial*, The area of Cueva Bermeja will be mainly reserved to Stocking and Industrial activities. The Plan Especial offers a more detailed description of the surface allocated to every specific task (our land of interest is denominated as industrial):

FUNCTIONAL ZONE		CUEVA BERMEJA
Prevailing Use		**Storage and Industrial**
Detailed Uses	**Surface m2**	**Building surface m2**
PORT RELATED ACTIVITIES		
Liquid bulks	35.284	3.423
Industrial	178.402	400.611
Port Authorities	7.403	6.275
Subtotal	**221.089**	**410.309**
TERTIARY USE		
Offices	382	529
Subtotal	**382**	**529**
PUBLIC OPEN SPACES		
Garden areas	14.620	0
Security open space	6.953	0
Embankment	1.331	0
Subtotal	**22.904**	**0**
INFRASTRUCTURE		
Docks and rockfields	11.635	0
Hydraulic infrastructure	636	636
Road infrastructure	74.201	0
Subtotal	**86.472**	**636**
TOTAL	**330.847**	**411.474**

Table 1. Allowed uses for the plot in Cueva Bermeja (7).

Industrial activity is defined by the PEPSCT: "Industrial activity directly linked with the goods that move in or out the port or that covers the needs of the port activities (6)".

It will therefore be necessary to justify that our facilities work in an activity related to the ports industry. It seems reasonable that, given the fact that fish fries will be sold to external parties, these will be distributed by sea, even if this activity is not assumed by the hatchery's owner. The specific area of interest for the development of the warehouse is defined as industrial land, as per the O-2 Detailed Uses plans within the PEPSCT.

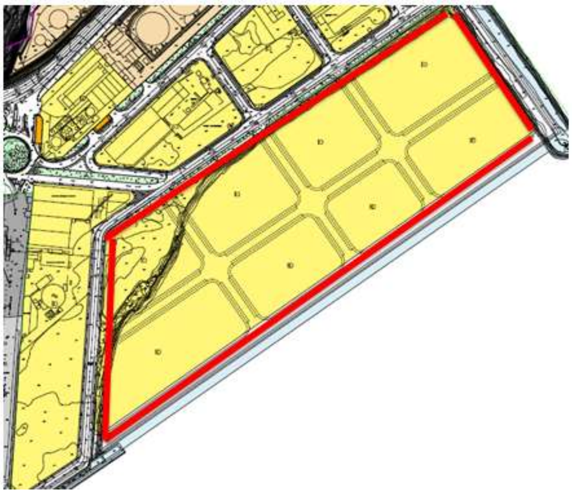

Figure 5. Portion of land to be reclaimed from the sea.

The plot's limits consist in two 622 m and 184 m sides next to the sea and two other sides (456 m and 248 m) separating the plot from the rest of the land in the port. The land plot is therefore 99.200 m^2, although once taken into account the different works to be done and the areas to be used for public services, the available land will be around 80.000 m^2.

Regarding the industrial use within the port related activities, the PEPSCT establishes the following categories:

- Industrial Production
  - Primary uses related industry
  - Light industry
  - Industrial workshops
  - Heavy or processing industry
- Craft Workshops

It is important to note that industrial activities are compatible with commercial uses of the land as long as they are related to the ports traffic. Another particular condition is parking space, which must be allocated at the minimal ratio of 1 parking space per 200 built square meters (6).

Regardless of the final use of the building, the PEPSCT establishes (via the O-3 Building Parameters plans, see Annex 2) that for our area of interest the typology should be Open Buildings, which is how the plan defines buildings whose façade can be designed anywhere as long as it respects the limits. In opposition, Closed Buildings's façades are already established on the development parameters. In our case we will therefore be able to design them as it best suits our purposes as long as it accomplishes other applicable norms.

In addition, the following parameters are defined:

Minimum plot size ≥ 500 m2 s
Minimum Front ≥ 20 m
Frontal setback ≥ 5 m
Side setback ≥ 3 m
Floor height ≤ 3 p * =3.6 m
Height in meters ≤ 15 m *

Table 2. Building parameters of the land (8). *specific parameters.

From the analysis done in the previous paragraphs we can deduce that as long as the building parameters are respected, the land plot of interest can be used for setting up a fish-farm as it belongs to the category 'Primary uses related industry".

Regarding the classification of the land, it will be developable (*urbanizable*). This means that before the construction of the project starts, a development project will have to be done, in order to fulfil all needed requirements: the plot might have to be divided into several smaller ones, roads will be built, connection points for utilities will be established, etc.

3.2 Zona Especial Canaria and Free Trade Zone

The Special Canary Zone (ZEC, for the Spanish *Zona Especial Canaria*) is a public institution belonging to the Spanish and Canary Governments and linked to the Treasury Department (*Ministerio de Hacienda y Administraciones Públicas*) (9).

Its main objective is to manage the ROEZEC, the register of enterprises within the ZEC. It has therefore the right to give the administrative licenses to the projects promoted by the future ROEZEC companies, as well as the obligation to control the existing registered activities. Companies on the ROEZEC benefit from a very appealing tax regimen, designed with the purpose of easing the economic development of the Canary Islands.

3.2.1 ZEC applying zones

When determining where a company can be established in order to benefit from the ZEC special measures, it is convenient to distinguish between the two different allowed activities. Whereas service related ROEZEC companies are allowed all over the Canary Islands, industrial activities can only be performed in the following areas:

Tenerife	Gran Canaria
Port of Santa Cruz de Tenerife	Ports of La Luz and Las Palmas
Los Rodeos and Reina Sofía airport areas	Airport area in Gando
Granadilla industrial site	Arinaga industrial site

Table 3. Areas of ZEC benefits for industrial activity.

Our plot, which is located at the Puerto de Santa Cruz de Tenerife, is therefore within the area where ZEC benefits can be performed.

3.2.2 ZEC tax benefits

Companies within the ROEZEC can benefit from several fiscal advantages depending on their characteristics, being the following the most important ones (10):

- **Corporate taxes.** Companies have a corporate tax of between 1% and 5%, whilst other companies in normal tax regime pay around 30% and 35% of their benefits. Corporate taxes will vary depending on the following criteria:
    - Number of employees
    - Time at which the company is registered into the ROEZEC
    - Novelty of the activity
    - Type of activity performed
- ZEC companies can benefit from the **Double taxation conventions** and the **Affiliate Company Directive of the European Union**.
- Exemption of **taxes on capital transfers and documented legal acts** for the following:
    - Acquisition of goods and rights bound to be used within the normal ZEC company activity
    - Document legal acts related to companies within the ZEC

- Exemption of the IGIC (VAT applied on the Canary Islands, usually ranging between 3 and 20% (11)) for the delivery of goods and services between ZEC companies and imports.

	ZEC rate	General rate
Corporate tax	1-5%	30-35% in Spain
Double taxation conventions and Affiliate Company Directive of the European Union	Yes	Yes
Capital transfers and documented legal acts	0%	1-7% in Spain (12)
IGIC/IVA (VAT)	0%	Canary Islands: 3-20% (general rate 7%) Mainland Spain: 4-21% (general rate 21%)

Table 4. ZEC tax benefits (12).

3.3 Activities allowed within ZEC

The only activities that are strictly not allowed on the ZEC are financial services. All other activities can be potentially performed within the ZEC, especially those explicitly named on Table 5.

Production, manufacturing and distribution of products	**Services**
Fishing	Transport and activities involved
Food, beverages and tobacco	Computer services
Textile and clothing	Electronic commerce
Leather and footwear	Telecommunications
Furniture and other manufactures	R&D
Paper, edition, graphic arts and reproduction	Natural resources and waste management
Packaging	Training
Construction prefabricated products	Consultancy
Machinery and medical equipment	Publicity
Electric material and equipment, electronic and optics.	
Chemicals	
Recycling	
Wholesale and intermediaries	
Ship maintenance and repairing	

Table 5. Allowed activities within the ZEC.

Fish farming activity should be included in the food, beverage and tobacco group. As can be seen above, the company managing the fish farm will be allowed to be registered in the ROEZEC.

3.4 Land reclaiming project

It is important not to forget that the land plot on which the warehouse for the fish farm is planned to be built does not yet exist.

In 2000 the Port Authorities ordered the study of a land reclaiming project to INTECSA, which was modified by NECSO and then combined with a geotechnical study in Cueva Bermeja, done by IGEOTEST. It was finally handed in by Acciona in December 2015, and hasn't been modified since then. The Project is called Second Phase of Embankment of the East Dock, from the 1st and 2nd lines to the Cueva Bermeja pier (*PROYECTO DE SEGUNDA FASE DE DEFENSA DE RELLENOS DEL DIQUE DEL ESTE, DESDE EL QUIEBRO DE 1º Y 2º ALINEACIÓN HASTA EL ESPIGÓN DE CUEVA BERMEJA)* (1).

Figure 6. Existing structures and future dock (1).

3.4.1 Marine works

Reclaiming works will consist in a three phase project. First of all, the sea bottom will have to be prepared in order to, in a second stage, settle the foundations of the 30 m high (in average) reinforced concrete blocks. In a third phase, once settled the concrete blocks, the enclosed area will be filled in, as explained in section 3.4.2.

Blocks have been chosen (by Acciona) as the best method to enclose the new land as they offer the possibility to set up a dock for ships to be berthed, in opposition to a solution with slope protected by a breakwater on its outside.

These reinforced blocks will not be all the same height nor have the same foundations. Taking into account the difference in height will be gradual, all blocks can be calculated once having determined those at the two ends. Type 1 will be the one in the South-East end of the dock, and Type 2 the one in the North-East side.

	Type 1. South-West end.	Type 2. North-East end.
Height of foundations	-25 m	-15 m
Adaptation to existing dock	Submerged 3 meters long concrete block between new and existing docks.	30 meters of dock with slope between the last caisson and the Cueva Bermeja breakwater.
Length and width at foundations	44,95 m x 24,30 m	44,95 m x 24,30 m
Slab	1 m	0,80 m
Total height	29 m	19 m

Table 6. Main data on reinforced concrete caissons (1).

As per Table 6, the only difference between caissons will be their height, the height of the foundations and the slab's width.

To protect the structure from the waves, the sea side of the settled caissons will be covered by a concrete shoulder that will rise until height +9 m. It will have a total length of 635 m.

3.4.2 Filling

Acciona's basic project states that once the concrete perimeter is executed, the portion of "empty land" will be filled in up until height +4 m with "general" filling material, while the water inside will be pumped out back to the sea. On top of it, a 0,25 m. graded aggregate will be laid on top of it. Finally, a provisional oil-shale coat will cover the plain.

The filling of the plot will cause a terrain settlement within the added material which will be added to the one taken place on the already existing material:

-Terrain settlement on the already existing surface ≈ 9 cm

-Terrain settlement on added material ≈ 48 cm

- Total settlement ≈ 57 cm

In order to estimate the settlement due to the operational use of the land, a very pessimist hypothesis was taken in order to arrive to a 6 cm settlement under a 20 kPa charge. This settlement will be produced shortly after the appliance of the charge, being long term settlement negligible.

The final height of the plot will be +4m over the sea, in average (because of tides).

3.4.3 Tender budget, overall planning and l/t project structure

The budget prepared by Acciona estimates that the cost of the works, including all engineering services and taxes, will be around 53 million €. The duration of the works should be of around 24 months.

With such an investment needed for the works, the APSCT and other related institutions must look for a profitable final use of the land. A private investor will put around one third of the total investment and will hold the ownership of the Land. The APSCT will pay a fixed rent, ensuring the profitability for the Private Investor. The final user is the missing actor. It is one of the main goals of this project to define the possibilities for final uses and to design all technical aspects related to them.

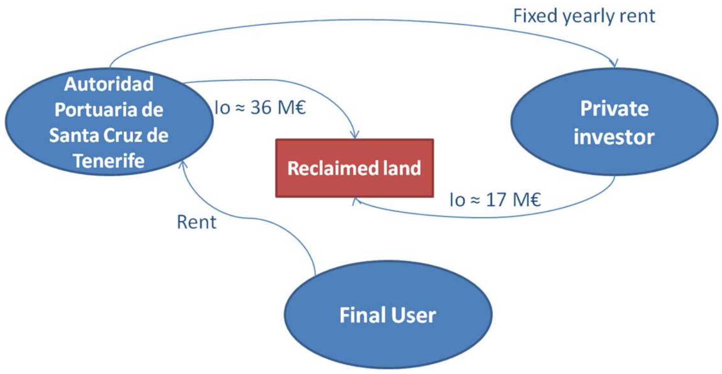

Figure 7. Land ownership structure

In the following chapters the feasibility of a fish-farm will be studied. The main operational and technical aspects of the facilities will be studied, allowing an estimation of the total costs of the facilities (CAPEX and OPEX). Once determined the main characteristics of the project, the time schedule and an approximated budget for the works will be done. Furthermore, due to the strictly regulations around fish-farms, we will analyse the bureaucratic procedure to follow until all required licenses are obtained.

4 Current situation of fish farming in the Canary Islands

For many reasons the fish-farm industry offers big opportunities for the upcoming years. The Earth's population is expected to have grown by 2.000 million inhabitants by 2050 (13), arriving to a total of 9.600 million. From the total amount of the Earth's population, 800 million still starve, so getting food closer to them is a clear objective all in the short, middle, and long term. At the same time, we see how natural resources keep getting increasingly damaged as the demand increases exponentially driven by population growth but also due to higher living standards. There is a huge need for controlled production, not just in the fish industry but on the whole food production and even in the whole primary sector.

We see how governments respond to the need of regulation, but many times the political factor has more leverage in the decision making, years can get passed without any real progress due to bureaucratic procedures, and a misalignment is generated between decisions made and 100 % logical and objective interests of the population. We see an example of this fact in the development of the PEACAN, for the Spanish *Plan Estratégico de la Acuicultura en Canarias*. This study, developed by the Fishing Department of the Canary Government (*Viceconsejería de Pesca y Aguas del Gobierno de Canarias*), was meant to cover the 2014-2020 period, but it has not yet been approved and will probably never be done in time, creating a sense of uncertainty among all actors in the sector.

This fact shows that there is a big need for private institutions to become conscious in order to support the always needed public actions. Only by developing our own strategies, parallel to public ones, we will achieve the sustainable growth needed in order to meet the earth's population's increasing needs.

Just as an example, I would like to invite readers to visit www.plantagon.com, a private initiative that is trying to enable food to be produced in smart greenhouses in the middle of big cities, throughout state of the art technology, in order to reduce the needs of arable land, water, energy and transport costs.

The key idea is to grow vegetables in a very controlled environment. By using a several-floor fully automated system land use is optimized, as plants get moved from bottom to top depending on the stage of the growth process. As can be seen on Figure 8, all light comes from natural sources and a glass carcase insulates the whole facility, which enables the use of nearly no pesticides. Another interesting aspect is the fact that the greenhouse works in synergy with the city in terms of heat, exchanging heat both ways (absorbing in summer and rejecting in winter) through heat exchangers, but also in terms of O_2 generation and CO_2 consumption.

Figure 8. Plantagon's prototype building in Linköping, Sweden (14).

This just represents an example of a huge tendency that will for sure get even bigger in the future. Food production needs to be reconceived, and this will only be possible with the help of private investment allowing long term R&D.

Regarding fish farming in Spain, and the Canary Islands in particular, we can't start anywhere but by saying that fish farms are an extremely regulated industry. All fishing related activity must be submitted to a long approval process. The goals of this project are completely subject to obtaining an activity license, which depends on technical, environmental and economic factors as well as on political decisions. As said at the beginning of this section, the current state of regulation around fish farms in the Canary Islands is not the best starting point for this study, as there are Strategic Studies and other decisions waiting to be approved due to political reasons. However, the technical matters are being study hoping that in the near future the industry will get an impulse from the authorities and, even if no subsidies are allocated, licenses start once again being given to new facilities.

The IFOP (*Instrumento Financiero de Orientación de la Pesca*), was a subsidy program created in the 90's in order to increase investment in the fishing sector. The result of this program was a great growth between 2001 and 2006, with 34 producers in the Canary Islands and a total sea bream and sea bass production (allowed production, not actually produced) of 12.000 tons per year. By 2008 the total allowed production was 14.000 tons. However, the financial crisis in 2008 reduced financing opportunities for the fish-farm industry, which pushed many producers to prematurely sell their production and therefore strongly decreasing the market price. The main effects of this crisis was the closedown of several producing facilities together with several merger processes, which ended up in having all producing facilities (except four) owned by three bigger enterprises: Tinarmenor, Pemarca and Ricardo Fuentes e Hijos (15).

By 2012, production capacity had recovered, with over 15.000 tons of bass and bream production capacity. Prices had also slightly increased after being the offer in the market too low for the previous two years.

Sea bass is the most produced fish in the Canary Islands, representing 60% of total production. In second place there is sea bream representing nearly all missing 40%. However, in 2012 and 2013 seaweed and prawn production was allowed for the first time in the Island of

Gran Canaria to Algalimento and Langostinos Real Canarias SL, respectively, and with an allowed production of 1 and 78 tons.

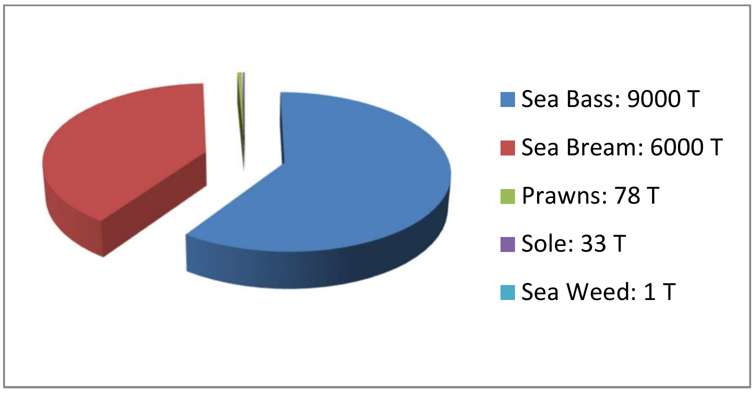

Figure 9. Total allowed production capacity in the Canary Islands in 2013.

