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Business Case Farming@Sea

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Author	Robbert Jak, Marnix Poelman, Maggie Skirtun, Sander van den Burg WUR Robbert.Jak@wur.nl

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Executive Summary

Within Farming@Sea options are explored for the possibilities of offshore production of various groups of species (micro-algae, seaweeds, mussels, fish) by making use of floating modules as being developed in Space@Sea. The purpose of the business cases described here is to assess the economic feasibility of producing mussels and Sea bream offshore by making use of floating modular islands.

North Sea – Mussel farming

Considering mussel farming, the business case elaborated here could encourage mussel farmers to expand their business to offshore areas. The mussels are cultured on longline systems, suspended in the vicinity of the floating island. The floating island is used as a processing site, and as an area for operation and maintenance activities. The business case intends to expand the production volume of mussels and to transpose (part of) production from the nature conservation area of the Wadden Sea to the coastal North Sea. There is a high biological potential for the offshore culturing of mussels, but the sector is still reluctant to invest for several reasons, including the high costs for technology and ships that can withstand offshore conditions. The floating modules as developed within Space@Sea could remove part of these constraints by providing suitable workspace in the operation and maintenance of mussel culturing. By applying the multi-use aspect to the floating islands investment costs can be shared with other industries.

Different types of information has been collected from several sources to assess costs and revenues, these included biological data on growth and production of mussels, capital investments needed for the culturing systems, and costs for the processing of mussels. Relevant information was mainly found for the ongoing bottom culturing of mussels in the Netherlands, longline systems in Denmark, and additional publications from international aquaculture sources such as STECF. A time period of 25 years was taken into account for this business case, since a longer term would introduce too much uncertainty is the estimates.

With overall costs of €236 million and total income of €247 million, the profit would amount to €11 million over the entire 25 year period of time, excluding the costs for the use of floating modules. The activities for this business case would require 4 modules and the costs of modules should not be higher than this to achieve a profitable business case. Further reductions of costs should be further studied in relation to the multi-use of floating islands. Cost savings could possibly result from sharing space, facilities and activities with other use at the island.

The price of mussels appears to have a major impact on the financial performance of the offshore Space@Sea farm. Therefore, negative impacts on the growth and quality of mussels pose a high risk to the business case. Also, incidents, such as severe storms events, may not only damage the culturing systems for which a re-investment is needed, but also reduce the revenues by destroying part of the production of mussels. Applications in sheltered areas such as fjords and bays will off course reduce these risks.

The assessment shows that the business case may well be viable in case costs savings could be achieved, e.g. by profiting from multi-use benefits. However, also additional costs may become evident from such an analysis. Apart from the financial performance of a mussel farm, the offshore production of mussels also has additional benefits to nature and environment, and stimulates economic development in the vicinity of the farming location.

Mediterranean – Sea bream farming

For culturing of Gilthead sea bream, we assessed the economic feasibility of using recirculating aquaculture systems (RAS) in the Mediterranean Sea placed on top of a floating modular island. The use of closed systems would considerably reduce the environmental footprint of the aquaculture of finfish. Furthermore, an offshore location would have less interferences with other human activities in the coastal zone. For the business case a high fish production volume was chosen as it would contribute to the aim to increase food production derived from marine waters. By making use of a multi-use set-up of a modular floating island, faming of sea bream in a RAS system could benefit from facilities and activities related to energy supply, accommodation for workers and transport and logistics.

The designed aquaculture facility requires a large number of modules. It is estimated that about 150 modules each measuring 45x45 m are required for the production of the aimed 50.000 tonnes of sea bream per year. Even without taking into account the costs for modules (either rent or purchase), the business case appears not to be profitable.

Given the assumptions made and the many uncertainties that are involved it is unlikely that culturing of seabream on floating modules in offshore areas will become profitable in the future.

Preface

Space@Sea sets out to provide sustainable and affordable workspace at sea by developing a standardised and cost-efficient modular island with low ecological impact. The consortium consists of a strong collaboration between 17 partners spread throughout Europe. Space@Sea will develop and demonstrate a modular floating island approach including four example applications which will result in three business cases to be further detailed.
Aquaculture is considered as one of the application options for multi-use platforms. Combining several functions may not only reduce costs but could also enable new technologies to be applied at sea. Business cases are developed based on optimal design options as developed in D8.4; optimal design options for aquaculture at modular floating islands a selection of most promising aquaculture options.

The work package on Business cases includes the development of several types of applications of standardised floating modules. One of the applications is Farming@Sea, i.e. aquaculture options that benefit from the modular floaters that are designed for Space@Sea. We considered culturing of fish, mussels, seaweeds and microalgae in different type of culture systems in relation to the floating modules (D8.1, D8.3). In addition to beneficial aspects of floating modules, benefits and constraints are considered of offshore conditions for culture technologies and target species.
Business cases for selected aquaculture options are developed for mussels in the coastal North Sea and for recirculating aquaculture systems (RAS) for fish (Sea bream) in the Mediterranean Sea In this report, these business cases are developed separately, starting with mussels and followed by sea bream.

The business cases are developed for offshore aquaculture applications for sea bream and mussels that make use of floating modules. They are based on the design options developed in D8.4 (Optimal design options for aquaculture at modular floating islands - a selection of most promising aquaculture options).

Part A - Mussel Business Case North Sea

1. Introduction to Mussel Business Case

1.1 Background and motivation

At present, the mussel culture sector in Europe is dominated by few countries, including the Netherlands, Spain, Portugal and France. This business case focuses on the development of longline systems for offshore application in the Dutch North Sea, making use of floating modules to process mussels on site, and activities involved in operation maintenance.