Despite the production capacities previously seen, the Canary Islands produced about 6.000 tons of fish in 2013 (many fish farms are not in operation), as can be seen in Table 7. In 2014, the market value of the production (nearly 6.000 tons) was of around 27.8 million euro.

Canary Islands	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Bream	3.983	3.605	2.664	2.524	2.526	2.311	2.300
Bass	2.930	4.795	3.219	4.125	3.592	3.645	3.600
Sole	0	0	0	29	26	33	33
Total	**6.913**	**8.400**	**5.883**	**6.678**	**6.144**	**5.989**	**5.933**

Table 7. Evolution of total fish-farm fish production.

As we can appreciate from the data analyzed in the previous paragraphs, real production is very low compared to the total production capacity allowed. The main reason for this is the loss of profitability, especially after transport has evolved both in time and cost, what has enabled global players to export all over the world, making prices sink. Table 8 lists the existing fish-farms in the Canary Islands in 2014 and their operational status. It is important to consider that most of these enterprises belong to the same groups, as explained just above.

Owner / Applicant	Region	Annual allowed production (tons)	Situation in 2014
Lanzarote			
Yaizatún, S.A.	Yaiza	1856	In operation
Insular de Cefalópodos	Yaiza	48	-
Gran Canaria			
Alevines y Doradas, S.A. (ADSA-Castillo)	S. Bart. De Tirajana	615	In operation
Alevines y Doradas, S.A. (ADSA-Melenara)	Telde	650	In operation
Canarias de Explotaciones Marinas, S.A. (CANEXMAR, S.L.)	Telde	340	In operation
Productos de Crianza, S.L. (PROCRIA, S.L.)	S. Bart. De Tirajana	1800	In operation
Granja Marina Playa de Vargas, S.L.	S. Bart. De Tirajana	2000	In operation
Granja Marina Playa de Vargas 2001, S.L.	Telde	500	-
Inter Aqua S.L.	S. Bart. De Tirajana	2800	In operation
Tenerife			
Cultivos Marinos Teide, S.L.	Arona	160	In operation
Efficient System Service, S.L.	Arona	125	-
Socat Canarias, S.L.	Arona	125	In operation
Industrias Acuicolas de Canarias, S.L. (Inac)	Arona	125	In operation
Cabo Pez, S.L.	Arona	125	In operation
Punta Rasca, Cultivos Marinos de Canarias, S.L.	Arona	125	-
Cultivos Marinos Atlántico, S.L.	Candelaria	125	-
Punta Rasca, Cultivos Marinos de Canarias, S.A.	Adeje	350	In operation
Efficient System Service, S.L.	Adeje	350	In operation
Marcultivos, S.L.	Adeje	125	-
Pérez Cortés, S.L.	Adeje	125	-
Cabo Pez, S.L.	Adeje	175	In operation
Exmarcan, S.L.	Adeje	125	-
Tingoe Canarias, S.L.	Adeje	125	-
Océano San Juan, S.L.U.	Adeje	125	-
La Palma			
Acuipalma, S.L.	Tijarafe	1000	In operation

Table 8. Fish-farm license situation in 2014 (15).

The state of the industrial facilities suggests a lot of potential, as there have been investments that have been lost due to the loss of profitability (mostly, too high operating costs). Many of these facilities could be adapted and recycled so that they start producing again. We will later see how this might be a good business opportunity.

A second point that justifies this project is the huge need for new investment in the fishing sector (not just in fish-farms) in the Islands. Many reports show the decrease of profitability for most fishing industry actors. Businesses have traditionally been family size, not able to afford the needed investment, which combined with the isolation of the population and difficulty to keep up to date with technology, has ended up with a very obsolete fishing fleet and methods.

The same increase in logistic efficiency that now enables countries like China to export fish all over the world is going to be the third strong point for our business model. Global transport lines will enable us to export our product at very low costs, being able to target a very important area, the west coast of Africa. This zone supposes a huge potential market that could be the key to our success.

In-land fish production still finds some technical limitations such as the very specific water conditions or the huge amount of land required for fattening the fish. This is pushing companies in the sector to specialize on only one of the growing phases of the fish: the hatchery, the pre-fattening or the fattening phase.

Considering the current gap between total capacity and production (of fattened, ready to consume fish) and the need for investment, this project aims at producing pre-fattened fish. By producing pre-fattened fish (also called fries) very close to the fattening facilities in the Islands, we will be able to sell the first part of our production within a few kilometres of distance, helping local producers to restart production. In second point, fries will be also sold to further clients, especially in Africa and mainland Spain. We will only have to worry about keeping our costs down.

5 Hatchery and Pre-fattening fish-farm: Process description

The normal cycle to be followed by fish in fish-farms is as shown in Figure 10, although most times it is limited to only some of the stages, typically hatchery and pre-fattening for in-land facilities and fattening for off-shore ones.

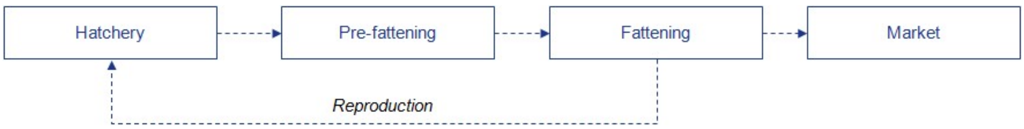

Figure 10. Fish's production process in fish-farms.

The aim of this project is to only focus on the hatchery and pre-fattening phases of the fish' life cycle: small fries, obtained from larvae, will be sold. On top of this, and as will be seen later on, a small portion of specimens will be kept in order to close the reproduction cycle, as per Figure 11..

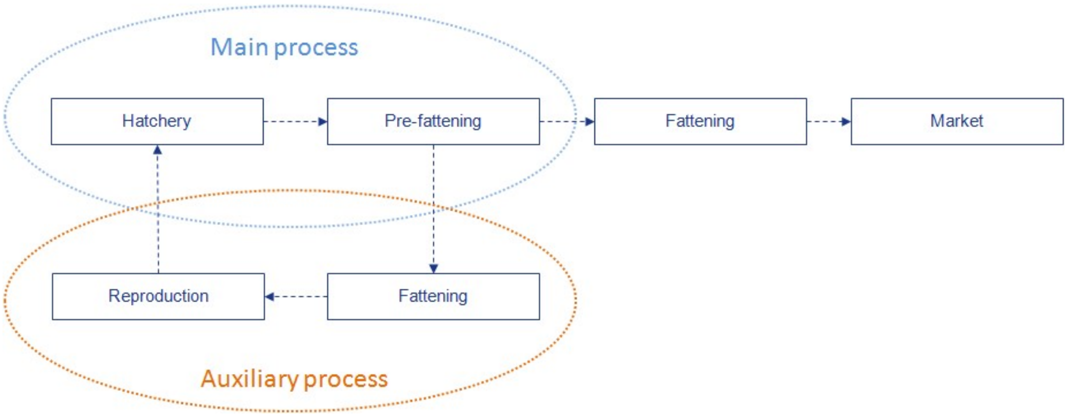

Figure 11. Production processes in the facilities.

Production will be composed of only two fish species: sea bass and turbot. As explained earlier, sea bass is already produced in the Canary Islands, so our aim is to supply existing facilities with larvae and pre-fattened fish that they will later fatten until sale. Turbot is still not grown in the Islands, although turbot fish farms do exist in mainland Spain and Africa. We will therefore export our fries in the first place, keeping as a second objective to support turbot production in the Islands, either building a new fish farm or reconverting one of the existing ones (as previously said, half of the Islands' production capacity is not in operation).

The reproduction cycle of turbot can be synthesized as follows:

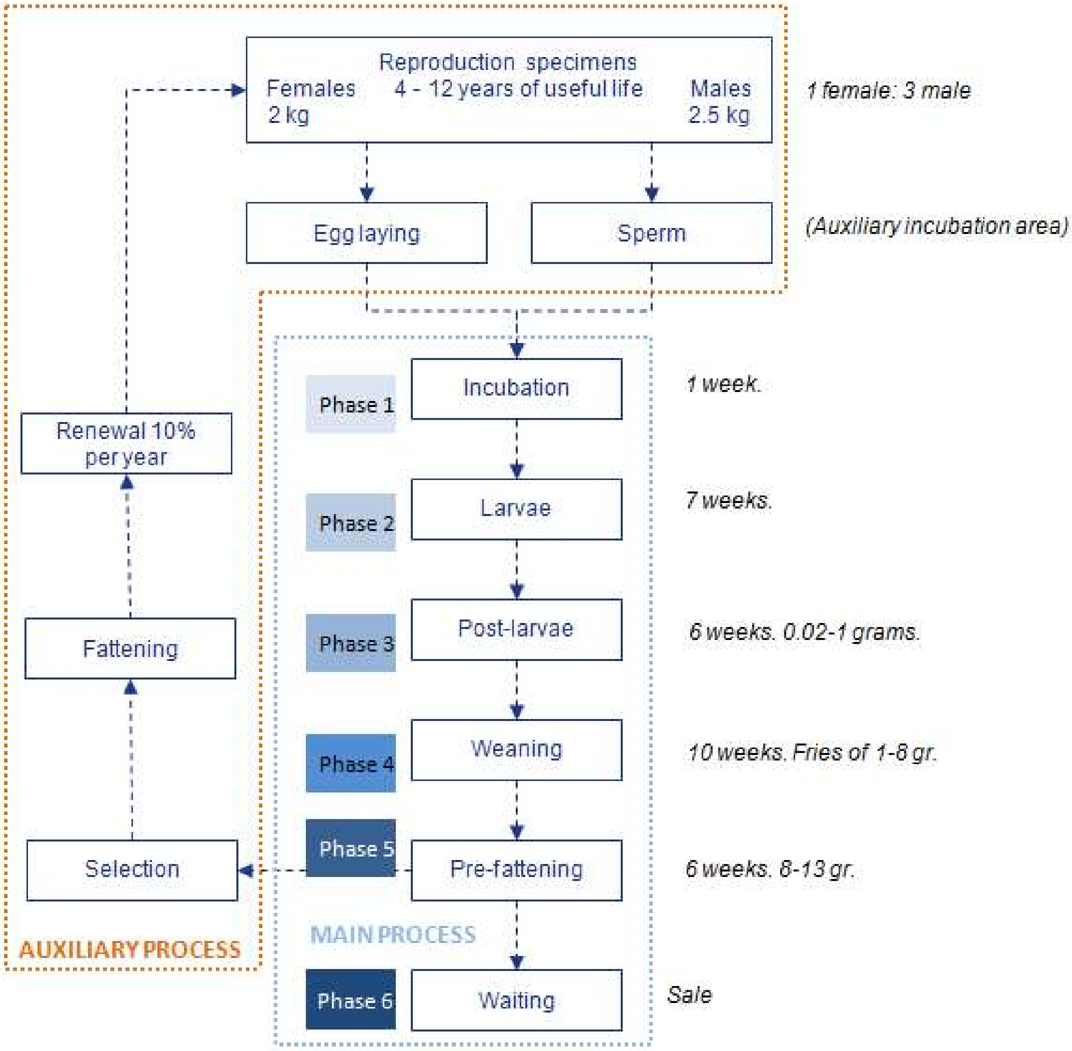

Figure 12. Turbot's life cycle.

Regarding sea bass, the different phases of its lifecycle (16) are shown in Figure 13.

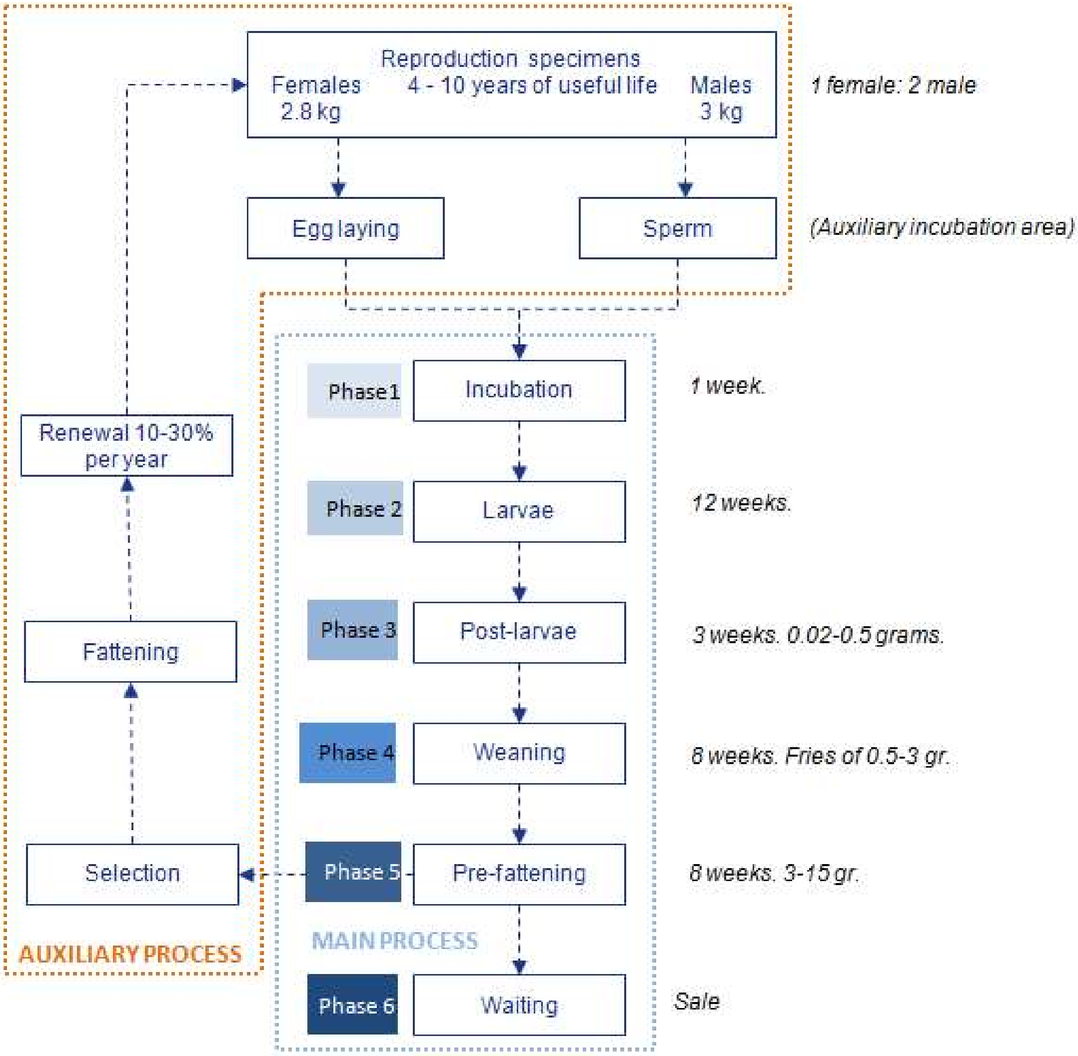

Figure 13. Sea bass' life cycle.

The main production process will consist in 5 phases, from incubation to pre-fattening, plus an additional one, which we will call *waiting*. At this stage fish is considered to have finished our production process but is still in our facilities waiting to be sold. Therefore, this phase should be considered as a storage area for our finished goods.

Although it would be possible to buy fish for the renewal of the reproduction specimens, the facilities will host an auxiliary process to ensure the gametes needed for incubation. This process consists in selecting the best pre-fattened fish, fattening them until they can reproduce and extracting the gametes for larvae production.

However, we will grow our own reproduction fish aiming to be as little dependant from external resources as possible. A further economic study will however have to support our decision.

It is common use in the industry to interfere in the reproduction of the fish by changing the photoperiod. Fish egg laying, like most animals, is influenced by the seasons of the year. By changing the amount of light received we will ensure a continuous stream of gametes. Table 9 is an example of this method applied to turbot eggs production.

	First year	**Second year**	**Third year**
Induced egg laying (long photoperiod)	March and December	September	June
Normal egg laying	June	March and December	September
Delayed egg laying (short photoperiod)	September	June	March and December

Table 9. Egging periods of the turbot with chosen method.

This method will be applied to all other produced species, changing the number of cycles and the months of the year at which we will force breeding. This will ensure us a constant supply of the needed gametes.

5.1 Main Process. Turbot Hatchery and Pre-fattening Area

As explained previously, our production site will focus on the hatchery and pre-fattening phases as the final product will be sold to other parties who will later grow them until they are ready to be consumed by the final customer.

This section aims at describing the main production process, which is decomposed in two independent processes (one for turbot and one for sea bass), both containing the following stages (as per Figure 12 and Figure 13):

1. Incubation
2. Larvae
3. Post larvae
4. Weaning
5. Pre-fattening
6. Waiting

In another section, the rest of the growth process will be studied, as we will implement an auxiliary process for obtaining the eggs required for incubation.

5.1.1 Main Process

The final production of turbot fries at the waiting area will be 1.200 tons per year. Taking this into account, together with the length of each of the turbot's lifecycle phases, the following production plan for the main process will be tackled:

Yearly production (T)	1.200
Number of lots at facilities	16
Lot size (final tons of fish)	44,4
Lot frequency	2 weeks
Process duration	32 weeks

Table 10. Lot size and frequency for turbot.

Lot 1 starts week 1 at phase 1, incubation. The second week, Lot 1 will go onto the first week of the Larvae phase (phase 2). The process goes on until, in week 31, the pre-fattened fish can be sold.

The numbers on the table (1 to 6) correspond to the phases on the bullet point in the previous section and with phases shown on Figure 12 and Figure 13.

	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	W16
Lot 1	1	2	2	2	2	2	2	2	3	3	3	3	3	3	4	4
Lot 2	6	6	1	2	2	2	2	2	2	2	3	3	3	3	3	3
Lot 3	5	5	6	6	1	2	2	2	2	2	2	2	3	3	3	3
Lot 4	5	5	5	5	6	6	1	2	2	2	2	2	2	2	3	3
Lot 5	5	5	5	5	5	5	6	6	1	2	2	2	2	2	2	2
Lot 6	4	4	5	5	5	5	5	5	6	6	1	2	2	2	2	2
Lot 7	4	4	4	4	5	5	5	5	5	5	6	6	1	2	2	2
Lot 8	4	4	4	4	4	4	5	5	5	5	5	5	6	6	1	2
Lot 9	4	4	4	4	4	4	4	4	5	5	5	5	5	5	6	6
Lot 10	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5
Lot 11	3	3	4	4	4	4	4	4	4	4	4	4	5	5	5	5
Lot 12	3	3	3	3	4	4	4	4	4	4	4	4	4	4	5	5
Lot 13	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4
Lot 14	2	2	3	3	3	3	3	3	4	4	4	4	4	4	4	4
Lot 15	2	2	2	2	3	3	3	3	3	3	4	4	4	4	4	4
Lot 16	2	2	2	2	2	2	3	3	3	3	3	3	4	4	4	4

	W17	W18	W19	W20	W21	W22	W23	W24	W25	W26	W27	W28	W29	W30	W31	W32
Lot 1	4	4	4	4	4	4	4	4	5	5	5	5	5	5	6	6
Lot 2	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5
Lot 3	3	3	4	4	4	4	4	4	4	4	4	4	5	5	5	5
Lot 4	3	3	3	3	4	4	4	4	4	4	4	4	4	4	5	5
Lot 5	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4
Lot 6	2	2	3	3	3	3	3	3	4	4	4	4	4	4	4	4
Lot 7	2	2	2	2	3	3	3	3	3	3	4	4	4	4	4	4
Lot 8	2	2	2	2	2	2	3	3	3	3	3	3	4	4	4	4
Lot 9	1	2	2	2	2	2	2	2	3	3	3	3	3	3	4	4
Lot 10	6	6	1	2	2	2	2	2	2	2	3	3	3	3	3	3
Lot 11	5	5	6	6	1	2	2	2	2	2	2	2	3	3	3	3
Lot 12	5	5	5	5	6	6	1	2	2	2	2	2	2	2	3	3
Lot 13	5	5	5	5	5	5	6	6	1	2	2	2	2	2	2	2
Lot 14	4	4	5	5	5	5	5	5	6	6	1	2	2	2	2	2
Lot 15	4	4	4	4	5	5	5	5	5	5	6	6	1	2	2	2
Lot 16	4	4	4	4	4	4	5	5	5	5	5	5	6	6	1	2

Table 11. Production plan for turbot.

It is important to note that fish will be sold under demand, and therefore an additional area should be provided for keeping the fish during weeks 31 and 32. It is expected to receive orders gradually, starting at the end of week 30 until week 32. By the end of week 32, all fish will be sold. During these two weeks fries will be kept in what will be called from now onwards the Waiting Phase, Phase 6.

Table 12 illustrates the number of lots at each phase in weeks 1 and 2. As the needed capacity is not constant every week, we will calculate the maximum capacity for dimensioning our facilities by applying taking the highest value.

	Week 1	Week 2	Needed
Total lots at Incubation Phase (1)	1	0	**1**
Total lots at Larvae Phase (2)	3	4	**4**
Total lots at Post-larvae Phase (3)	3	3	**3**
Total lots at Weaning Phase (4)	5	5	**5**
Total lots at Pre-fattening Phase (5)	3	3	**3**
Total lots at Waiting (6)	1	1	**1**

Table 12. Needed capacity for turbot (lots).

Taking into account the desired final production, the number of lots and the survival rates (Table 13) it is possible to determine the number of specimens per phase, as shown in Table 14.

	Survival rate
Incubation	11%
Larvae	28%
Post-larvae	79%
Weaning	93%
Pre-fattening	94%

Table 13. Turbot's survival rates.

	Total weight per lot at end (kg)	Number of specimens per lot at end	Number of specimens per lot at beginning
Total Incubation	-	17.679.835	160.725.772
Total Larvae	-	4.950.354	17.679.835
Total Post-larvae	3.910.779	3.910.779	4.950.354
Total Weaning	29.096.199	3.637.025	3.910.779
Total Pre-fattening	44.444	3.418.803	3.637.025

Table 14. Lot specification throughout the turbot's lifecycle.

As per Table 13, the accumulated survival rate for the whole cycle is 2.12%, which implies we will need 161 million eggs to be fertilized at the beginning of the incubation phase to produce 44.44 tons of fries. This number will be important when dimensioning the breeding specimens to be kept for gamete production.

5.1.2 Tanks specification

To design the tanks, phases 3, 4 and 5 of the main production process are decomposed in shorter 2-week stages, as shown in Table 15. This will enable us to use less space, as tanks at each phase will be dimensioned using more precise parameters (fish size, density, etc) instead of just 1 set of parameters for a long 10-week period which would dramatically increase the use of space.

Setting the required tank diameter for each of the phases, the turbot's hatchery and pre-fattening tanks are to be dimensioned as follows:

$$Tank\_surface_i[m^2] = \pi x \frac{d[m]^2}{4} \tag{1.1}$$

$$Tank\_capacity_i[l] = Tank\_surface_i[m^2]xh[m]x1.000 \tag{1.2}$$

$$Specimens\_per\_\tan k_i = \frac{Tank\_capacity_i[l]xDensity[\frac{fish}{m^3}]}{1.000} \tag{1.3}$$

$$Number\_\tan ks\_per\_lot_i = \frac{Number\_of\_specimens_i}{Specimens\_per\_\tan k_i} \tag{1.4}$$

Please find in Annex 4 the tank specifications for the entire facilities.

In order to dimension the additional tanks for the waiting area it has been taken as hypothesis that the increase in size of the fries will be compensated by the quantity of fries that get gradually sold. Under this hypothesis, another 22 tanks will be needed at the beginning of the waiting phase, and they will be gradually emptied.

Small barrels (400 litres) will be used at the incubation phase as they are a great option for keeping eggs in a very controlled environment. In addition, this phase requires a big amount of handling.

For similar reasons, 1.500 l barrels will be used for the larvae and post-larvae phases.

5.1.3 Water requirements

The total volume of water to be renewed can be easily obtained, as the total water volume and the renewal rate at each stage are known. Table 15 shows the optimal water renewal rate for each lot.

$$Total\_renewal_i[\frac{l}{h}] = Tank\_volume_i[l]xN\_\tan ksxRenewal\_rate[\frac{\%}{h}] \tag{1.5}$$

	Tank volume (litres)	Total number of tanks (all lots)	Total water volume (litres)	Hourly water renewal	Total hourly water renewal (litres)	Hourly water renewal per tank (litres)
Incubation	400	45	17.858	15%	2.679	60
Larvae	1.500	943	1.414.387	15%	212.158	225
Post-larvae	1.500	495	742.553	50%	371.277	750
Weaning 1	102.141	2	205.830	50%	102.915	51.071
Weaning 2	102.141	2	230.046	50%	115.023	51.071
Weaning 3	102.141	3	260.719	50%	130.359	51.071
Weaning 4	102.141	3	279.771	50%	139.886	51.071
Weaning 5	102.141	3	341.880	50%	170.940	51.071
Pre-fattening 1	117.855	21	2.424.683	50%	1.212.342	58.928
Pre-fattening 2	117.855	22	2.597.875	50%	1.298.937	58.928
Pre-fattening 3	117.855	22	2.614.379	50%	1.307.190	58.928
Waiting	117.855	22	2.592.810	50%	1.296.405	58.928
		Total m3	**13.723**	**Total m3 per hour**	**6.360**	

Table 15. Water needs for the Turbot fries production (renewal rates (16)).

The total amount of water to be pumped through the turbot's hatchery and pre-fattening areas is therefore 6.360m^3/h. However, 60% of this water will not be brought from the sea but recycled from the used water system, converting it into a semi-closed system with a fresh water flow of 40%. This will be explained in more detail in further sections.

5.2 Main Process. Sea Bass Hatchery and Pre-fattening Area

Sea bass production process is very similar to turbot's. The method followed for dimensioning the facilities is the same, although some parameters such as the process duration or the survival rates at each stage slightly change.

5.2.1 Main Process

The hatchery will also have a yearly production of 1.200 tons of sea bass fries of around 15 gr. per unit. This production will be done, just like for turbot, in 26 lots per year with an average weight of 44.44 tons of final product.

Yearly production (T)	1.200
Number of lots at facilities	17
Lot size (final kg of fish)	44,44
Lot frequency	2 weeks
Process duration	34 weeks

Table 16. Lot size and frequency for sea bass.

Taking into account the duration of each one of the life cycle's phases of sea bass, the following production plan is established.

	w1	w2	w3	w4	w5	w6	w7	w8	w9	w10	w11	w12	w13	w14	w15	w16	w17
Lot 1	1	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	4
Lot 2	6	6	1	2	2	2	2	2	2	2	2	2	2	2	2	3	3
Lot 3	5	5	6	6	1	2	2	2	2	2	2	2	2	2	2	2	2
Lot 4	5	5	5	5	6	6	1	2	2	2	2	2	2	2	2	2	2
Lot 5	5	5	5	5	5	5	6	6	1	2	2	2	2	2	2	2	2
Lot 6	5	5	5	5	5	5	5	5	6	6	1	2	2	2	2	2	2
Lot 7	4	4	5	5	5	5	5	5	5	5	6	6	1	2	2	2	2
Lot 8	4	4	4	4	5	5	5	5	5	5	5	5	6	6	1	2	2
Lot 9	4	4	4	4	4	4	5	5	5	5	5	5	5	5	6	6	1
Lot 10	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	6
Lot 11	3	3	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5
Lot 12	2	3	3	3	4	4	4	4	4	4	4	4	5	5	5	5	5
Lot 13	2	2	2	3	3	3	4	4	4	4	4	4	4	4	5	5	5
Lot 14	2	2	2	2	2	3	3	3	4	4	4	4	4	4	4	4	5
Lot 15	2	2	2	2	2	2	2	3	3	3	4	4	4	4	4	4	4
Lot 16	2	2	2	2	2	2	2	2	2	3	3	3	4	4	4	4	4
Lot 17	2	2	2	2	2	2	2	2	2	2	2	3	3	3	4	4	4

	w18	w19	w20	w21	w22	w23	w24	w25	w26	w27	w28	w29	w30	w31	w32	w33	w34
Lot 1	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	6	6
Lot 2	3	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5
Lot 3	3	3	3	4	4	4	4	4	4	4	4	5	5	5	5	5	5
Lot 4	2	2	3	3	3	4	4	4	4	4	4	4	4	5	5	5	5
Lot 5	2	2	2	2	3	3	3	4	4	4	4	4	4	4	4	5	5
Lot 6	2	2	2	2	2	2	3	3	3	4	4	4	4	4	4	4	4
Lot 7	2	2	2	2	2	2	2	2	3	3	3	4	4	4	4	4	4
Lot 8	2	2	2	2	2	2	2	2	2	2	3	3	3	4	4	4	4
Lot 9	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	4	4
Lot 10	6	1	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3
Lot 11	5	6	6	1	2	2	2	2	2	2	2	2	2	2	2	2	3
Lot 12	5	5	5	6	6	1	2	2	2	2	2	2	2	2	2	2	2
Lot 13	5	5	5	5	5	6	6	1	2	2	2	2	2	2	2	2	2
Lot 14	5	5	5	5	5	5	5	6	6	1	2	2	2	2	2	2	2
Lot 15	4	5	5	5	5	5	5	5	5	6	6	1	2	2	2	2	2
Lot 16	4	4	4	5	5	5	5	5	5	5	5	6	6	1	2	2	2
Lot 17	4	4	4	4	4	5	5	5	5	5	5	5	5	6	6	1	2

Table 17. Yearly production plan for sea bass.

Once again, production areas need to be dimensioned taking into account the maximum capacity, as production will not be identical every week:

	Week 1	Week 2	MAX
Total lots at Incubation Phase (1)	1	0	**1**
Total lots at Larvae Phase (2)	6	6	**6**
Total lots at Post-larvae Phase (3)	1	2	**2**
Total lots at Weaning Phase (4)	4	4	**4**
Total lots at Pre-fattening Phase (5)	4	4	**4**
Total lots at Waiting Phase (6)	1	1	**1**

Table 18. Needed capacity for sea bass.

For the same reason as for turbot, sea bass' waiting area will also be composed of just 1 lot. Taking into account the desired final production and the survival rates in Table 19, each lot will be composed of the following number of specimens:

	Survival Rates
Incubation	9%
Larvae	20%
Post-larvae	74%
Weaning	95%
Pre-fattening	95%

Table 19. Sea bass survival rates.

	Number of lots (max load)	Total Weight at end (kg per lot)	Number of specimens at end per lot	Number of specimens at beginning per lot
Total Incubation	1	-	22.182.847	246.476.085
Total Larvae	6	-	4.436.569	22.182.847
Total Post-larvae	2	164	3.283.061	4.436.569
Total Weaning	4	9.356	3.118.908	3.283.061
Total Pre-fattening	4	44	2.962.962	3.118.908

Table 20. Lot specification throughout the sea bass' lifecycle.

As can be seen in Table 19, the accumulated survival rates throughout the process are very low. The accumulated survival rate is 1.2%.

5.2.2 Tanks specification

Following the same method as for turbot, the tanks size and water volume are set to obtain the required number of tanks for each phase. The desired diameter has been set up to 0.8 m for larvae and post-larvae, and 10 m for weaning pre-fattening and waiting.

5.2.3 Water requirements

As done for turbot, Table 21 shows the total amount of water to be pumped between the Water Treatment System and the tanks.

	Tank volume (litres)	Total number of tanks (all lots)	Total water volume (litres)	Hourly water renewal	Total hourly water renewal (litres)	Hourly water renewal per tank (litres)
Incubation	400	51	20.540	15%	3.081	60
Larvae	1.500	1.775	2.661.942	15%	399.291	225
Post-larvae	1.500	296	443.657	50%	221.828	750
Weaning 1	102.141	2	164.153	50%	82.077	51.071
Weaning 2	102.141	2	193.121	50%	96.561	51.071
Weaning 3	102.141	2	252.543	50%	126.272	51.071
Weaning 4	102.141	3	311.891	50%	155.945	51.071
Pre-fattening 1	117.855	7	850.611	50%	425.306	58.928
Pre-fattening 2	117.855	15	1.819.363	50%	909.682	58.928
Pre-fattening 3	117.855	24	2.878.992	50%	1.439.496	58.928
Pre-fattening 4	117.855	25	2.962.963	50%	1.481.481	58.928
Waiting	117.855	25	2.946.375	50%	1.473.188	58.928
		Total m3	**15.506**	**Total m^3 per hour**	**6.814**	

Table 21. Water needs for the Sea Bass fries' production.

While for turbot the estimated amount of water is 6.360 m^3/h, sea bass' main process will require an hourly renewal of 6.814 m^3/h.

5.3 Breeding Process

At this point, the process of fish breeding for producing the needed gametes is to be studied. This process will be calculated in parallel for sea bass and for turbot.

The area where reproduction specimens are grown is divided into two areas. In the main area, the mature specimens are kept in big tanks and used for gamete production following the schedule explained in Table 9. This stage will be called fattening from now onwards. Secondly, young selected specimens are left to grow in an auxiliary area until they reach mature age and are suitable for reproduction. This area is called *fattening area*.

Once they have arrived to the reproduction stage, fish are around 2 years old.

	Time at main process	Time at fattening	Total time before reproduction
Turbot	30 weeks	18 months	25.5 months
Sea Bass	32 weeks	18 months	26 months

Table 22. Total time spent until reproduction.

Figure 14. Turbot and Sea Bass breeding process.

Taking into account the fish's useful life, it would be possible to deduce an optimal renewal rate for the fish. However, for ease of design and operations, a 10% yearly renewal rate has been established (which is something realistic), as we will see in the following paragraphs.

5.3.1 Reproduction area

5.3.1.1 Process

The starting point for the design of the facilities is the needed number of eggs to be fertilized. At this point it is necessary to remember section 0, where it has been mentioned that fish used for reproduction will live under artificial light cycles in order to reach a constant gamete production. This means that, considering the 24 yearly lots desired and the 3 egg-layings per year, we will need to have at least 8 different tanks per category (turbot or sea bass, male or female), so that the amount of light received by each one of them can be individually controlled. These tanks will be individually covered to efficiently control this amount of light. We will therefore do the calculations for this section per lot, and then multiply the results times the eight different tanks (we need 24 lots of gametes, but each tank produces 3 lots of gametes per year).

The number of eggs laid per female depends on the fish's size, so we have established an average number for a 2 kg turbot and 2.8 kg sea bass, for female. The corresponding number of males and females is then calculated, including a 15% security margin in order to ensure the needed production.

$$Needed\_number_{i,female} = \frac{Needed\_eggs_i}{Eggs\_per\_female_i} x(1+15\%) \quad (1.6)$$

$$Needed\_number_{i,male} = Needed\_number_{i.female} xRatio_i \quad (1.7)$$

	Needed eggs (per lot)	Eggs per female (per egg-laying/lot)	Ratio Female/Male
Turbot	3.778.043.152	10.333.333	3
Sea bass	10.251.640.222	14.000.000	2

Table 23. Main characteristics of gamete production.

	Number of fish a reproduction area (per lot, incl. +15% margin)
Turbot females	420
Sea bass females	842
Turbot males	1.261
Sea bass males	1.684

Table 24. Number of grown fish for gamete production (per lot).