In the Netherlands, over 60.000 tonnes of cultured shellfish is produced, dominated by mussels (*Mytilus edulis*), and complemented by oysters (*Magallana (Crassostrea) gigas*,*Ostrea edulis*). In the current practice, mussels are being grown in inshore and near shore located bottom cultures. In the past, all mussel seeds were collected from natural mussel beds, and transposed to culture plots. Since these activities take place in Natura 2000 areas, alternatives for mussel seed collections were sought for to minimize the impacts on the natural ecosystem. This resulted in the application of mussel seed collector installations, where larval mussels attach to, which are then harvested and transferred to culture plots. As pointed out in Space@Sea report D8.3, in 2015 about 75% of the mussel seed was fished in the Wadden Sea (Producer organization Mussel culture) while 25% of the mussel seed was captured using seed mussel collector installations (SMCs) in the Wadden Sea, Oosterschelde and Voordelta. The two latter locations, also referred to as part of the Delta region, are situated in the south west of the Netherlands and completely rely on mussel seeds from collectors. This limits the further development of the sector in that area.

In addition to collecting mussel seeds, offshore longline systems could also be used to grow mussels to consumption size. In this case, part of the mussel seeds can be removed and transported to culture plots, while the remaining part stay on the long lines to enable further growth. Desk studies have shown that it is biologically and technically possible to capture offshore mussel seed in the North Sea where it can grow into consumption sized mussels (see also D8.3). Especially in the food-rich south west off the Dutch coast, a high production of mussels can be expected. High growth rates and a high meat content have been shown for offshore grown mussels.

It has been estimated that there is a potential to acquire 25% (5500 tons) of the annual mussel seed requirement in the Netherlands from offshore aquaculture. This is about 50% of the mussel seed that stems from seed mussel collectors in 2016. Part of this mussel seed will be transported and used to seed cultivation plots in the Delta region, while another part will be left to grow on the offshore longline systems into medium sized mussels (an estimated 4125 tons) and a third part will remain and grow to full consumption size (an estimated 2750 tons).

In addition to economic drivers, other goals can be achieved from offshore mussel culturing:

- An increase in production volume, thus increased food production from the sea for human consumption;
- A potential reduction of activities in Natura 2000 areas, by transposing activities from near shore nature protection areas to offshore locations.

In Table 1 a SWOT analysis for offshore mussel farming is presented, adapted from Kamermans et al. (2016).

Table 1 SWOT analysis for the offshore farming of mussels in windfarms

Stengths • Biological potential for offshore mussel culture present • Mussels found have high meat content • Lower risk of diseases and parasites • More available area and increase of total production •18 months consumption mussels production without socking and / or move	**Weaknesses** • High costs for technology and ships that can withstand offshore conditions • Uncertainty about the most appropriate method • No need for offshore mussel cultivation in the sector
Opportunities • The Netherlands has the expertise and the companies necessary to develop mussel cultivation at sea • "Rewarding" of companies that invest by granting rights • New mussel cultivation technologies are already used in other countries • Development of mussel farming in combination with other products (oysters and algae) • Little predation of starfish and crab • Opportunities for benefits for staff, infrastructure and transport within wind farm	**Risks** • 10 years needed for development new techniques • Little trust between mussel farmers and government • Too few opportunities to claim results of pilot projects as intellectual property (patents) • Little interest in collaboration between companies from the wind sector and the mussel farms • Conflicts between wind, government and mussel cultivation • Ecological impacts are unknown

1.2 Subject

In the Netherlands, mussel culturing is not being performed offshore yet, even though biological and technical preconditions can be met. Mussel farmers appear to prefer their current business practices, where new opportunities involve certain weaknesses and risk, see SWOT analysis above.

Floating modular islands as developed in the Space@Sea project could be beneficial to offshore mussel cultivation by serving as a:

- Mussel processing site;
- Area for operation and maintenance activities.

In addition, sharing these activities with other applications on the island may potentially decrease the costs for mussel cultivation.

1.3 Purpose

Mussel culturing offshore in an interesting option to expand production, and to transpose (part of) production from the nature conservation area of the Wadden Sea to the coastal North Sea.

The purpose of the business case is to assess the economic feasibility of producing mussels offshore by making use of floating modular islands. This could encourage mussel farmers to expand their business to offshore areas.

An increase of seafood in the form of mussels will contribute to the general aim to obtain more food from the sea for the growing human population. It would further offer jobs to local communities involved in the production and sales of mussels.

Mussels form a food source from low in the trophic food web, thereby being an ecologically efficient producer of valuable proteins for their consumers. Mussels feed on live and dead floating particles that occur naturally in the water column, especially along coastal areas that are fed with nutrient rich river water.

Within Space@Sea, a location is proposed to serve as a Transport&Logistics hub (Figure 1), and this area is also very suitable to culture mussels, because of the input of nutrient and particle rich waters from the rivers Scheldt and Rhine where upon mussels feed.

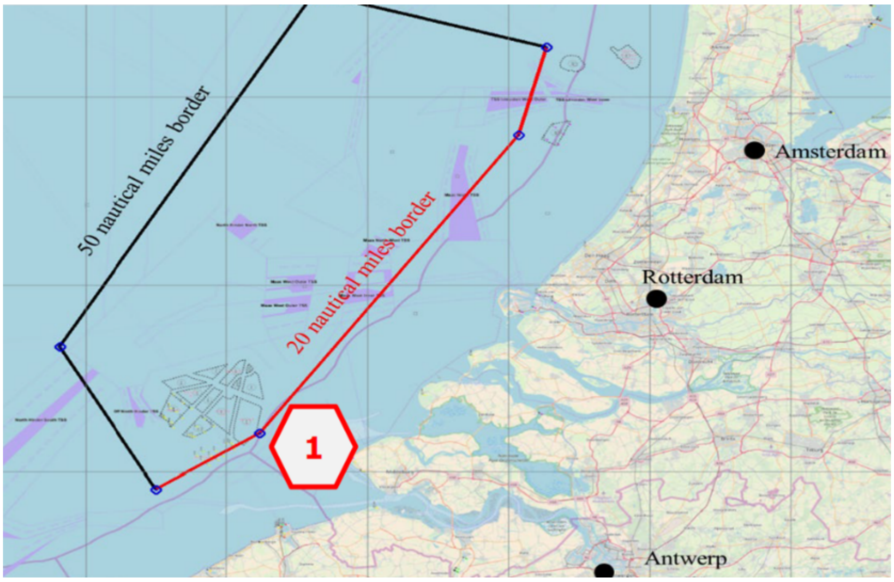

Figure 1 Considered area for the offshore culturing of mussels.

2. Methods & Assumptions

2.1 Scope

The business case is developed from the perspective of the mussel farmer, the enterprise that owns the culture system, and is taking care of all the equipment, operations, and employers that are needed to enable the mussels to grow, harvest, packaging and sell the mussels as a product to customers, such as wholesalers and (chains of) supermarkets. Mussels can only be cultured in food rich areas that usually occur in shallow coastal water.

Although costs for employers are taken account of, no costs for accommodation is considered, since the culture systems are located near shore. A floating modular island is considered to act as a workplace, that facilitates all operation and maintenance activities in the close vicinity of the culture system.

Use can be made of information, knowledge and expertise developed from near shore culturing in the Netherlands, and from inshore and nearshore longline culturing in other parts of Europe, especially from Denmark.

Although culturing does not take place in offshore areas yet, appropriate methods for doing so are in development. Therefore, we assume that offshore culturing can start from now on. For the business case a production period of 30 years is considered.

One of the uncertainties in offshore operations, is the risk of failure or losses due to climate and weather conditions, including waves by storms. These risks are not being considered as part of the costs for this business case. The assumption is thus that systems will be developed that can withstand these offshore conditions.

2.2 Metrics & Decision criteria

2.2.1 Financial Metrics

The financial metrics used in the Space@Sea business case is summarised as the following:

- Annual finance profit
- Return on Investment (ROI)
- Discounted Cash Flow (DCF) and Net Present Value (NPV)
- Payback Period
- Internal Rate of Return (IRR)

The most basic metric for assessing the financial feasibility of a business case is the **annual financial profit**, which is calculated as revenue less expenses. Expenses include both operating costs for day-to-day activities of the farm, and capital costs of financing borrowings and depreciation. The latter is not a cash expense or outflow, but needs to be accounted for in the financial performance of the business case as it captures the loss in value in the capital investment, which needs to be recovered or replaced over time. More specifically, annual financial profit is calculated as:

$$Financial\ profit_t = Revenue_t - Operating\ cost_t - Capital\ cost_t$$

Or

$$Financial\ profit_t = Revenue_t - Cash\ cost_t - Depreciation_t$$

where *t* is the time period, whether it is a calendar year or a financial year.

The next metric that needs to be considered is the **Return on Investment (ROI)**, which measures the annual return as a percentage of initial capital investment. This is calculated as:

$$ROI_t(\%) = \frac{Capital\ gains_t + Net\ profit\ or\ dividend\ yield_t}{Captial\ investment_t} \times 100$$

For the purpose of this study, we do not assume that any capital investments are sold during the period of operation, so that the ROI simplifies to:

$$ROI_t(\%) = \frac{Net\ profit_t}{Captial\ investment_t} \times 100$$

As the value of money declines with time, it is important to establish the worth of cash flows in today's dollars, or present value, so that it can be accurately weighed against the capital investment needed upfront. The present value of cash flows is reflected by the metric **Discounted Cash Flow (DCF)** and the cumulative sum of all DCF over the period of interest is defined by the **Net Present Value (NPV)**. The two metrics can be calculated as the following:

$$DCF = Present\ Value = Net\ cash\ flow_t/(1+i)^t$$

$$NPV = \sum_{t=0}^{n} \frac{Net\ cash\ flow_t}{(1+i)^t}$$

where i is the discount rate or the return that could be earned in alternative investments, and t is the time period (with the maximum number of periods set to n).

Related to the concept of NPV are the **Payback Period** and **Internal Rate of Return (IRR)**. The Payback Period is specified as the number of years for the NPV to become positive – that is, the number of years for initial investment to be recuperated or paid back with discounted cash inflows. On the other hand, the IRR corresponds to the discount or interest rate that will equate to a NPV of zero. It is used to evaluate the attractiveness of various business cases against others, or against a company's minimum threshold rate to take on an investment. For example, if the IRR falls below the desired rate of return, the project may be rejected. As mentioned earlier, the IRR is calculated by setting NPV to zero:

$$NPV = \sum_{t=0}^{n} \frac{Net\ cash\ flow_t}{(1+IRR)^t} = 0$$

The combination of financial metrics outlined here provides a comprehensive assessment of the attractiveness of the Space@Sea business case for farming mussels in the North Sea.

2.2.2 Other Decision Criteria

In addition to financial factors, the business case may also serve other objectives. An important one is that mussel production may increase in volume, especially in the southern Delta area where mussel seed (needed as inoculum to grow mussels) cannot be harvested from natural mussel beds.

Harvesting mussel seeds from natural beds is also not desirable, since it hampers the development of natural mussel beds, that have important nature values because of their high biodiversity. For this reason, the collection of mussel seed from offshore locations would reduce the need for mussel seeds currently harvested from natural beds in the nature conservation area of the Wadden Sea.

2.3 Scenario Design

The proposed set up of the offshore mussel culture systems by making use of floating platforms, would increase the volume of mussel production in the Netherlands, for supplies to the French, Belgian and Dutch market.
It would therefore add to the existing market and should be competitive to the on-going inshore and near-shore culturing of mussels.
The baseline for the assessment of the feasibility of offshore culturing is therefore the current practise of mussel culturing.