Considering the weight indicated on the previous paragraph and 2.5 and 3 kg for males, we can obtain the needed volume of water for each of the four categories of fish.

$$Total\_volume_{i,j}[\frac{l}{lot}] = \frac{Needed\_number_{i.j} xWeight_i[\frac{g}{fry}]}{Density[\frac{kg}{m^3}]x1.000} \quad (1.8)$$

	Total weight per lot (kg)	Density (kg/m³)	Total volume per lot (m³)
Turbot females	841	30	28
Sea bass females	2.358	35	67
Turbot males	3.153	32	99
Sea bass males	5.053	37	137

Table 25. Volume of water for breeding specimens (per lot).

5.3.1.2 Tanks specification

Using 1,2 m high tanks and setting the desired number of them to 1 per category and per lot (there will be 8 lots), the diameter of the tanks should be as per Table 26.

$$Diameter_{i,j} = \sqrt{\frac{4xTotal\_volume_{i,j}}{\pi xH}} \tag{1.9}$$

	Number of tanks in total	Diameter (m)	H_w (m)
Turbot females	8	5,45	1,2
Sea bass females	8	8,45	1,2
Turbot males	8	10,22	1,2
Sea bass males	8	12,04	1,2

Table 26. Reproduction area tanks' specification.

More details about the tanks will be set further along this study in order to adapt our global layout for reducing waste in terms of space, time, energy and labour.

5.3.1.3 Water requirements

Regarding the water to be recycled at these tanks, we can assume 30% is an appropriate renewal rate for the reproduction area, obtaining the following water flows.

$$Total\_renewal_{i,j}[\frac{m^3}{h}] = N\_\tan ks_{i,j} xUnit\_volume_{i,j}[m^3]x\frac{\mathrm{Re}newal\_rate_{i,j}[\frac{\%}{h}]}{100} \tag{1.10}$$

	Number of tanks	Unitary volume (m3)	Hourly renewal rate	Unitary renewal rate (m3/h)	Total renewal (m3/h)
Turbot females	8	28	30%	8	67
Sea bass females	8	67	30%	20	162
Turbot males	8	99	30%	30	237
Sea bass males	8	137	30%	41	328
			Total renewal reproduction area(m3/h)		793

Table 27. Water renewal at reproduction area.

The total amount of water to be renewed hourly at the reproduction area is 793 m³. In addition, an extra volume of water should be provided to feed the auxiliary incubation area, where eggs and sperm are taken out of reproduction area and put into incubation. This process will require an extra amount of water considered to be 10% of the water needed for incubation for each of both species.

$$Aux\_water\_incubation_i[\frac{m^3}{h}] = 10\% x \text{Re}newal\_water_{i,incubation}[\frac{m^3}{h}] \quad (1.11)$$

Although this water, around 300 l per species, will only be used whenever the eggs are moved from reproduction to incubation, we will consider this flow to be constant in order to be closer to the maximum load situation.

5.3.2 Fattening area

5.3.2.1 Process

Reproduction fish will be renovated at a 10% rate per year, selecting the best pre-fattened fries from our hatchery. For this reason, we will provide an intermediate stage in which pre-fattened fish grow until they are fit for use, as per Figure 14.

Fish need around 1,5 years at this stage (both turbot and sea bass), which is why we will design our facilities for the 15% per cycle and not 10%. This way, we will have a 1 lot process with a frequency of 1,5 years. The number of fish will be around 5.500 per lot. Once every 18 months, the best fries from the pre-fattening process will be selected and put to grow in the fattening area. Once ready to go into the reproduction area, they will be divided into 8 groups.

5.3.2.2 Tanks specification

Establishing a water height of 1,2 m and a suitable diameter, the number of tanks can once again be calculated as per the following table. The real tanks will all be designed the same size, so they should have around 7 meters of diameter and a water height of 1,2 m or less, depending on the exact water volume.

$$Total\_weight\_at\_end_{i,j}[\frac{l}{lot}] = Total\_weight_{i.j}(repr.)x15\% \quad (1.12)$$

$$Diameter_{i,j}[m] = \sqrt{\frac{4x\dfrac{Total\_weight\_at\_ent_{i.j}(repr)[kg]}{Density[\frac{kg}{m^3}]xN\_\tan ks_{i.j}}}{\pi x H[m]}} \quad (1.13)$$

	Total weight at end (before going into reproduction tanks, kg)	Density (kg/m³)	Needed m³	Number of tanks	Diameter (h_w = 1,2 m)
Turbot females	1.009	27	37	1	6,3
Sea bass females	2.829	32	88	2	6,8
Turbot males	3.784	27	140	4	6,1
Sea bass males	6.063	32	189	5	6,3

Table 28. Fattening area tank's theorical specifications.

	Water height (m)	Diameter (m)
Turbot females	1,0	7
Sea bass females	1,1	7
Turbot males	0,9	7
Sea bass males	1,0	7

Table 29. Fattening area tank's real specifications.

The tanks within the fattening areas will therefore have to be, at least, around 1.4 m high, leaving a 30 cm margin for the fullest tank (sea bass females).

5.3.2.3 Water requirements

Regarding the water renewal for these tanks, an hourly rate of 30% of the tank's volume is enough, just as it was for the reproduction tanks.

	Number of tanks	Unitary volume (m^3)	Hourly renewal rate	Unitary renewal rate (m^3/h)	Total renewal (m^3/h)
Turbot females	1	37	30%	11	11
Sea bass females	2	44	30%	13	27
Turbot males	4	35	30%	11	42
Sea bass males	5	38	30%	11	57
			Total renewal fattening area(m^3/h)		151

Table 30. Water renewal at the fattening area.

The distribution of the tanks and their location on the plot will be studied in the layout section, adapting them to other critical areas and reducing the distance from the sea and water treatment facilities.

5.4 Other operational needs

Having described the production tanks and areas, it is time to determine all other areas, equipment, or devices to be included in our design.

5.4.1 Auxiliary incubation areas for turbot and larvae

The first auxiliary area is the one needed for manipulating the eggs before the incubation phase, which will be dimensioned as two 400 m^2 areas (one for turbot and one for sea bass), adjacent to the incubation rooms. Please note that this area is being called auxiliary just because there are no tanks in it, while we should consider it as the first step of our production process.

5.4.2 Product handling

Larvae will be moved on a weekly basis from one tank to the next one. This process is very important as the stress caused to the fish can have very negative effects.

This task will be done using special pumps, such as the ones offered by Innovaqua, a company specialized in fish-farming (17). These pumps are specially designed so that fish are not damaged and the stress is as little as possible, and their layout and speed can be adapted to the type and size of the fish.

Figure 15. Innovaqua’s pump selection.

These pumps will also be used for filling up the tanker trucks in which larvae will be shipped. As their size is relatively small and their position will not be fixed, no specific space must be provided in the layout for this kind of pumps.

5.4.3 Food, chemicals, and equipment storage

The facilities will also be provided with 3 stocking spaces for food and 3 for chemicals for water treatment, with an estimated surface as per Table 31. Another additional 150 m^2 are provided for equipment and machinery storage.

They will strategy placed when studying the production building’s layout to reduce the logistic complexity at the site.

5.4.4 Packaging, short term product storage and shipping

A packaging area will be needed, where fries will be taken out of the tanks and put into the bags and containers for transportation. 500 m^2 will be provided for this handling and very short-term storage (some hours).

However, most times, shipment takes place in big tanker trucks that are directly fed from the tanks (waiting area). This has two consequences. Firstly, it means that the handling and S/T storage areas will only be used under specific (small) orders. In addition, an area must be provided for these trucks to load the larvae. These areas (1 truck per specimen) should be located as close as possible to the tanks. We will call them DTLT (Direct Truck Loading Turbot) and DTLS. Small hatches will be provided to the building's walls (one for DTL area) so that the pump's pipe can go straight from the tanks to the tanker truck.

It would also be an interesting option to be able to directly load fish onto tanker ships, although this is left for further studies. This could be a good option for customers out of in-land Tenerife.

A third truck loading area (1 truck) will be located right next to the packaging area, so that smaller orders (packed in big barrels or bags) can be loaded onto the trucks.

5.4.5 Waste storage

A waste storage area will be provided to the facilities. Waste will mostly comprise plastic generated at the packaging stage as well as all packaging in which our raw materials will arrive wrapped in. 50 m^2 will be enough space for this area.

In addition, another 50 m^2 will be provided for biological waste such as food or dead fish. This waste must be kept in a controlled space to avoid any risks to the ecosystem around the fish farm in terms of diseases or pollution. Waste can be taken by authorised companies, which would imply an extra cost and would bring no benefits. However, it is known that this waste is commonly used in agriculture and producers near the city will come to pick it up for free. This also applies to the waste generated in the water filters which can be treated and sold as fertilizer.

5.4.6 Offices

There is also the need to provide an office building, with an office, toilets and a small eating area and a big meeting room. 500 m^2 is considered to be enough as there will be several floors. For humidity and isolation reasons, this office building will be independent to the production facilities.

5.4.7 Changing rooms (including lockers)

Changing rooms including a locker area must also be provided. This area, estimated to require a total surface of around 100 m^2 (50 m^2 for men and 50 m^2 for women), should be located at the entrance to the production area. Another 4 auxiliary changing rooms will be located at the entrance to the incubation and larvae areas, as these stages must take place in a particularly clean environment. This zone will also require 4x50 m^2.

5.4.8 Water treatment devices

On top of the areas earlier described, the water system requires additional space, as big filters and pumps are needed. Although this equipment will be described in further along the study, it has been included on the table below to be as close as possible to reality.

5.4.9 Car and Truck parking area

Regarding other auxiliary areas, parking spaces must also be provided, including 4 EV charging stations and 2 truck parking areas. The number of car spaces is imposed by the PEPSCT to 1 space per 200 built m^2, which results in 260 car spaces (3m x 5m). EV charging spaces will be 6m x 3m and truck spaces 13m x 6m.

All the zones previously described are summarized in Table 31.

Area	Surface (m^2)
Stocking space food 1	300
Stocking space food 2	200
Stocking space food 3	200
Stocking space chemicals 1	100
Stocking space chemicals 2	70
Stocking space chemicals 3	70
Stocking space equipment and machinery	150
Waste storage	100
Packaging and short term storage	500
Main male changing rooms	50
Main female changing rooms	50
Auxiliary male changing rooms 1	50
Auxiliary female changing rooms 1	50
Auxiliary male changing rooms 2	50
Auxiliary female changing rooms 2	50
Water treatment system 1	100
Water treatment system 2	100
Water treatment system 3	100
Offices, toilets and meeting room	500
Truck loading docks (3)	450
Parking (incl. EV + Truck parking (2))	4.713

Table 31. Needed auxiliary operational areas.

6 Facilities

In this section it is pretended to determine the space requirements within the buildings, the different flows to be followed by our product, workers, material, vehicles, and waste as well as other restrictions such as those imposed by the PEPSCT regarding the plot's setbacks.

The main outcomes will be a detailed layout of the facilities (both interior and exterior) and the production building requirements regarding its structure, which will allow us to establish a provisional budget until a more detailed study is done.

Although the water system is established in section 7.1, it has been considered in this section as it is a key factor when establishing the layout.

6.1 Urbanization restrictions

At this point it is necessary to consider the restrictions extracted from the PEPSCT, which was analysed in section 3.1.1. Annex 2 shows the parameters needed to be respected in our land of interest, although these are summarized in Figure 33.

Imposed by the PEPSCT	Real parameters
Minimum plot size ≥ 500 m2 s	>90.000 m2 s
Minimum Front ≥ 20 m	>170 m
Frontal setback ≥ 5 m	>13 m
Side setback ≥ 3 m	>6 m
Floor height ≤ 3 p * =3.6 m	0-0.5 m
Height in meters ≤ 15 m *	6.5

Table 32. Required and real development parameters.

In addition, no restrictions regarding the road entrance have been found within the PEPSCT, so it has been assumed that it will be at the top left corner of the plot (see Annex 5). This will make logistics' coordination within the facilities much simpler as vehicles (and the subsequent people flows) can be divided at the entrance depending on their type (workers, delivery trucks, visitors).

As another requirement, it is imposed to provide 1 car parking space per 200 built m^2. This means that our facilities will need to have at least 260 car parking spaces. There are no restrictions regarding the truck's parking spaces.

Other development restrictions will be imposed by the *Código de Urbanización*, which will have to be studied and included in the Development Project (*Proyecto de Urbanización*) as one of the first steps of our project.

6.2 Layout

All the different sectors previously described will be located within the same facilities. Although fish factories do not always need to be completely covered, it has been chosen to build a simple warehouse, completely adapted to our layout. Keeping the process within a closed environment has many advantages, such as a much longer life for the equipment, the protection it offers against rain and storms and the fact that tanks will not have to be individually covered.

Once determined all the needs regarding tank locations and all other operational and auxiliary areas, it is time to establish the preliminary layout of the fish-farm. The following factors are considered:

Product flow. Each area (and tanks) should be placed considering the natural flow of the fish, so that after each phase they must only be moved to the adjoining area, going gradually from one side of the sire to the other one throughout the whole process. This will minimize the need of human labour and space (no need for big corridors for moving around thousands of m^3 of fish). In addition, longer distances between phases will cause more damage and stress to the fish, so minimizing these is vital for obtaining a high-quality product.

Water flow. This is a key aspect as the energy consumption of the site will directly depend on the total distance between the sea and the tanks, passing through the filters, and going back to the sea. Using a recirculation system allows us to be more flexible about the distance from the sea, as only 40% of the flow will go through this section. In exchange, our priority will be reducing the distance between tanks and the water treatment areas. Energy consumption in fish-farms normally represents one of the highest operating costs, so reducing it will always be important, even if it is only by a small percentage.

People flow. This is a very important aspect both for the areas within the warehouse and for the exterior. People and vehicles related to production should be separated from visitors as soon as they enter the facilities.

Waste flow. It is also an important factor to consider, as the distance between the areas where the most waste is generated should be close to the waste storage area. In addition, it is important to have a clear passage so that trolleys or similar can be pushed without restrictions.

Vehicle flow. The fact that the flow of incoming visitors and operator's cars can be divided from the high-weight trucks that come into the facilities helps keeping the logistic flows simple. They will be separated at the north-west corner of the plot, just after the entrance to the facilities.

Feeding systems. The required systems will be based next to each of the water treatment systems. Food storage will be placed next to each of the 3 feeding systems' distribution points. In fact, the way to be covered by food all the way to the tanks will be the same as for the water piping.

Stocking spaces. This area should of course be located considering the nature of the goods stocked. Food should be placed next to the feeding systems' input, while chemicals will be located next to the water filters. Equipment's storage will be given less importance as it is not considered to be a critical aspect. Regarding waste, its storage space will be placed next to the final product storage area.

Changing rooms. They will be strategically located at the entries to the facilities, in the case of the main changing rooms. The auxiliary changing rooms for the incubation area will isolate this area from the rest of the facilities.

Packaging and short-term storage. It will be placed taking into account that fries will come from the waiting area and that, once stored, they will soon be sent or picked up by the customer. This area should therefore be located as close as possible to one of the limits of the building, next to the truck loading area.

Parking spaces. See section 6.1.

Having determined the logistic needs for the different areas, a preliminary layout is established as per Figure 16. Please find attached in Annex 5 a more detailed overall layout, as well as an exhaustive list of all individual areas in Annex 6.

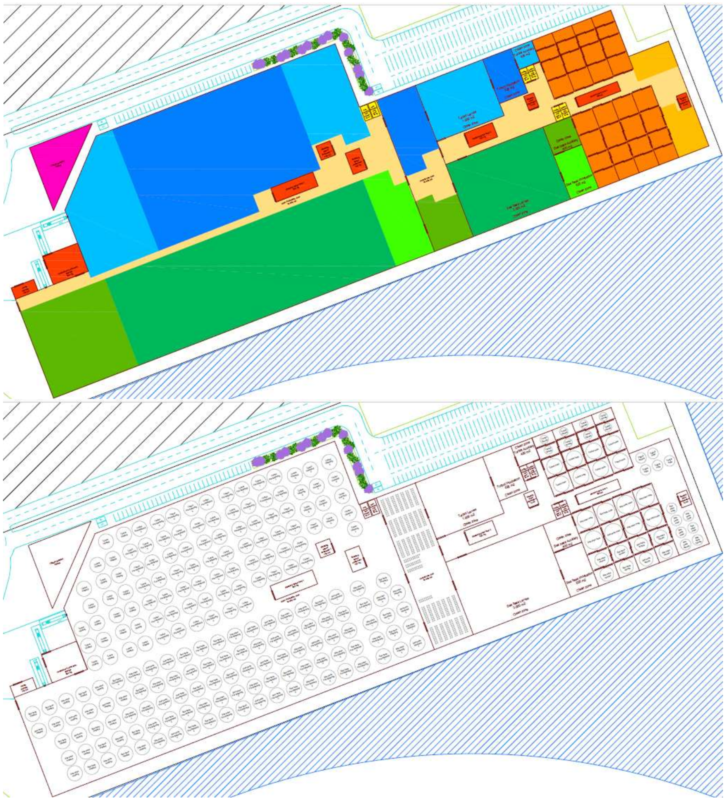

Figure 16. Preliminary overall layout (more detailed version in Annex 5**).**

Regarding the buildings height, there are no special needs as the highest water tanks will be around 1.5 m high. A clear height of 3 meters will be provided to the whole production building, as the water treatment systems will need a higher height and operational tasks might require this space.

The production building will only count with one floor. On top of this 3 m floor there will be small mezzanines, where auxiliary equipment, such as the HVAC system will be located. A 2 m height will be provided to this area. In addition, the roofs structure is estimated to be 1.5 m high at the highest point. The maximal height will therefore be around 6.5 m.