As shown in Figure 1, the proposed location is relatively nearby the south-west coast of the Netherlands, where landing of mussels is already facilitated, e.g. in the harbours of Vlissingen, Yerseke and Stellendam. Most of the mussels are being traded and transported directly to the market: restaurants, supermarkets, etc.

2.4 Major Assumptions

It is assumed that the mussels produced offshore in addition to the current production volume, does not have an effect on the market value of mussels.

Some basic assumptions are made on the basis of available information for production figures (see Deliverable 8.3), growth period of mussels and the monetary value of mussel stages. Basically, mussel seeds grow in a period of 9 months to a juvenile stage. Part of these mussels are harvested and sold for bottom culture, while the other part is left on the longlines to grow to consumption size mussels. The basic parameter values for this scenario are presented in Table 2.

Figures on the mussel production is based on the chosen production volume and predicted growth rates in offshore conditions (assessed from available literature information).

Table 2 Basic parameters for the scenario design

Parameter	Unit	Space@Sea case study
Seed mussel production	Tonnes/year	5,460
Juvenile mussel production	Tonnes/year	6,506
Consumption mussel production	Tonnes/year	5,693
Seed mussel growth period	Months	9
Juvenile mussel growth period	Months	15
Consumption mussel growth period	Months	21
Seed mussel price	Euros/kg	0.25
Juvenile mussel price	Euros/kg	0.70
Consumption mussel price	Euros/kg	1.00
Percentage of included tare	% total production tonnage	25
Processing waste	% net production tonnage	10

The production of 17,660 tons per year requires 2.400m^2 of workspace, equivalent to 4 modules of 45x45 m as designed in Space@Sea. The advantage of an on-site platform/floating module mainly lies in the ability to harvest and process mussels year round (with a gap during spawning in April-May, when most of the mussels energy goes into reproduction and meat content is lower and potentially a low use, maintenance only period during heavy seas/winter conditions). This way harvesting can be spread out in time (approx. 8 months a year), instead of bulk processing (see seaweed farming) and optimal use of the facilities on the platform that are scaled to the supply of mussels.

2.5 Data Sources

Relevant data sources were searched for in literature and requested from experts in the field. Information from the commercial mussel culturing industry is hardly available from individual stakeholders, as it is considered confidential information. Overall figures are used that are available from overview reports (see section 0).

2.6 Data Structure

For the results of the cost revenue assessment in section 3, a full value approach is used. That is, total revenues and costs are calculated for the business case in order to present a benchmark measure of financial feasibility for setting and operating longline mussel farming at sea. Financial sensitivity analysis in section 5.1 is presented in incremental values (e.g. ratios or percentages) against this benchmark measure to illustrate the deviations from the base case from changes in underlying financial assumptions.

3. Cost-Revenue Assessment

3.1 Annual Financial Performance, Farming

The calculation of annual revenue and expenditures for mussel farming in

Table 3 is based on data extracted from the Scientific, Technical and Economic Committee for Fisheries (STECF) of the European Union[1]. Average farm data for the years from 2014 to 2016 for Denmark longline mussel culture, and from 2014 to 2015 for bottom culture in the Netherlands are reported in the first two columns of Table 3, standardised to a production output of 1.000 tonnes. The reason for excluding the year 2016 from the Dutch farm data is due to the exceptional poor performance of the industry in that year, primarily attributed to poor mussel quality. Inclusion of the Dutch financial performance for 2016 would cause significant negative distortion to the data, and as such was omitted from the analysis.

Annual revenue for longline culture in the Netherlands is calculated by applying the prices from Table 1 in the Scenario Design to the estimated production volume, net of tare. In this case study, no additional revenue from subsidies or work for third parties are assumed.

Cost of mussel farming is broken down by operating cost (OPEX) and capital cost (CAPEX). OPEX includes expenditures directly attributable to the day to day farming of mussels on the Space@Sea platform while CAPEX relates to the depreciation, or wear and tear, of machinery and equipment as well as the cost of financing capital (i.e. interest payments). The calculation of these costs is based on the selection of the most appropriate per tonne cost from the Danish longline and Dutch bottom culture data, or a combination of both. For example, the category 'wages and salary' uses the annual salary per worker from the Netherlands but the productivity (i.e. tonnes per worker) from the Danish data. This is because while the annual salary is likely to reflect the country of operation, labour productivity is expected to be influenced by the method of farming.

For energy use, while it is also likely for the method of farming to be of considerable influence, Dutch cost per tonne is applied owing to the fact that the Space@Sea platform is offshore and would therefore incur additional fuel use compared to the average Danish longline farm. The energy cost per tonne of mussels production is only applied to the seed and juvenile mussels as the energy or transport cost for consumption mussels will be borne by the processing plant. The remaining OPEX items are taken at the average cost per tonne of the Danish longline and Dutch bottom culture systems.

[1] https://stecf.jrc.ec.europa.eu/reports/economic

Table 3 Annual revenue and expenditures for the mussel farming model

	DK longline	NL bottom culture	Longline for NL	Space@Sea
Income per enterprise				
Turnover	773,458	1,090,420	657,580	8,709,150
Subsidies	33,094	54,354	0	0
Other income	0	0	0	0
Total income	**806,551**	**1,144,774**	**657,580**	**8,709,150**
Operating costs per enterprise				
Wages and salaries	159,450	179,691	217,784	2,728,887
Imputed value of unpaid labour	74,911	0	0	0
Energy	1,533	73,741	49,968	661,790
Livestock	46,812	47,413	0	0
Repair and maintenance	85,109	103,597	94,353	1,249,632
Other operational costs	152,481	291,417	221,949	2,939,547
Total operating costs	**520,295**	**695,859**	**584,054**	**7,579,857**
Capital costs per enterprise				
Depreciation	45,008	42,283	31,975	423,487
Financial costs	37,084	56,057	20,653	273,529
Total capital costs	**82,092**	**98,339**	**52,628**	**697,017**
Profit per enterprise	**204,164**	**350,575**	**20,898**	**432,276**
Capital investment	1,143,864	2,205,702	812,634	10,762,725
Return on capital	18%	16%	3%	4%
Employment				
Female FTE	0	0	0	0
Male FTE	2.4	2.9	3.3	44
Production				
Volume of production (tonnes)	1,000	1,000	1,000	13,244
Volume of livestock (tonnes)	39	65	0	0
Income/kg output	0.77	1.09	0.66	0.66
Operating cost/kg output	0.52	0.70	0.58	0.57
Profit/kg output	0.20	0.35	0.02	0.03