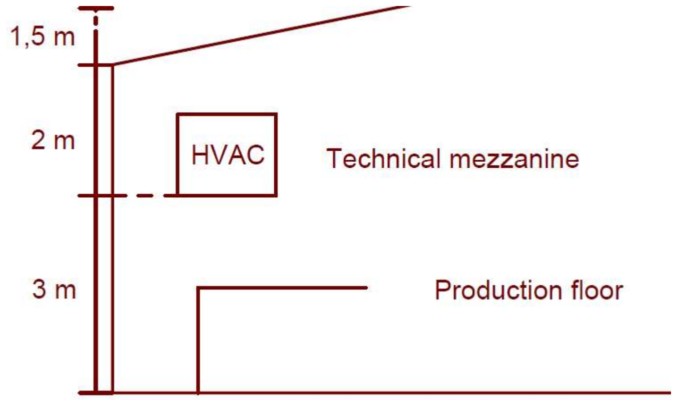

Figure 17. Production building preliminary height requirements.

6.3 Flows within the facilities

This section is the result of an iterative process based on the optimization of the process layout and the people, material, waste, and vehicles flows, combined with the development restrictions, while trying to reduce the complexity of the design and construction of the production building as well as reducing water pumping distances.

The following flows are attached as annexes:

- Main and Auxiliary product flow: Annex 7
- People, material, waste, and vehicle's flow: Annex 8

6.4 Building's civil works and site infrastructure

At this point it is possible to define a first set of characteristics that the production building should include. They will be listed and given a short description in order to give a first estimation of its cost in the budget (section 8.1).

Site preparation. The base material will be determined by the Authorities and their technical suppliers when defining the detailed project for the land reclaiming works (see section 3.4.2). The general contractor will be responsible for the preparation and approval of the ground's materials and gradient. Earthworks will be minimal as the plot is completely artificial and will be made for use.

Substructure. Foundations will be designed to limit settlement to its minimum and considering the ground conditions. They foundations will be simple as the structure's weight is expected to be very low. Regarding the building's slab, it will be made of reinforced concrete with minimal joints.

Superstructure. It will comply, at least, with Eurocode 1 and its steel frame grid is to have a maximum distance between beams of 25 m. Space requirements as well as the different flows within the facilities have been considered for establishing the approximated column distribution.

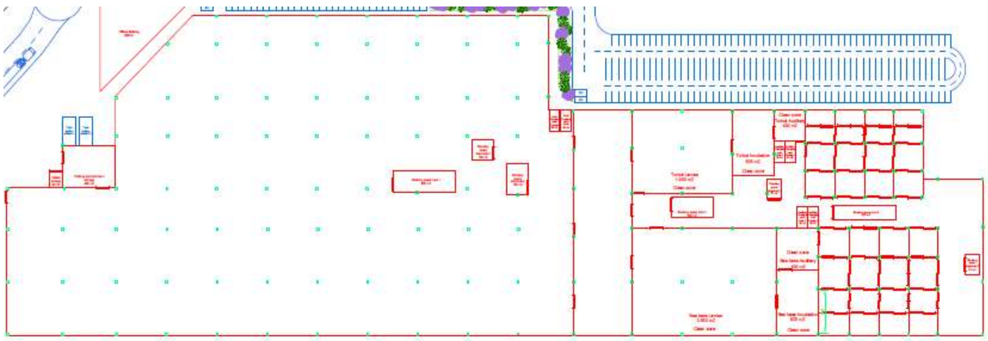

Figure 18. Approximated column distribution (columns in green).

The main warehouse frame will be of portal frame construction with lateral stability provided by a system of roof bracing and vertical bracing. No bracing is to affect the clear volume of the building or any window or door opening.

Roofs. The roof will be composed of premade panels, such as those offered by Kingspan or EuroPanel, specifically chosen regarding the isolation needs (noise, temperature, and fire) and their moderate weight. The roof will include daylight solutions that will help keeping electricity costs down. These types of panels are very suitable as they are very easy to fit and offer very good isolations characteristics. However, it is key to consider that there is no need for an extraordinary amount of heat isolation in the Canary Islands. The panels will be chosen trying to keep their weight down and therefore making the structure as light as possible. Roof hatches will also be provided for smoke ventilation purposes.

Figure 19. Kingspan KS1000 DLTR Plus Day-Lite Trapezoidal Plus (18).

Mezzanines. Small mezzanine structures will be provided at a height of around 3 meters (see section 6.2). They will only have a surface of around 6 m^2, enough to place auxiliary equipment such as HVAC groups. They will be accessible via ladders placed next to the walls.

Walls. External walls will also be composed of thin pre-made panels, keeping low the building's complexity but in accordance with safety regulations as well as ensuring a comfortable environment inside the building. Façades will include big windows to provide extra lighting and ventilation.

Internal thin walls will be made of precast reinforced concrete covered by isolating panels where needed to respect fire safety standards. A metal or plastic surface will cover the walls in the incubation and larvae areas to reduce dust.

Loading dock. The loading dock will comprise the loading module, an electric door and the shelter. Hormann standard equipment will be used as it offers some of the best technical conditions in the market as well as good guarantees.

Figure 20. Hormann loading docks.

External works and landscaping. The hard-standing surfaces and yards will be designed to resist the truck and vehicle traffic (up to 10 tons per axle). The slab will include all necessary contraction and expansion joints. The agglomerate on roads and car park areas will have a 20 cm minimum thickness. At a 60€/t of asphalt and 2,5 t/m3, the approximate cost will be 327.000 for asphalting all roads and parking areas. In addition, all parking / road areas are to be provided with the necessary pavement. The site will count with a green area including the associated irrigation system.

Fencing. The site's boundary perimeter will be provided with the required fencing, also provided with the corresponding security items. The site's entrance could be provided with a security post.

Considering what's been said up to this point, the estimated cost for the erection of both buildings together with the site infrastructure is 4.267.000€, as can be seen in Annex 12. This amount does not include any of the utilities nor the process equipment.

7 Utilities

Having determined the required spaces, their relative location between them and the main characteristics of the production building, it is time to study the utilities to be used both for the production processes and for all other auxiliary activities.

The most important aspect to be studied is the water system (pipes, pumps and valves), as its cost is likely to be the highest one out of all the utilities, both in CAPEX and OPEX. For this reason, it is important to design it as efficiently as possible, although this has already been considered when determining the overall layout by minimizing the distance between tanks and the WTS.

Other utilities to be thought about will be the feeding system, the electrical system, the HVAC and the Low Current Systems such as phone or internet connexions. In addition, part of our production process will require an automation system, as well as for other aspects such as lighting, although its design will not be included in this project.

7.1 Water system

7.1.1 Total water requirements

In this section we will study the piping system of the fish farm as well as other auxiliary equipment, such as the filters, pumps, or valves.

The water requirements for the four main production areas have been previously determined. The results have been summarized in Table 33.

In addition, the two auxiliary incubation areas will be fed 10% of the total water needed for incubation, this is, 270 l/h and 310 l/h for turbot and bass.

The required amounts of renewal water in each area calculated throughout the previous sections are summarized on Table 33. This table has been important when deciding the position of the Water Treatment Systems relative to the different production areas (the areas with the biggest flow should be closer to the WTS).

Area	Water flow (m3/h)
Turbot Incubation	2,7
Turbot Larvae	212,2
Turbot Post Larvae	371,3
Turbot Weaning	663,9
Turbot Pre-fattening	3.830,3
Turbot Waiting	1.296,4
Sea Bass Incubation	3,1
Sea Bass Larvae	399,3
Sea Bass Post Larvae	221,8
Sea Bass Weaning	459,6
Sea Bass Pre-fattening	4.183,9
Sea Bass Waiting	1.473,2
Reproduction Turbot Female	67,3
Reproduction Sea Bass Female	161,7
Reproduction Turbot Male	236,5
Reproduction Sea Bass Male	327,7
Fattening Turbot Female	11,2
Fattening Sea Bass Female	26,5
Fattening Turbot Male	42,0
Fattening Sea Bass Male	56,8
Auxiliary water for turbot's incubation	0,3
Auxiliary water for sea bass' incubation	0,3
TOTAL	13.981,5

Table 33. Total required water renewal.

The total amount of water to be pumped through the tanks, barrels and other production devices will be around 14.000 m^3. However, all this water will not have to be fully extracted from the sea, as the fish farm will count with a recirculation system that will treat the water to recycle around 60% of the flow (19). This will significantly reduce one of the most important costs for this kind of facilities, energy consumption for water pumping. The total amount of water pumped from the sea will therefore be around 5.590 m^3/ h, while the other 8.410 m^3/h will be reused water.

7.1.2 Water treatment system

The water treatment system is composed of 5 main elements, as shown in Figure 21.

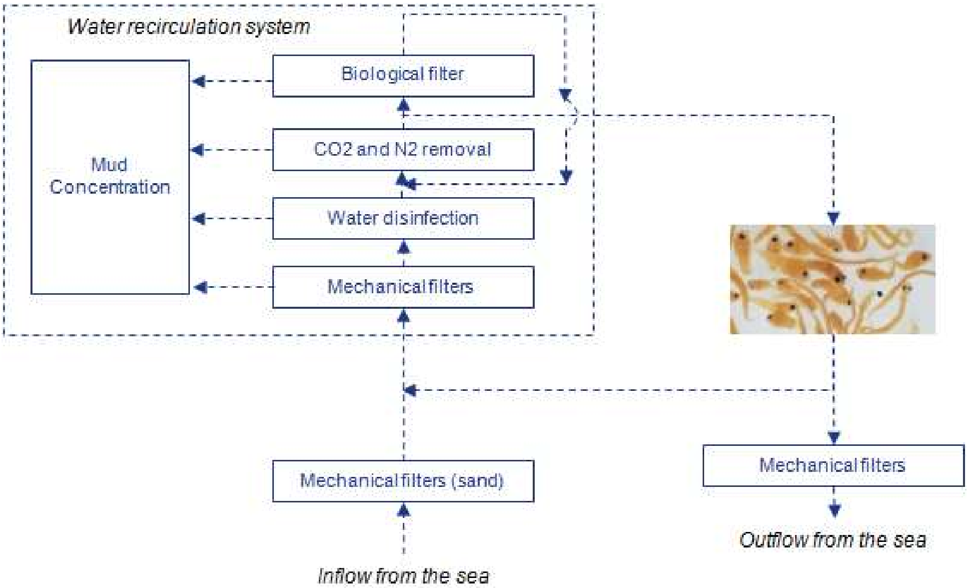

Figure 21. Water recirculation system diagram.

The first step of the recirculation system consists in mechanical filters used for removing particles bigger than 50 microns. All the water then goes into the disinfection area, where it is treated via ozone or UV rays (there are different technologies available) to eliminate excrements. Then, CO_2 and N_2 are removed from the flow before it gets divided into two different flows. One goes into the biological filter and is then put back to the main flow before degasification. The proportion of water to pass through the biological filter depends on many factors: the fact that not all the water passes through this stage is so that not all bacteria is killed, as a some of it is useful for killing the pathogenic bacteria. The spare water output will be filtered (mechanical filters) before being rejected to remove waste from the production process. Incoming water will also pass through a filter in order to remove sand and other solid particles, typically over 200 microns, just after being extracted from the sea. Waste generated during this recycling process can be put together and easily treated in order to be sold in form of mud, to be used as soil fertilizer. This product will however be considered economically negligible.

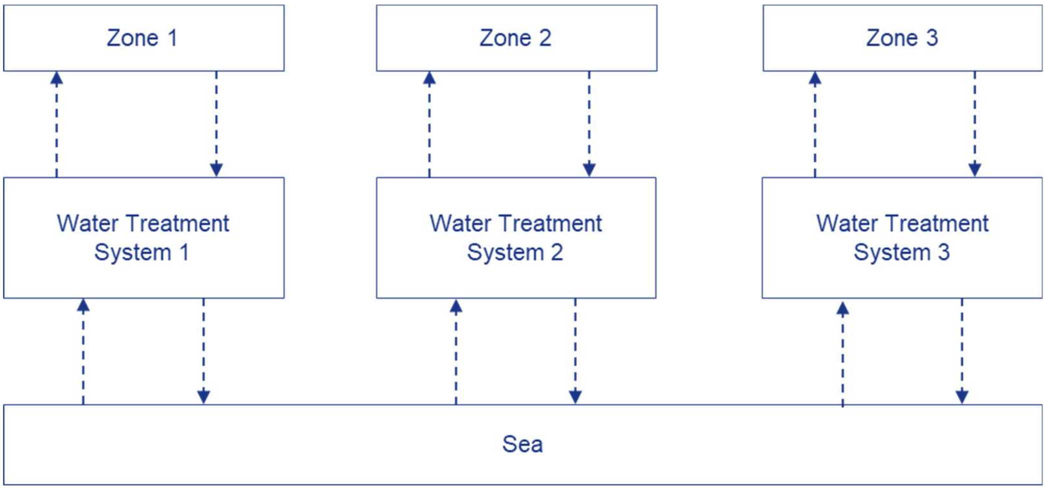

Figure 22. Water distribution systems' schema.

Considering fish at different stages will need different water conditions, it has been established to provide 3 different water treatment systems: one for post-larvae, weaning and pre-fattening, a second one for incubation, larvae, and auxiliary incubation, and a third one for fattening and reproduction. The small differences between the two species will be tackled in more detailed studies, as they should be tackled by introducing smaller auxiliary equipment (such as a small heater for increasing the temperature by a few degrees). As can be seen in section 7.1.4, these gaps will be very small as sea water conditions in Tenerife suit very well the necessary conditions. Each WTS will be integrated into an independent cycle:

	WTS-tanks (m^3/h)	Sea-WTS (m^3/h)
Cycle 1	12.650	5.060
Cycle 2	618	247
Cycle 3	930	372

Table 34. Water cycles.

7.1.3 In- and out-flow filters

As well as the water treatment systems described above, the water cycle should also filter the water coming in from the sea as well as the one going back out. The in-flow only requires a mechanical filter to intercept all particles in the water (typically those over 200 micros). There are many solutions for this problem, such as the mechanical filters offered by Hydrotech or Veolia. Except for these first filters placed just after the intake pumps, the inflow water follows the same treatment process as the recirculation water, also going through the chemical and biological processes. It is estimated that the total price for the inlet mechanical filters will be around 48.000 €, each.

Figure 23. Filter-pump system (ETEC).

Regarding the outflow water, the effluent, it is important to note that more than 90% of its waste is in solid form (20). This is mainly why drum or gravitational filters are a very good option for this purpose, as they are also very efficient. Once again, the inside system of the pumps will be bronze-covered to ensure a resistance against corrosion caused by sea water. An estimated cost of around 35.000 € for each of the 3 cycles is considered.

Figure 24. Drum filter to be used for effluent (21).

7.1.4 Water parameters

The following parameters are to be always kept under control, as they will have a huge influence on productivity:

Temperature. It is the most important factor, slowing growth down when the water temperature is not high enough. The optimal temperature is between 16 ºC and 18 ºC for both species. However, during the first weeks of growth it is recommended to use slightly warmer water. As per several studies done by public and private institutions, the water temperature in Tenerife is around 17 ºC in winter and around 20 ºC during summer. This means that water will not have to be heated up or cooled down when it is extracted from the sea, as it is at an already suitable temperature.

Salinity. It is another important aspect to be controlled, as it affects the other parameters such as the required temperature. Water in the Atlantic Ocean presents levels of around 36 g/l of salt (measured in the Canary Islands) (22), which is a relatively low number compared to smaller seas or the areas around the tropic, where evaporation is more intense.

Oxygen. Fries should be kept with 6 mg/l during the first phases and 5,5 mg/l for pre-fattening phase. Sea water in Tenerife has a high oxygen concentration (23) due to its temperature and salinity conditions. However, our recirculation cycle will force us to replace the oxygen, as 60% of the flow going into the tanks has already gone through the system. It will be done in a centralized way via, making sure the oxygen concentration is optimal when water leaves the WTSs.

Ph. It should always be kept between 6.5 and 9. Incoming sea water has a Ph of between 8.1 and 8.6 (23), which is dangerously near the limit. However, once mixed with the feedback flow coming from the tanks, with a lower Ph, it will be compensated. This means that the effort made at the filtering stage will be low, as the mixture's Ph will be within the required range.

Turbidity. It is caused by particles and organisms in the water, and it reduces oxygen absorption by sea bass and turbot, as it blocks and irritates the gills. To reduce turbidity, it is vital to count with a good filtering system. However, Tenerife's sea water is very clear because of its oligotrophic character: the water contains low primary activity (low presence of algae) because of the lack of nutrients.

Ammonium. It is caused by excrements from fish and the breakdown of organic material. The maximum levels of ammonium in the water depend on the stage of growth. It is harmful for fish, and it should be kept under a maximum level of 0,005 g/m^3. Fresh incoming water will have a low ammonium concentration because of its lack of nutrients, which will help us reduce the effort to be made by the biological filter.

Solid waste. Solid waste floating on the surface causes stress to the fish, affecting productivity. However, it doesn't cause death to the fish. Solid waste is easy to eliminate via the mechanical filters.

Parameter	Desired value	Real value (incoming flow)
Temperature	16 – 18 ºC	17 – 20 ºC
Salinity	35 g/l	36 g/l
Oxygen	5.5 mg/l	6 mg/l
Ph	6.5 – 9	8.1 – 8.6
Turbidity	As low as possible	Very low
Ammonium	0.005 g/m3	Excrements
Solid waste	As low as possible	-

Table 35. Water parameters.

7.1.5 Piping system

Pipes will be made from high density polyethylene due to its resistance to a continuous use during long periods of time. In addition, it prevents rustiness and corrosion while stopping algae and other organisms to get stuck to it. Another advantage of polyethylene is its low roughness, which will help reduce energy consumption for water pumping.

Considering the required flows and the tank distribution, the piping system for turbot's process has been established in Annex 9. Only one-way has been drawn, so all results are to be multiplied by 2, to take into account the return piping.

In the incubation, larvae and auxiliary incubation areas, barrels and small tanks will be individually fed. Water coming from WTS2 feeding turbot's process will go through a big pipe whose flow will be divided in order to feed the different areas. In parallel, a second pipe with a separate pump will feed the sea bass process. The other areas will be fed in an equivalent way, with the water flow being divided in a cascade way.