For CAPEX, the rate of depreciation of 4% is taken from the average Danish farm, which is equivalent to a useful life of 25 years under straight line depreciation. The depreciation rate of 2% from the average Dutch farm implies capital useful life of 50 years, which is not realistic (Erumban 2008)[2]. However, the interest rate of 2.5% is taken from the Dutch data as the country of finance will determine the borrowing rate applicable. For capital investment, the investment cost per tonne of mussel production from the average Dutch bottom culture farm is used but only applied to the highest harvest season (i.e. half-grown mussels). This is because harvest seasons of seeds, juveniles and consumption size mussels take place during different times of the year, and there is no need for additional investment in extra vessels for each season as long as the highest season can be harvested.

[2] https://onlinelibrary.wiley.com/doi/full/10.1111/j.1475-4991.2008.00272.x

The capital investment breakdown capital for the farming division further is shown in Table 4. Percentage breakdowns from Theodorou et al. (2014)[3] and Thong et al. (2013)[4] are used to split the investment figure in the revenue and expenditures table, standardised to sum to 100 per cent.

Table 4 Breakdown of capital investment for longline mussel farming (not incl. platform fixtures)

Capital breakdown	Theodorou et al. 2014	Thong et al. 2013	Average	Space@Sea
Capital investment	*100%*	*100%*	*110%*	*10,762,725*
Licences and permits	7%	n.a.	7%	681,539
Moorings of longline system	13%	38%	26%	2,524,216
Units (incl. ropes and floats)	20%	32%	26%	2,541,203
Buoys	1%	2%	2%	160,570
Working vessels	35%	12%	24%	2,309,881
Small boats	2%	1%	1%	134,437
Vehicles	6%	6%	6%	591,148
Land tools	6%	0%	3%	296,857
Machinery	10%	n.a.	10%	965,513
Installations	n.a.	3%	3%	317,465
Other	1%	4%	2%	239,895

n.a. not applicable

It should be noted that all capital investment costs shown in Table 4 refer to the longline farm itself, and does not include fixtures or equipment on the platform. For example, moorings, buoys, ropes and floats are those used in securing the longlines for the mussel farm rather than the platform itself. With the capital investment for buildings and equipment located on top of the platform, and for the purpose of processing, this can be found in Table 6 in the next section.

3.2 Annual Financial Performance, Processing

Data on cost of processing for the mussel sector is limited. The best available information comes from the price structure study by EUMOFA (2019)[5]. For the most part, the processing cost per kilogram in Germany and Denmark are considerably close, with the exception of employment cost, see Table 5.

Table 5 Price structure along supply chain for Mytilus edulis *(EUMOFA 2019)*

EUR/kg	Germany	Denmark	Average
Ex-farm mussel price (first sale)	**1.4**	**0.68**	**1.04**
Transport to wholesaler	0.3	0.41	0.36
Cleaning/sorting/packaging costs	0.45	0.41	0.43
Employees	n.a.	0.81	0.41
Processor-wholesaler's margin	0.4	0.41	0.41
Ex-wholesaler price	**2.55**	**2.70**	**2.63**
Retailer's logistic and transport cost	0.5	0.81	0.66

[3] Theodorou, J.A., Tzovenis I., Sorgeloos P., Viaene J. (2014) Risk factors affecting the profitability of the Mediterranean mussel Mytilus galloprovincialis Lamarck 1819, farming in Greece. Journal of Shellfish Research 33 (3): 695–708.
[4] https://www.marbio.sdu.dk/uploads/MarBioShell/Thong%20et%20al%202013%20Final%20-%20SDU%20%20Thongrapport.pdf
[5] https://www.eumofa.eu/

Retailer's other costs and margin	0.8	0.81	0.81
Retail price excl VAT	**3.85**	**4.32**	**4.09**
VAT (7%)	0.27	1.08	0.68
Retail price incl VAT	**4.12**	**5.40**	**4.76**

n.a. not available

For the processing division of Space@Sea, revenue is calculated by multiplying the average wholesale price of €2.63 to the output volume after processing, net of waste (see Table 2). No subsidies or income from processing of third-party mussels are assumed for the purpose of this case study. Table 6 lists the figures used for the mussel processing model, which are described in more detail in the text below.

Table 6 Annual revenue and expenditures for the mussel processing model

	Per 1000 tonnes input	**Space@sea**
Income per enterprise		
Turnover	2,362,500	10,087,284
Other income	0	0
Total income	**2,362,500**	**10,087,284**
Operating costs per enterprise		
Wages and salaries	202,500	864,624
Imputed value of unpaid labour	0	0
Energy/cleaning/packaging	430,000	1,835,993
COGS: fish and other raw materials	1,000,000	4,269,750
Repair and maintenance	113,073	482,793
Other operational costs (e.g. transport)	319,500	1,364,185
Total operating costs	**2,065,073**	**8,817,345**
Capital costs per enterprise		
Depreciation	73,314	313,033
Financial costs	47,353	202,187
Total capital costs	**120,667**	**515,220**
Net result per enterprise	**176,760**	**754,719**
Capital investment	1,863,240	7,955,570
Return on capital	9%	9%
Employment (workers/100 ton)		
Total FTE	3.3	14.0
Production		
Volume of raw materials (tonnes)	1,000	4,270
Volume of output (tonnes)	900	3,843
Income/kg output	2.63	2.63
Operating cost/kg output	2.29	2.29
Profit/kg output	0.20	0.20

Similar to the calculation of income, costs are extrapolated using per kilogram data from EUMOFA (2019) for the corresponding categories. The only exceptions are cost of goods sold (COGS), which is imported from the farm gate value of consumption mussels from the farming division, and employment cost. Average employment cost of €0,41 is discounted by 50% to account for the fact that workers from the farming division are able to be mobilised in processing on the platform as required. That is, there is some productivity gains from vertically integrating the farming and processing operations in the case study.

For capital costs, the same depreciation and interest rates are used from the farming model. Capital investment, on the other hand, is calculated by multiplying by a ratio of income. This ratio, which equates to 79%, is derived from the STECF data on the average investment across processing sectors in the Netherlands from 2012 to 2014. According to the accompanying report (STECF 2019)[6], the key processing segments in the Netherlands are flatfish, shrimp and mussels. However, detailed data by segment is not available, and 2014 is also the latest year data is available for the Netherlands. Therefore, some care is needed in interpreting the estimated capital investment required.

[6] https://stecf.jrc.ec.europa.eu/reports/economic/-/asset_publisher/d7Ie/document/id/2571760

4. Business Case Results

4.1 Cash Flow Projections

Cash flows and net present values (NPVs) projections are computed for a vertically integrated model, inclusive of both the farming and processing divisions. These are displayed in Table 7. The average annual revenue of €14.5 million is the combination of €4.4 million for seed and juvenile mussels sold directly post-harvesting, and income from consumption mussels after processing of €10.1 million. As the results are presented for both farming and processing divisions as a single integrated model, the intermediate revenue of unprocessed consumption mussels is fully absorbed in the revenue of processed mussels. Also to note, in the first year only seed mussels are produced as juvenile and consumption mussels take longer than 12 months to grow. Hence, the income is limited to only €1 million for the first year of operation.

Similarly, average operating costs consist of the €7.6 million from the production division and €4.5 million from the processing division, less COGS of intermediate/unprocessed consumption mussels. In the first year, the operating cost is reflective of only of the farming division as no processing takes place. In the second year, operating costs for both divisions are accounted for with the exception of repairs and maintenance of the processing sector as all equipment are assumed new and only require servicing from the second year of operation.

In terms of capital investment, it is estimated that it will take 15 years before the NPV of all initial investments for the vertically integrated company to be recuperated. The initial capital investment is the sum of €10.7 million for the farming division (see Table 4 for detailed breakdown), and €8 million from the processing division. This is based on the assumption of a single set of capital investment for the full 25 years the platform is in operation, with only repairs and maintenance needed during the period. This is because, while the useful life in depreciation calculations for tax purposes is generally 10 years for machinery in fishing and manufacturing, the actual lifetime of capital assets before it is discarded is estimated to be 28 years for Dutch manufacturing industries (see Table 8, Erumban 2008). Hence, for the purpose of this case study, we assume lifetime of capital assets cover the 25 years the Space@sea platform is expected to operate. This also matches the assumed 4% depreciation rate for section 3.

In summary, with a total average annual cash profit of €1.9 million, the initial capital investment is repaid over 15 years, leaving the NPV for the last 10 years accumulating as net discounted profit. At the end of the 25 year period, NPV is projected to be a little over **€11** million, with a residual capital asset value of €1.4 million that may be utilised in another project or sold as scraps.

The costs for the use of the four floating modules needed for this business case are not included in the cost assessment. With an NVP of 11 million, there is not much financial room for covering the costs for the use of modules.

Table 7 Summary of combined cash flows and NPVs for the mussel farming and processing models

Assumptions							**IRR:**	**7.42%**
Discount rate	3%							
Depreciation	4%							
Interest rate	2.50%							
Year	1	2	3	10	14	15	20	25
Revenue								
Harvest of seeds	1,023,750	1,023,750	1,023,750	1,023,750	1,023,750	1,023,750	1,023,750	1,023,750
Harvest of juveniles	0	3,415,650	3,415,650	3,415,650	3,415,650	3,415,650	3,415,650	3,415,650
Harvest of consumption mussels	0	10,087,284	10,087,284	10,087,284	10,087,284	10,087,284	10,087,284	10,087,284
Total revenue	1,023,750	14,526,684	14,526,684	14,526,684	14,526,684	14,526,684	14,526,684	14,526,684
Operating cost								
Wages and salary	2,728,887	3,593,512	3,593,512	3,593,512	3,593,512	3,593,512	3,593,512	3,593,512
Energy/cleaning/packaging	661,790	2,497,783	2,497,783	2,497,783	2,497,783	2,497,783	2,497,783	2,497,783
Repairs and maintenance	0	1,249,632	1,732,426	1,732,426	1,732,426	1,732,426	1,732,426	1,732,426
Other costs	908,881	4,303,732	4,303,732	4,303,732	4,303,732	4,303,732	4,303,732	4,303,732
Capital costs								
Depreciation	0	423,487	736,520	736,520	736,520	736,520	736,520	736,520
Finance	273,529	475,716	475,716	475,716	475,716	475,716	475,716	475,716
Initial investment	10,762,725	7,955,570	0	0	0	0	0	0
Depreciated amount	*10,762,725*	*18,294,808*	*17,558,287*	*12,402,646*	*9,456,566*	*8,720,046*	*5,037,445*	*1,354,844*
Total cash cost	4,573,088	12,120,375	12,603,169	12,603,169	12,603,169	12,603,169	12,603,169	12,603,169
Cash profit	-3,549,338	2,406,309	1,923,516	1,923,516	1,923,516	1,923,516	1,923,516	1,923,516
Discounted Cash Flow	**-14,312,062**	**-5,387,632**	**1,813,098**	**1,474,215**	**1,309,821**	**1,271,671**	**1,096,954**	**946,242**
Cumulative Net Present Value	**-14,312,062**	**-19,699,694**	**-17,886,596**	**-6,590,482**	**-1,110,680**	**160,990**	**5,984,869**	**11,008,598**