As it is explained in Annex 10 and summarized above, the total cost for the piping of the facilities will be **103.141€**.

	Piping cost
Incubation, Larvae & Auxiliary Incubation Areas (Turbot)	2.131 €
Incubation, Larvae & Auxiliary Incubation Areas (Sea Bass)	2.197 €
Post-larvae (Turbot)	17.571 €
Post-larvae (Sea Bass)	17.656 €
Weaning, Pre-fattening and Waiting (Turbot)	22.686 €
Weaning, Pre-fattening and Waiting (Sea Bass)	26.813 €
Breeding (Turbot)	3.534 €
Breeding (Sea Bass)	4.029 €
Sea-WTS1	4.100 €
Sea-WTS2	1.752 €
Sea-WTS3	672 €
TOTAL	103.141

Table 36. Total piping cost.

7.1.6 TDH, pumping system and other mechanical devices

Once known all water flows, it is necessary to determine the required pumps to be used both for extracting sea water and for taking it from the water treatment area to each one of the tanks. TDH caused by valves and other accessories is calculated in this section so that pumps can be properly chosen.

7.1.6.1 Valves

In order to adjust all water flows it will be necessary to include in the system a number of valves, electronically monitored by a centralized system that will ensure all flows are as desired (see section 7.4).

It is supposed that all tanks and barrels will have an attached valve at its inflow connexion. In addition, all flow junctions will include one as per Table 37.

	Valves at tanks	Other valves	Total number of valves
Turbot Incubation	45	5	50
Turbot Larvae	943	10	953
Turbot Post Larvae	495	30	525
Turbot Weaning	13	2	15
Turbot Pre-fattening	65	5	70
Turbot Waiting	22	2	24
Sea Bass Incubation	51	5	56
Sea Bass Larvae	1.775	10	1.785
Sea Bass Post Larvae	296	15	311
Sea Bass Weaning	9	2	11
Sea Bass Pre-fattening	72	15	87
Sea Bass Waiting	25	5	30
Reproduction Turbot Female	8	4	12
Reproduction Sea Bass Female	8	4	12
Reproduction Turbot Male	8	4	12
Reproduction Sea Bass Male	8	4	12
Fattening Turbot Female	1	2	3
Fattening Sea Bass Female	2	2	4
Fattening Turbot Male	4	2	6
Fattening Sea Bass Male	5	2	7
Auxiliary water for turbot's incubation	-	2	2
Auxiliary water for sea bass' incubation	-	2	2
Sea-WTS1	-	1	1
Sea-WTS2	-	1	1
Sea-WTS3	-	1	1
		Total	3.991

Table 37. Total number of valves.

Although these valves will manage different flows, we will simplify the numbers by supposing an average cost of 50 € per valve, which means a total cost of 199.565 €. In addition, the control system that will monitor and regulate the flows will have to be included in the budget. It will be estimated in section 7.4.

Figure 25. Electro-valves (17).

7.1.6.2 TDH & Pumps

The system's TDH is generated by 4 sources: tanks, valves, pipes' roughness and the height to be gained at section Sea-WTSs. Taking the total TDH data (see Annex 11) together with the water flows, it is possible to define the pumps to be used in our system.

-Lower section (Sea to WTSs + return): Etecsa's Vertival Axial pumps have been chosen, as they suit the flow and TDH to be handled and they are well adapted for a continuous use. In addition, they are suitable for working in an environment affected by tides.

Pump	Qp,real (l/seg)	TDH per pump (m)	Type	Supplier	Power supply	Qp,max (l/sec)	Unit price	Total
PA	662	4,73	Axial stationary (20" - 500mm)	ETECSA	Diesel (eff.=0,6)	875,00	65.000 €	**65.000 €**
PB	69	5,05	Axial stationary (12" - 305mm)	ETECSA	Diesel (eff.=0,6)	325,00	50.000 €	**50.000 €**
PC	103	4,56	Axial stationary (12" - 305mm)	ETECSA	Diesel (eff.=0,6)	325,00	50.000 €	**50.000 €**

Table 38. Lower section pump's specifications.

-Upper section (WTS to tanks + return): In this case horizontal pumps will be used. Grundfos has been chosen as they supply copper covered pumps (good for salt water) as well as with the possibility to be electronically controllable and designed for a continuous use.

Pump	N pumps	Qpump,real (m3/h)	TDH per pump (m)	Type	Supplier	Power supply	Qpump,max (m3/h)	Unit price	Total
P1_1	4	804	1,19	NBG	Grundfos	Electrical (eff.=0,75)	1.000	45.000	**180.000 €**
P1_2	1	414	1,05	NBG	Grundfos	Electrical (eff.=0,75)	1.000	35.000	**35.000 €**
P1_3	9	6	1,38	UPS Serie 200	Grundfos	Electrical (eff.=0,75)	70	10.000	**90.000 €**
P1_4	1	27	1,03	UPS Serie 200	Grundfos	Electrical (eff.=0,75)	70	15.000	**15.000 €**
P2_1	1	17	4,45	UPS Serie 200	Grundfos	Electrical (eff.=0,75)	70	15.000	**15.000 €**
P3_1	1	28	1,30	UPS Serie 200	Grundfos	Electrical (eff.=0,75)	70	15.000	**15.000 €**
P3_2	4	1	0,62	UPS Serie 200	Grundfos	Electrical (eff.=0,75)	70	15.000	**60.000 €**

Table 39. Upper section pump's specifications.

A margin of at least 15% in the maximal water flow has been left when choosing the pumps, as they might have to punctually work under more demanding conditions than average.

To estimate the energy consumption of the pumps, the theoretical amount of power needed. It is computed by applying:

$$Nb[HP] = \frac{Q[m3/s]xTDH[m]x1.000[kg/m3]}{75*\mu} \qquad (1.14)$$

Pump	Number	Q (m3/sec)	TDH (m)	Nb(HP)	Required power for turbot (kW) (n pumps)	Required power for sea bass (kW) (n pumps)	Total required power (kW) (n pumps)
P1_1	4	0,22	1,19	353,56	1.054,60	1.114,16	2.168,76
P1_2	1	0,11	1,05	161,63	120,53	72,12	192,65
P1_3	9	0,0017	1,38	3,09	20,74	21,91	42,65
P1_4	1	0,01	1,03	10,36	7,73	4,62	12,35
P2_1	1	0,005	4,45	27,34	20,39	38,12	58,50
P3_1	1	0,0077	1,30	13,25	9,88	15,86	25,74
P3_2	4	0,0004	0,62	0,34	1,00	1,61	2,61
PA	1	0,66	4,73	5.210,27	3.885,31		3.885,31
PB	1	0,07	5,05	577,41	430,57		430,57
PC	1	0,10	4,56	785,34	585,63		585,63

Figure 26. Required power for pumping.

Taking into account that some of the pumps will work on diesel, the total yearly consumptions for pumping are as per the table above.

	Only turbot (incl. Sea to WTSs)	Only sea bass	Both processes, both ways
TOTAL kW	6.136	1.268	7.405
kWh	53.754.586	11.111.177	64.865.763
MWh/t	22,4	4,6	27,0
Total elec (kW)	1.235	1.268	2.503
MWh elec/year	10.817	11.111	21.929
MWh/ton elec	4,5	4,6	9,1
Total (kW) diesel	**3.921**		**3.921**
MWh diesel/year	**34.350**		**34.350**
Q diesel (l/ton)	**1.443,9**		**1.443,9**

Table 40. Electricity and diesel consumptions (process).

Diesel's LCV has been set to 11.8 kWh/kg as per the IDAE's 2014 update and 840 kg/m³ as its density. Please bear in mind that consumptions above only include process pumping. Lighting and other consumptions will be added later on.

Pumps will be made of or covered by bronze, as it offers the best characteristics when dealing with sea water (24).

7.2 Feeding system

The feeding system will ensure the measurement and transportation of the food to the water tanks. Of course, all different stages in our growth process will need different types of nutrients. In the case of turbot, they are fed with zooplankton from week 2 until week 5, and then go onto brine shrimp from week 6 to 10. At week 11 they start getting fed artificial pellets until the end of the pre-fattening phase (25) and waiting phase. Regarding the reproduction specimens, they are fed pellets especially designed for them. The feeding needs of sea bass are very similar, although times change slightly, as can be seen in Table 41.

Turbot	
Week 2 – Week 5	Zooplankton
Week 6 – Week 10	Brine Shrimp
Week 11 – Week 30	Pellets
Waiting	Pellets
Reproduction	Pellets
Fattening	Pellets
Sea bass	
Week 2 – Week 8	Zooplankton
Week 9 – Week 13	Brine Shrimp
Week 14 – Week 32	Pellets
Waiting	Pellets
Reproduction	Pellets
Fattening	Pellets

Table 41. Feeding demands.

It is important to remark the fact that all pellets on the table above have different compositions, which means that they will have to be distributed through different lines. The same applies to zooplankton and shrimp, which will be distributed through, at least, 2 different lines. However, it is common use in the industry to use centralized systems that enable to handle different types of nutrients at the same time, feeding the fish the right amount of food, at the optimal rate. This is done through PLC connected systems, explained in section 7.4.

We will therefore use a feed distribution system as centralized as possible. This will enable us to reduce the number of redundant devices and storage areas.

<u>Feeding system 1</u>: Pellets. Week 11 until Waiting for Turbot. Week 14 until Waiting for Sea bass.

<u>Feeding system 2</u>: Zooplankton and Brine Shrimp. Incubation, Larvae and Post-larvae (until week 10) for Turbot. Incubation, Larvae and Post-larvae (until week 13) for Turbot.

<u>Feeding system 3</u>: Pellets. Fattening and Reproduction for Turbot and Sea Bass.

Each of these systems will count with the following elements:

<u>Feed storage.</u> The best solution for this problem will be a silo, as it ensures a constant and reliable flow. There will be one stocking space next to each one of the three feeding systems. In order to establish the wished capacity for each of the tanks it would be necessary to study the

feeding necessities at each stage as well as details such as the rate at which our supplier will deliver the food or how much in advance we should make the order before it arrives to the facilities.

Feed transport. This will be done through a piping system with compressed air. The air pressure will be adjusted in order to ensure pellets arrive in optimal conditions. The food is to pass through a valve and to be delivered through stainless steel pipes, being it highly important to avoid all kinds of waste in the process, as even a very low percentage rate of waste can mean tens of thousands of euros per year. Between the valves and the tanks there will be a feed selector that will ensure the right amount of food is supplied to each one of the different tanks.

Feed spreading. To ensure an optimal spread of the food around the whole volume of water, a turning disperser will be placed at the end of each pipe. This disperser will be adapted to the type and size of the pellet or shrimp.

The feeding systems will do the same path as the water piping, so using feed pipes placed next to the water pipes (preferably on top) will help reducing the complexity of the works low.

As per the research done, a feeding system adapted to our needs should have an average price of 65.000 €, this is, **195.000 €** in total.

7.3 LV electrical system

Once having calculated the amount of power needed by the pumping system and other consumptions of the production process, it is our objective to sum it up with an estimation of the rest of the facilities' electricity needs. Once done this, a first approach to the MV and LV electrical distribution system will be done, to better estimate its cost.

In section 7.1.6.2 it was established that the total amount of power needed by the pumping system was 3.972 kW. Besides this, Table 42 shows other applications needing electricity.

Prod. Facilities	**Annual consumption (MWh)**	**Max required power (kW)**
Pumps	21,929	3,738
Feeding system	219	37
WTSs	1,096	187
Pumps (for fries)	1,535	262
Lighting	91	16
Security system	9	2
Hot running water	27	5
220V	273	48

Office building	**Annual consumption (MWh)**	**Max required power (kW)**
Lighting	9	2
Hot running water	273	10
220V	136	24

Parking	**Annual consumption (MWh)**	**Max required power (kW)**
Lighting	18	6
Electric car stations	48	44

Total	25,663	4,380

Table 42. Total power needs in the fish farm.

Feeding system. It is estimated as 1% of the pumps' consumption. This power will mostly be needed by the compressed air system to push pellets along the pipes.

Water treatment systems. Some of the biological and chemical reactions that take place during water treatment, as well as the internal pumping system of the "WTS blocks", need energy input. We will compute it by adding an extra 5% to the main pumping consumption.

Pumps for fries' handling from tank to tank. Depending on their number and maximal flows they will be used during a certain amount of time. We have estimated their consumption and needed capacity to represent a 7% of the main water process pumping.

Lighting. The production facilities will be provided with LED lighting to complement the sunlight provided both by the roof systems and the wide windows. Around 40 400W luminaries should be used, during 8 hours per day.

Security system. Cameras and sensors, if provided, will consume an extra 10% of the lighting consumption.

Hot running water. Water heating for bathrooms and changing rooms, as well as the kitchen and other small applications, is computed by adding an extra 30% to the lighting's consumption.

EV charging stations. They have been estimated following Schneider Electric's EVF2S22P22P EVLink Changers' specifications and supposing a 3 hour use per day.

The rest of the electricity consumptions shown above have been estimated following similar approximations.

For obtaining a reasonably adjusted budget for the electric power system, the following components are taken into account:

LV	Cost
MV/LV Transformers (800KVA, 630KVA, 400KVA and 250KVA)	61.401 €
LV transformer-area lines	113.268 €
Circuit breaker and measuring cases	28.317 €
Individual branch lines, including fuses	67.961 €
General LV boards	28.317 €
Mono-phase and tri-phase cables	113.268 €
TOTAL LV	**412.532 €**

Table 43. Electrical LV and total cost.

7.4 Automation system

The automation system will regulate or help manage, at least, the following systems:

Feeding system. A PLC system will ensure that all tanks get the right type and amount of food. This will be done with the help of a complete set of sensors placed in each of the tanks and barrels as well as a very accurate distribution system. We have chosen to use 3 independent feeding systems for two main reasons:

1. Logistics are optimized by allocating small food storage areas (and therefore distributors) next to the areas that will require the specific type of food, as we are saving thousands of meters of piping (less energy consumption and maintenance) for its distribution.

2. It is very useful to set up the feeding distribution system in parallel to the water piping, as this results in a reduction of the complexity of the works as well as the simplification of the final layout.

Water Treatment Systems. A centralized automation system will monitor and manage the entire water treatment systems. Once again, sensors will be placed at each tank to register the water parameters and then give orders (through the PLC) to the three different WTSs so that parameters are adjusted in a short time lapse.

Reproduction area's lighting. As explained in section 0, the lighting at this area should be strictly regulated in order to induce the egging periods in the fish. As well as the lighting, it will be interesting to establish a schedule to rule the isolation of each tank: at certain hours, several doors will be automatically locked so that no operator can go in it (and break the light cycle) by mistake. This system could be provided with a good signalisation system next to each door or in the corridors to make it easy for operators to move around.

Figure 27. Automated set of doors.

Water pumping devices. Both the pumps and the valves will all be connected to a centralized PLC that will regulate the water flow to arrive to and leave each tank. It is crucial to be accurate in the management of these two flows as the water volume in the tanks can easily increase or decrease due to small errors over long periods of time. Each tank will also include a 'security sensor' at the maximal height to decrease the inflow when this limit is met.

The entire data acquisition system should be connected to an ERP so that it can be analysed and monitored together with other key data such as real production, electricity and fuel consumption, total worked man-hours, etc.

The system will count with the following devices, separated in 3 completely independent systems (although acquired data will be put together in the ERP):

	Unitary Price	**Number**	**Total cost**
Water flowmeters	40,00 €	997	39.870,40 €
Water height sensors	35,00 €	997	34.886,60 €
Feed sensors	65,00 €	997	64.789,39 €
Chemical and biological sensors	65,00 €	997	64.789,39 €
Lighting sensors (repr.)	30,00 €	10	300,00 €
Connexion to feeding systems	15,00 €	3	45,00 €
Connexion with pumps and electro-valves.	10,00 €	3.705	37.045,36 €
Connexion to WTSs	15,00 €	3	45,00 €
Connexion lo lighting (repr.)	10,00 €	10	100,00 €
Connexion to automated doors (repr.)	10,00 €	48	480,00 €
PLC + modules + SCADA	6.500,00 €	3	19.500,00 €
Cable and others			26.185,11 €
		Total cost	**288.036,25 €**

Table 44. Preliminary automation system components.

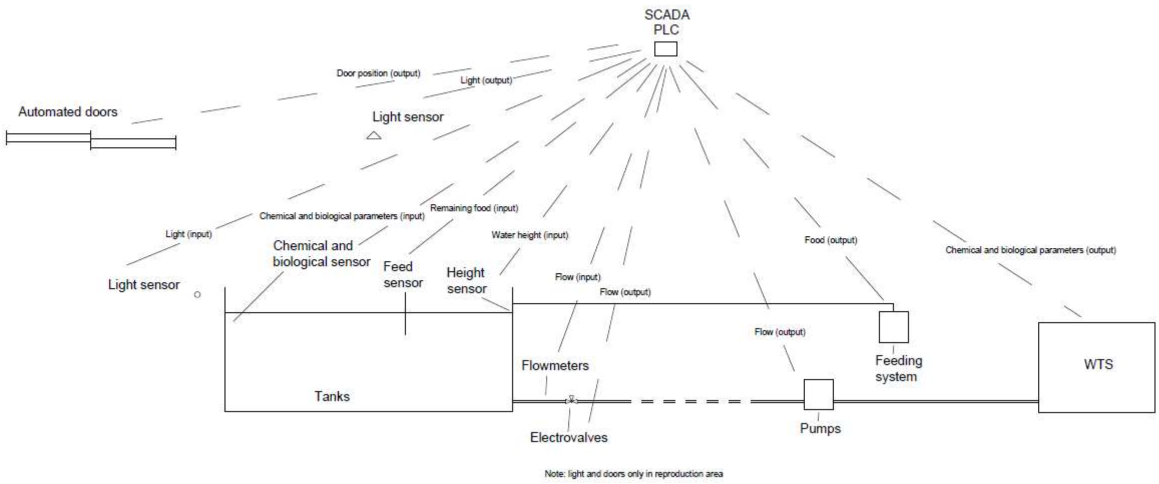

Figure 28. Preliminary production automation system.

7.5 Other utilities and auxiliary systems

The facilities will also have to be provided with auxiliary utilities not belonging to the process itself. These are the following:

-Diesel deposit. As it has been seen at the end of last section, the facilities will need a monthly supply of 100.000l of diesel fuel. It is therefore going to be necessary to provide a diesel deposit in order to store it. As diesel is easily found in the market, we will only dimension the deposit for a 1 month capacity, this is, 100 m^3. It will be similar to the one shown on Figure 29, but adapted to our needed capacity: around a 4,3m diameter and a 7m length.

Figure 29. Diesel tank configuration.

Its price is estimated to be of around 200.000 €, with an additional 40.000 € for the piping to each one of the three pump engines.

When taking it into account for the layout, a 15 metre security distance has been established, where there will not be trees or vegetation neither operational activities nor people or vehicle passages.

-Sanitary water for both buildings.

-HVAC system. Although the process itself will not need HVAC, the production building will count with a small system to ensure optimal working conditions. In addition, the office building will also be provided with a small system. Considering Santa Cruz's weather conditions all throughout the year, only ventilation will have to be provided to remove latent heat produced by the high amounts of evaporated water. Both the initial investment and the operating costs of these two systems will be negligible.

-Fire protection system: sensors, sprinklers, extinguishers, alarms, and fire brigade connexions.

-Security system: alarms, cameras, and sensors.

-Rainwater drainage system. A gravity drainage system will be provided, adequately sized and in accordance with technical norms.

- Data & Communications network. Internet and phone connections.

8 Project management of the works

Once established all technical needs and requirements, it is important to plan the preparation, execution and commissioning of the project. A good preparation and follow-up of the works will be essential for the success of the project and business plan, as it is easy to arrive to cost and time deviations, as well as in quality and design, which can have big economic effects.

8.1 Budget (CAPEX)

The objective of this section is to give an estimation of the total cost of the development of the facilities, one of the key points when making the “to invest or not to invest” decision. Starting from the basic design, licenses, etc and finishing with the construction and commissioning, all costs should be considered.

Find in Annex 12 a budget for the CAPEX of this project. It includes all aspects described or named along this feasibility study.

Hard costs will be 8.482.858€, while soft costs sum up a total amount of 626.755€.

As has been explained along this study, FEMP subsidies can be allocated to this kind of projects to boost competences of the European fish industry. Although the maximal subsidized amount can go up to 85% of the investment (see end of section 8.3), in order to be conservative, it will be assumed that a maximum of 25% the investment is subsidized. This will be included in the economic feasibility study.

8.2 Overall Time Schedule

Once determined the main tasks to be tackled during the preparation, execution and commissioning of the project, it is crucial to establish their coordination in time.

Please find in Annex 13 an overall time schedule for the project, which has been summarized in Figure 30. It is important to note that some of the stages of the project do not appear on the figure above as they are not in the critical path. This is the case, for example, of the procurement of each one of the packages.

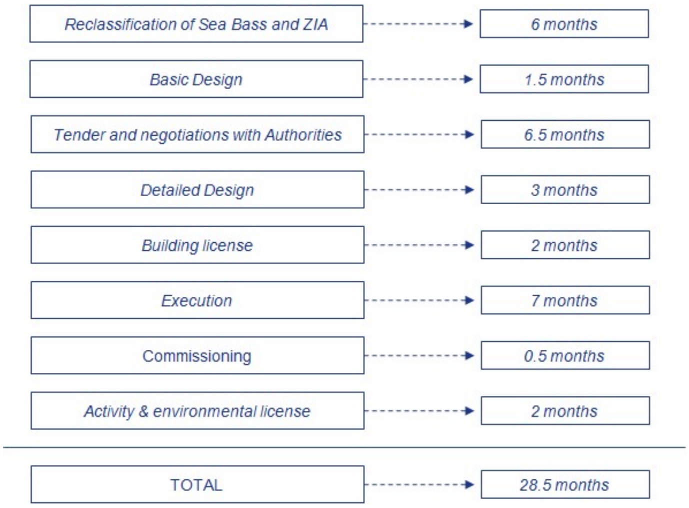

Figure 30. Overall time schedule (see Annex 13**).**

8.3 Permitting roadmap

Another key aspect for the success of the project will be obtaining all required licenses. This section aims at describing the permitting process that applies to the planning and execution of this project. In fact, fish farming is a very regulated activity which not only requires a normal activity license, but is allowed only via estate concessions that need to the justified in terms of forecasts of increase in demand.

The main regulatory frame for fish farming in Spain is the Strategic Plan for Spanish fish farming 2014-2020 (*Plan Estratégico Plurianual de la Acuicultura Española, PEPAE*), developed by the Agriculture, Food, and Environment Ministry (*Ministerio de Agricultura, Alimentación y Medioambiente*). This strategic plan provides an analysis of the sector and a good basis for more detailed planning for the coming years, considering the worldwide situation of fish farming as well as the particular possibilities and threats for Spanish producers.

After several conversations with experts in the matter, it has become clear that regulatory constraints are at this moment the major factor slowing down, or drastically stopping, new investments in the sector, especially in the Canary Islands. As an example, the PEACAN, whose situation is described in section 4. In fact, even the PEPAE considers that reducing bureaucracy is one of the most important aspects to be tackled in the short term in order to boost the activity.

At a national level, fish farming is mainly controlled and planned by the government departments shown in Figure 31. Other important government actors are involved on specific aspects of fish farming, such as the Ministry of Development and Civil Works (*Ministerio de Fomento*) through the Spanish Ports Office (*Puertos del Estado*), who's approval is needed in order to obtain an activity license on the port areas (26).

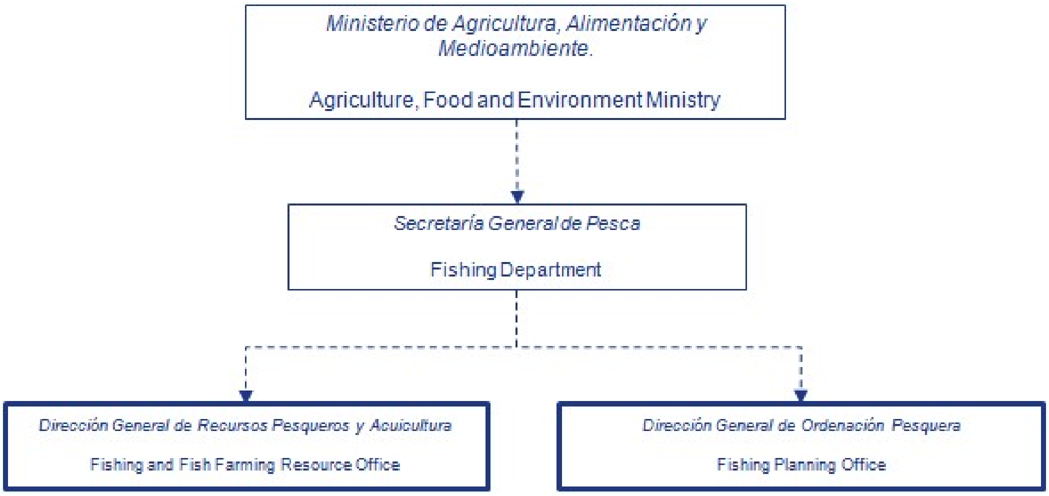

Figure 31. Two main national offices controlling fish farming.

Just as a reference, the Spanish legal frame of fish farming at a national level is defined by the five following laws:

- Ley 3/2001, de 26 de marzo, de Pesca Marítima del Estado

- Ley 2/2013, de 29 de mayo, de protección y uso sostenible del litoral y de modificación de la Ley 22/1988, de 28 de Julio, de Costas
- Ley 41/2010, de Protección del Medio Marino
- Ley 23/1984, de 25 de junio, de Cultivos Marinos
- Ley 20/1942, de Fomento y Conservación de la Pesca Fluvial

Regarding the specific situation within the Canary Islands, in December 2013, a regional development plan was developed under the order of the fishing and water office (*Viceconsejería de Pesca y Aguas)*. It was the PROAC, for the Spanish *Plan Regional de Ordenación de la Acuicultura en Canarias*. It classifies the fish farming activities in function of the main characteristics of the production process:

- Regarding the location of the fish, it's an on-land marine fish farm.

- Regarding the fish's life cycle, it's a closed cycle of complete production, as the whole life cycle of both turbot and sea bass is known and can be controlled while it takes place at the same facilities (at least for the auxiliary process).

- At the same time, it is considered a poly-species farming, as it involves turbot and sea bass (27).

In addition, the PROAC classifies the coastal area of the Canary Islands in three groups in function of its suitability for fish farming activities and sets the basis for more detailed planning. The three categories are: ZIA (Zone of Interest for Fish Farming), ZA (Suitable Zone although with less interest) and ZP (Prohibited Zone). As per Annex 3, our area in Cueva Bermeja is considered as a Suitable Zone. As it is established on the PROAC, zones classified under ZA can only be suitable (being classified as ZIA) after 2020 or after a modification approved by the Chamber of Agriculture, Farming, Fishing and Water (*Consejería de Agricultura, Ganadería, Pesca y Aguas*). It is to take into account that the fact that the exact piece of land does not yet exist. It could be possible to, once it is developed, classify it as a ZIA, which would be more advantageous for our objectives.

Regarding the production of turbot and sea bass, the first is considered as Species of Interest to be grown in on-land facilities, while the second one is only considered in off shore fish farms. However, it is possible to change the status of a species if capable of proving that the risk of escape of any specimen is zero or nearly-zero by using a closed water cycle.

Any of these two changes of category (ZA to ZIA and sea bass as an on-land species of interest) are not considered as a modification of the PROAC, and can be approved by the Chamber of Agriculture, Farming, Fishing and Water (*Consejería de Agricultura, Ganadería, Pesca y Aguas*) under request of the Office of Fishing and Water (*Viceconsejería de Pesca y Aguas*).

Considering solved both of the previous aspects, the general procedure to follow to obtain the administrative concession would be as shown in Figure 32, including a public tender and further detailed studies.

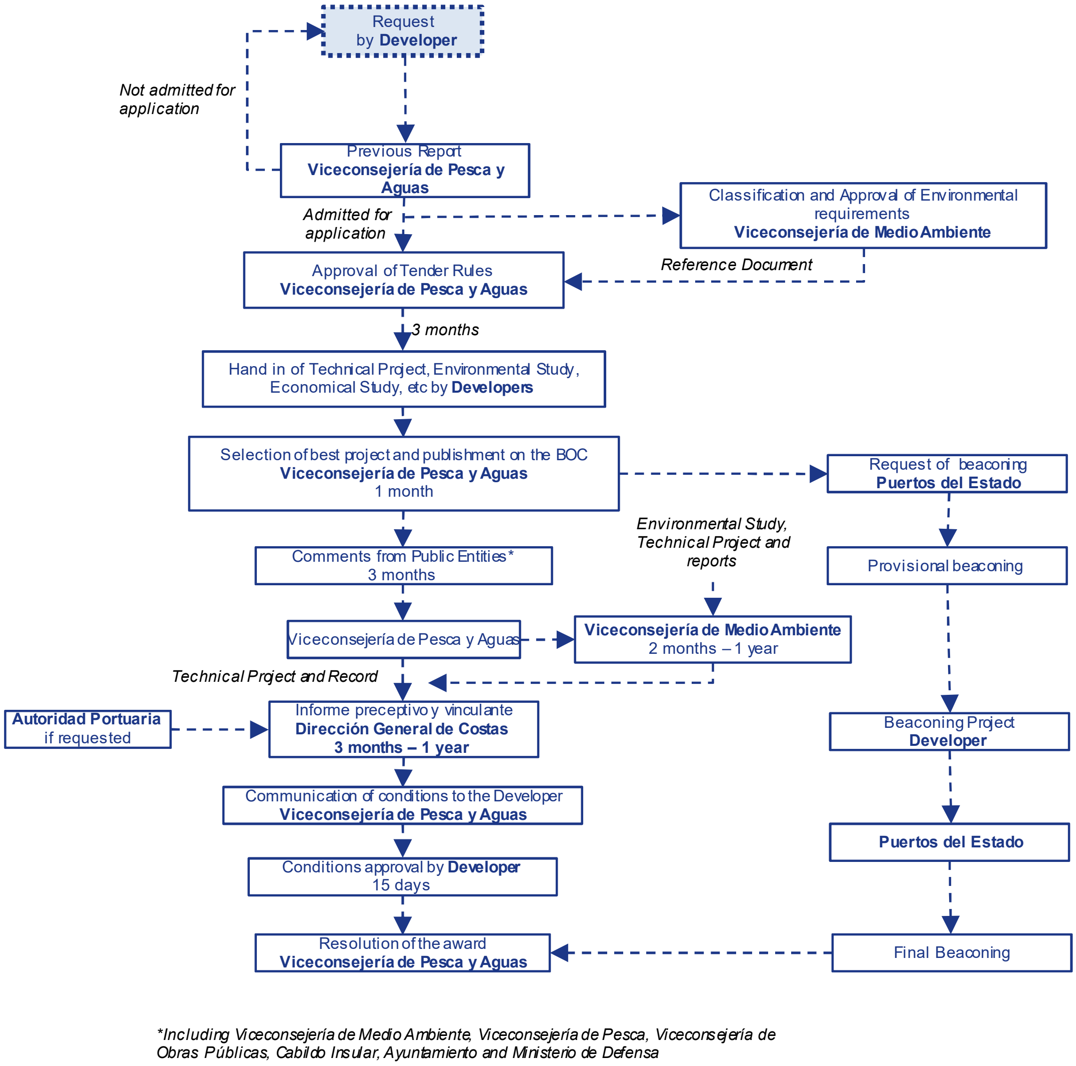

Figure 32. Tender procedure for obtaining a fish farming concession.

It is important to note that timings on the chart above are those for off-shore fish farming, with 10 year concessions and for a maximum of 75 years (if several conditions present on the new Coastal Law (*Ley de Costas*) are fulfilled (15)). However, as per the PEACAN, total procedure time can be reduced to up to 6 months for on-land facilities, with a concession unlimited in time. The beaconing procedure does not have to take place, although the other rest of the process is similar. In addition*, Dirección General de Costas* shouldn't be involved in the decision process.

Of course, the process described above must start once the area has been classified as ZIA by the Chamber of Agriculture, Farming, Fishing and Water following the procedure established on the *Artículo 21 de la Ley de Protección de Costas*.

Regarding the overall permitting process, a simple overall roadmap is defined in Figure 33.

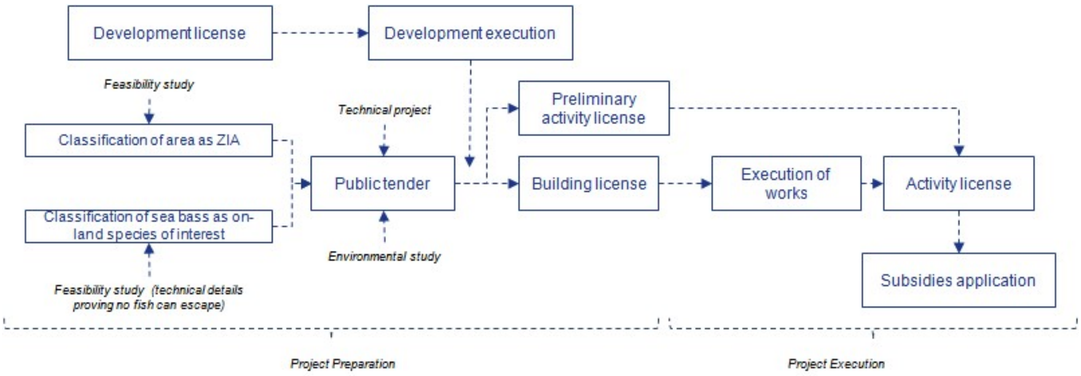

Figure 33. Overall permitting roadmap.

Subsidies must be processed through the Vice*consejería de Pesca y Aguas* (28). However, it is important to note that a maximum of 40% of the investment can be financed from the FEMP (European funds for the fishing sector), being the regional government (*Comunidad de Canarias*) able to complement it with an extra of up to 45%. The FEMP budget for Spanish territory is nearly 206.000.000€ for the period 2014-2020, being most of it European contributions (29).

8.4 Project organization chart

In order to ensure the good development of the project, it is important to establish a clear organization chart that sets the responsibilities of all the parties.

Please find Figure 34 the organization chart to be used for this project. The steering committee should be composed by the client and his representative, belonging to the project management firm. The project managers will also be in charge of the coordination of all the project's actors, controlling that both the project's planning and budget are being followed and no deviations take place, from the design to the final handover of the facilities. The project manager will also have the responsibility of ensuring required licences are obtained as well as the coordination of the design team, that will work with the support of a fish farming specialist when designing the production process: tanks, piping and feeding system, auxiliary equipment, etc.