4.2 Financial Metrics

The financial metric results for the entire vertically integrated farming and processing operations are summarised in the following:

- Annual financial profit: €1,19 million accounting for depreciation
- Return on Investment (ROI): 6% p.a.
- Discounted Cash Flow (DCF) and Net Present Value (NPV): graphed in Figure 2 and Figure 3 below
- Payback Period: 15 years
- Internal Rate of Return (IRR): 7.4%

As illustrated in Figure 2, Discounted Cash Flow (DCF) in the first two years of operation is hugely negative owing to the initial capital investment and operating costs, which must be paid before the inflow of income. As discussed in section 4.1, income in the first year is only that of seed mussels and this further reduces the capital repayment capabilities. Over the first 14 years, the cumulated discounted cash profit does not cover the NPV of capital investment and hence, total NPV is negative (Figure 3). However, by year 15, the cumulated discounted cash profit covers the NPV of initial investment and total NPV becomes positive henceforth.

By year 25, the total cumulative NPV reaches €11 million in today's value. This equates to an IRR of 7.4%, that is the discount rate which yields a NPV of zero in the final year. The annual ROI for the average operating year is 6%, not including the first two years of operation for reasons discussed above.

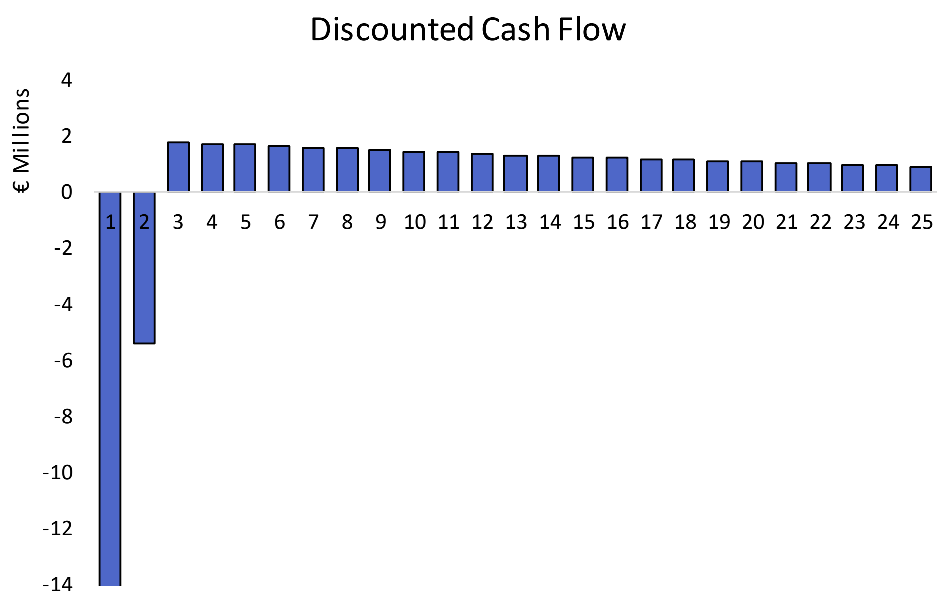

Figure 2 Discounted cash flow over a time period of 25 years.

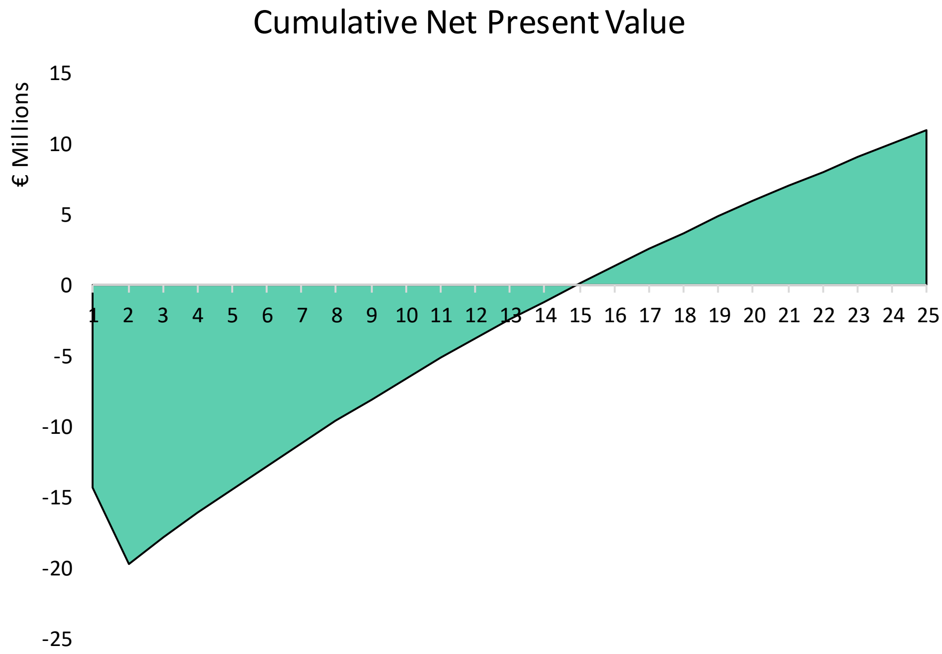

Figure 3 The cumulative net present value over a time period of 25 years.

4.3 Non-Financial Results

As pointed out in section 2.2, some benefits and costs to society in general may apply to the implementation of offshore mussel farming, which are summarized in Figure 4.

The Business Case is developed to increase production of mussels as a source of food for the human population. It thereby contributes to the overall food security.