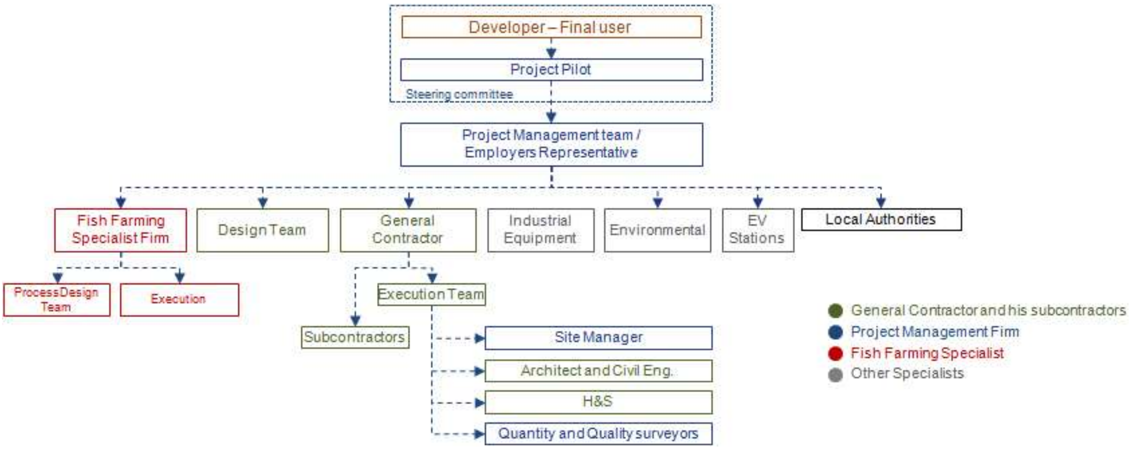

Figure 34. Project organization chart.

A general contractor will be in charge of the execution in a turnkey contract for the civil works and non-process utilities, who will at the same work with his subcontractors. At the same time, the works will be monitored by the project managers, while a specialised company will handle the specific fish farming aspects.

In addition, an industrial supplier will be in charge of the supply of technical equipment such as forklifts or the loading dock equipment.

Other actors will be involved both during the preparation and the execution of the works, such as environmental specialists for measuring and reducing emissions or an EV charging station supplier, all of which will be coordinated by the project managers.

8.5 Procurement Strategy

Another very important aspect for the project's good development is the procurement strategy to be followed. All aspects of the project works should be grouped into packages according to the nature of each of them and to the competences of the subcontractors.

Due to the nature of our project, several tender packages arise. They are summarized in Figure 35.

Package 1. Civil works. This package includes the erection of the two buildings (production and offices) as well as all related utilities. A general contractor will be chosen after a tender process, including all auxiliary systems such as electricity, sanitary and fire protection. External works will also be under the responsibility of the general contractor.

Package 2. Process. Tanks, pumps and all other process equipment will be purchased from a fish-farming specialist as this equipment requires big adaptation to the specific project needs. In addition, this supplier will add value in the process design phase. Some companies have been found on the internet and contacted for the development of this feasibility study:

- AKVA systems. Turnkey process projects and specialised equipment. Automated water recirculation and feeding systems.

- Aquatec-solutions. Turnkey process projects and specialised equipment. Automated water recirculation and feeding systems. They also provide food and chemicals.

- Etec. Specialised equipment for water management. Mainly pumps.

Package 3. Specific auxiliary equipment. In addition, all specific equipment needed for the auxiliary processes (for incubation, for example) will be purchased from a specialised supplier as a big number of barrels and other small equipment (test tubes and other objects used for gamete handling). This package might be possible to be combined with the process equipment (point 2) and bought from the same supplier, as, if possible, it will result in a price reduction. However, not all fish farming companies include both sorts of equipment in their catalogues.

Package 4. Other machinery such as forklifts or the required truck loading systems. Several industrial suppliers, probably from within the area, will be invited to a brief tender for the procurement of this package. The best option will probably be asking for several budgets and compare them in function of the needs and price.

Package 5. EV charging stations. They will have to be purchased from a specialised supplier. It might be important to include the installation in the order so that technical risks are avoided.

Package 6. Technical studies. An independent party will do the required environmental studies. There are multiple local enterprises that could do this task.

Package 0 represents the project management firm, preferably an independent company who will represent the owner during the project's development face to the rest of the contractors, the authorities, etc.

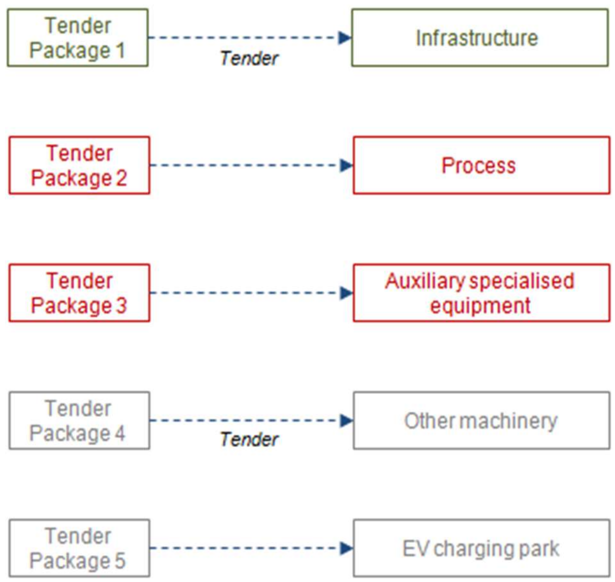

Figure 35. Procurement strategy summary.

The procurement of each of the packages will be strategically located in time so that it doesn't interfere in the critical path.

8.6 Operating Costs and Economic Feasibility

At this point it is necessary to study the operational costs and the long the economic profitability of the project. As has been determined in the CAPEX budget, the total initial investment would be 9.109.000 €.

Regarding the operational costs of the facilities, the main ones are listed below:

- Personnel. 12 operators and 2 administration staff will have a 570.000 € yearly cost, working only one shift a day.

- Food. It is estimated that food consumption will be around 1.66 tons per ton of sold fries. Market price varies from 500 to 1.000 €/ton, depending on quality and on exact type of feed. We have used 900 €/t to arrive to a 3.855.000 € yearly cost. Please find in Annex **14** the feeding needs for each species and phase.

- Chemicals. 166 kg of chemicals will be necessary per ton of sold fries. This makes 398 tons per year, which at an average price of 1.800 €/ton sum up 771.000 € per year.

- Electricity. Taking the 9,1 MWh/t for the water pumping and adding up all other smaller consumptions we arrive of a final number of 10,69 MWh/t and 2.538.000 € as yearly expense (92€/MWh).

- Fuel. Taking the result from Table 40 and assuming a 0,9 €/l price we arrive to a yearly expense of 3.351.484 €.

- Maintenance. It is estimated to be a 7% of the total sales, this is, 924.000 € per year.

A 7% waste factor has been included in food, chemicals, and electricity and fuel consumptions.

In addition to the business-related costs, the project is to include a fixed quota to be paid to the authorities for the lease of the land. It has been supposed that the annual quota will be 396.800 €, this is, 4 €/m^2.

Considering the previous hypotheses, several cash flow predictions have been done, attached in Annex 15. It is important to note that one main hypothesis has been established: all our production will be sold at a price of 5,5 €/kg of fries. In addition, no financial expenses have been included in the model. Additionally, no taxes have been included as ZEC zone offers this advantage (see section 3.2.2).

Following what's explained above, the CF projection is shown in Table 45.

BASE CASE	0	1	2	3	4	5	6	7	30
Net income		13.200.000 €	13.200.000 €	13.200.000 €	13.200.000 €	13.200.000 €	13.200.000 €	13.200.000 €	13.200.000 €
Operating costs		- 12.010.381 €	- 12.010.381 €	- 12.010.381 €	- 12.010.381 €	- 12.010.381 €	- 12.010.381 €	- 12.010.381 €	- 12.010.381 €
Personnel		570.304 €	570.304 €	570.304 €	570.304 €	570.304 €	570.304 €	570.304 €	570.304 €
Food		3.855.484 €	3.855.484 €	3.855.484 €	3.855.484 €	3.855.484 €	3.855.484 €	3.855.484 €	3.855.484 €
Chemicals		771.097 €	771.097 €	771.097 €	771.097 €	771.097 €	771.097 €	771.097 €	771.097 €
Electricity		2.538.013 €	2.538.013 €	2.538.013 €	2.538.013 €	2.538.013 €	2.538.013 €	2.538.013 €	2.538.013 €
Fuel		3.351.484 €	3.351.484 €	3.351.484 €	3.351.484 €	3.351.484 €	3.351.484 €	3.351.484 €	3.351.484 €
Maintenance		924.000 €	924.000 €	924.000 €	924.000 €	924.000 €	924.000 €	924.000 €	924.000 €
Investment	- 9.109.613 €								
Yearly quota		- 396.800 €	- 396.800 €	- 396.800 €	- 396.800 €	- 396.800 €	- 396.800 €	- 396.800 €	- 396.800 €
Cash Flow	- 9.109.613,06 €	792.818,58 €	792.818,58 €	792.818,58 €	792.818,58 €	792.818,58 €	792.818,58 €	792.818,58 €	792.818,58 €
Cumulated	- 9.109.613,06 €	- 8.316.794,48 €	- 7.523.975,89 €	- 6.731.157,31 €	- 5.938.338,73 €	- 5.145.520,15 €	- 4.352.701,57 €	- 3.559.882,99 €	14.674.944,36 €

Table 45. Base case.

The key financial figures are summarized Table 46.

ROI	-13%
Payback period	11,49
IIR (10 years)	-2,4%
IIR (30 years)	7,8%
Discount rate	7,0%
NPV (10 years)	- 3.541.187 €
NPV (30 years)	728.505 €

Table 46. Project's key financial figures (Base case).

No subsidies have been considered in this model. As can be seen on the financial model, taking 7% as a reasonable discount rate, the project itself is not profitable enough to make it interesting for an investor.

9 Conclusions

This project has been developed in order to study the technical and economic feasibility of a fish farming facility in Cueva Bermeja. As was expected, state of the art techniques are needed in order to make the process profitable, as operating costs (mostly energy consumption) are still too high in comparison with market selling prices. This idea is backed by studying the effect of different modifications on the base case to test the sensibility of the model to each one of the inputs. Three parameters are modified: subsidized CAPEX, reduction in OPEX (thanks to design and technical improvements) and a variation in the market price.

Subsidy (CAPEX)	OPEX	Market price	Initial investment	Yearly CF	ROI	Payback period	IIR (10 years)	NPV (10 years)	DELTA CF
No	**Base case**	**Base case**	**9.109.613 €**	**792.819 €**	**-13%**	**11,49**	**-2,4%**	**- 3.541.187 €**	
No	10%	Base case	9.109.613 €	- 447.900 €	-149%	-20,34	-	- 12.255.472 €	**-156%**
No	Base case	-15%	9.109.613 €	- 1.187.181 €	-230%	-7,67	-	- 17.447.879 €	**-250%**
No	-5%	Base case	9.109.613 €	1.413.178 €	55%	6,45	8,9%	815.955 €	**78%**
No	-10%	Base case	9.109.613 €	2.033.537 €	123%	4,48	18,1%	5.173.098 €	**156%**
No	Base case	10%	9.109.613 €	2.112.819 €	132%	4,31	19,2%	5.729.941 €	**166%**
No	-10%	10%	9.109.613 €	3.353.537 €	268%	2,72	35,0%	14.444.226 €	**323%**
10%	Base case	Base case	8.198.652 €	792.819 €	-3%	10,34	-0,6%	- 2.630.226 €	**0%**
25%	Base case	Base case	6.832.210 €	792.819 €	16%	8,62	2,8%	- 1.263.784 €	**0%**
40%	Base case	Base case	5.465.768 €	792.819 €	45%	6,89	7,4%	102.658 €	**0%**

Table 47. Sensibility analysis.

As per the analysis above, the model is not profitable due to the high operating costs. Even if a subsidy was received to cover part of the initial investment, NPV is negative or very low due to the low cash flow. In opposition, we see how a 5% reduction in all costs already makes the project slightly more interesting, and a 10% reduction gives us a return of the investment in less than 5 years. One conclusion can be extracted: a 5% cost reduction has more effect on profitability than a 40% subsidized initial investment, so efforts should focus on reducing OPEX even if CAPEX is slightly increased.

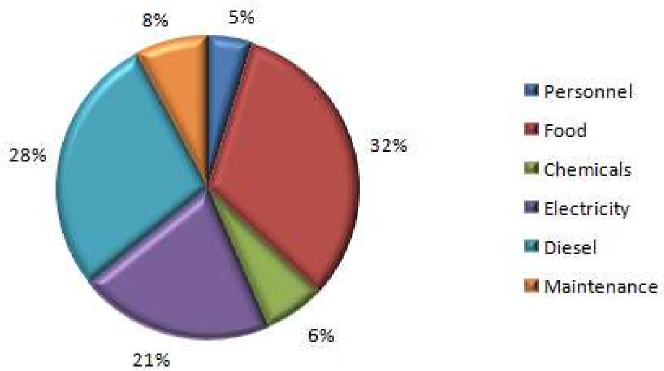

Figure 36. Cost distribution (base case).

The energy consumption for pumping represents by itself 44% of the income, which is in accordance with average consumptions for this kind of activity. However, this result is not to be taken as a limit, as the optimization of the production process and the auxiliary processes around it can always be re-studied. In our case, for example, a single change in one of the parameters could have had a big impact on the operating costs: floor level height of the initial plot, which is yet to be built.

As said in the introduction of this study, the land-reclaiming works will take place in the coming months or years, having as result an average land plot at a height of +4m above sea level. It comes to our minds that maybe the land plot could be designed from the beginning for fish-farming purposes. As shown in Figure 37, if tanks were built under ground level instead of on top of it, the water height would be reduced by 1,5 m for all water flow on the lower section (from the sea to the WTS). Assuming energy consumption is directly linked to the Total Dynamic Height, this would have an impact of 914.000€ per year in fuel cost reductions, as well as offering the possibility to build the warehouse slightly lower and the diesel system smaller. In addition, some savings would be made in the land reclaiming project as less filling material would be used.

$$C_{diesel}' = C_{diesel} x \frac{TDH'}{TDH} = 3.351.000 x \frac{4}{5.5} = 2.437.000€ / year \quad (1.15)$$

$$\Delta C_{diesel} = 914.000€ / year \quad (1.16)$$

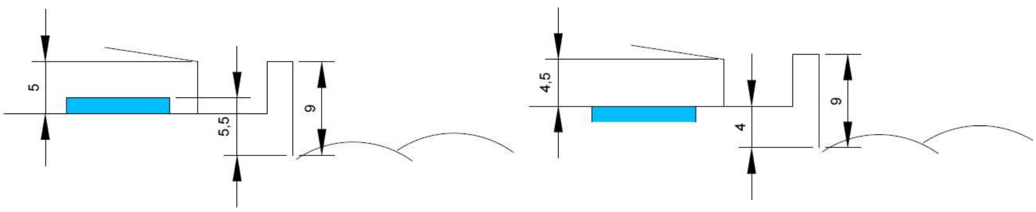

Figure 37. Tank possible future distribution (in meters).

Another idea would be to combine our process with some energy generation system. A wind turbine, rooftop solar modules or a wave/tidal energy recuperation system (or a combination of them) could be studied. If the total electric power was to be supplied by rooftop photovoltaic panels (in solar radiation peaks), around 50.000 m^2 would have to be used (180 Wp/m2 and 10% losses). This would give us a total generation power of 6.260 kW, with the following associated costs:

- 850 € per installed kWp, this is, 3.590.000 € as initial investment for the modules, inverters, and other related equipment.

- 0.065 €/kWh as operating cost, this is, 556.000 € per year.

The modules are supposed to work 8 hours at optimum conditions. This means that, out of the 25.600 MWh consumed per year, 8.550 MWh will come from the modules while the rest will have to be bought from the network. It results in yearly savings of 231.000 € (27 €/kWh discount on a third of the consumption).

Both options above, and their combination, are summarized in Table 48. As can be appreciated above, even though the solar roof increases profitability in the long term (30 years, see Annex 15), it actually decreases the 10 year NPV. This is because the payback period for the photovoltaic project itself is around 12 years. However, once the CAPEX has been written down, the yearly 231 k€ savings mean the addition of a recurring 1.8% to the net margin over sales.

Subsidy (CAPEX)	OPEX	Market price	Initial investment	Yearly CF	ROI	Payback period	IIR (10 years)	NPV (10 years)	DELTA CF
No	**Base case**	**Base case**	**9.109.613 €**	**792.819 €**	**-13%**	**11,49**	**-2,4%**	**- 3.541.187 €**	
No	-914.000€ fuel	Base case	9.109.613 €	1.706.819 €	187%	5,34	13,4%	2.878.366 €	**115%**
No	Solar roof	Base case	12.829.613 €	1.023.819 €	80%	12,53	-3,9%	- 5.638.740 €	**29%**
No	Both options	Base case	12.829.613 €	1.937.819 €	151%	6,62	8,3%	780.814 €	**144%**

Table 48. Cash flow projection for two optimization options.

On the other side, we see how there are only advantages (and big ones) to the idea of designing the tanks' placement during the land reclaiming project, as the 1.5 m height difference means a straight 914 k€ yearly profit increase.

We see how big scale projects must be developed for gaining economies of scale and achieving sustainable operating costs, and this requires a "corporatization" of the sector. Large companies with a big financial support can make the investments required both in research of new methods and in the construction and operation of these big fish-farming facilities. Of course, the public sector should support individual actions by removing as many barriers as possible. The fact that the regulatory situation in the Canary Islands regarding fish farming is frozen since at least 2014 and that average procedure times for obtaining an off-shore license are over 5 years do not help private initiatives within our territory.

What is for sure is that food production methods will have to continue evolving in order to keep up with the global demographic trends, as the world's population keeps growing and living standards improve for developed and developing countries, all while concerns about the sustainability of current methods, processes and ways of living increase.

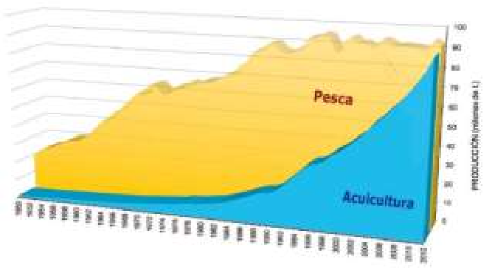

Figure 38. Historical world's fishing and aquaculture production (t).

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11 Annexes