Not only the quantity, but also the quality of offshore grown mussels appears to be high in comparison to coastal grown mussels. They benefit form high food availability, resulting also in high growth rates. Mussels feed on particles, mainly phytoplankton (microalgae). Coastal areas often have a high turbidity because of large amounts of detritus (dead organic material) that has less nutritive value as compared to living algae.
The additional production of mussels is not only reflected by higher flesh contents, also additional shell material is produced that contributes (but to a minor extend) to the sequestration of carbon, and therefore to the reduction of CO_2-induced climate change.

Coastal zones are intensively used for human activities. In the coastal areas concerned, i.e. the southern coast of the Netherlands and the Dutch Wadden Sea, these activities including nature conservation, shipping, fisheries, and tourism. The offshore farming of mussels may reduce the intensity of mussel culture activities in the Dutch Wadden Sea, especially the need to collect mussel seed from natural mussel beds. This will benefit the development of natural mussel beds, which have a high nature value because of their high associated biodiversity, and filtering function.

By shifting activities from the coast to offshore located areas, the competition of space with other activities may be diminished. Also the potential risks of negative interferences between these activities, such as collisions, may be reduced.

Loss of any materials from the culture installations due to rough sea state may forms a source of litter, i.e. non-organic waste pollution. This might negatively impact vulnerable organisms such as sea mammals and seabirds.

Another source of pollution are emissions by ships, that are needed for transport of goods, and people for the shore to the offshore location.

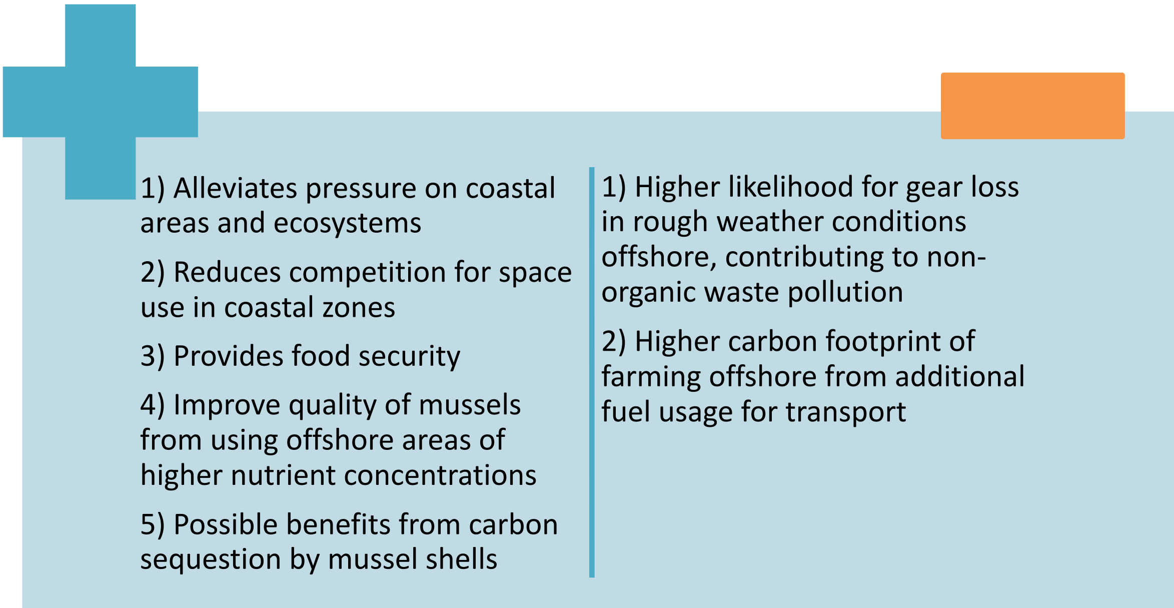

Figure 4 Overview of positive (left) and negative (right) impacts of offshore mussel farming for society

5. Risk Analysis

Costs have been financially estimated in the preceding chapter on the basis of assumptions, made on several aspects. Uncertainty ranges in the quantitative assumptions contribute to the financial risks of the business case. These will be analysed below with a sensitivity analyses wherein assumed main factors in the financial results will be varied. In addition, also non-financial risks will be inventoried and listed in a risk register. The risk levels will be assessed semi-quantitatively. Where possible, risk management measures are proposed.

5.1 Sensitivity Analysis

5.1.2 Financial data

For sensitivity analysis on the financial performance calculations, the following changes relative to the base case were applied:

- Revenue:
    - Base price of mussels was adjusted by ±20% to reflect historical variations in price. That is, no demand and supply impacts from the increased production of the offshore platform is explicitly accounted for
- Operating costs:
    - Energy/fuel costs are adjusted by ±20%, to account for variability in the global fuel price
    - Labour costs are also adjusted by ±20% to account for improvements in productivity (i.e. reduction in labour cost) or higher costs of employing more skilled labour (e.g. additional training necessary for longline farming offshore)
    - Half of other operating costs are adjusted by ±20% to account for increased energy costs related to transport of mussels from the platform to the destined markets (i.e. assuming that 50% of other operating costs are related to transport or other energy dependent expense)
- Capital costs:

  - Depreciation: doubling the rate of depreciation to 8% to account for the higher wear and tear of machinery and equipment offshore
  - Capital investment: as a result of a higher depreciation rate, this implies that initial capital investment would need to be invested again at 12.5 years (i.e. each investment round covers only half of the time period examined in the study)
- Discount rate:
  - Real discount rate is examined for the range between 1% to 10%, against the base case assumption of 3%. The lower end of the real discount rate is to account for deep recession periods while the higher end of the discount rate captures not only economic booms but also increased options of investment options in the future that may yield higher returns. This is examined separately to the alterations to financial factors.

Using the combination of these changes relative to the base case, 4 scenarios are examined:

- Best case scenario: where positive changes in revenue (i.e. +20% in mussel price) and costs (i.e. -20% in operating costs, and no changes to capital costs) are assumed
- Worst case scenario: where negative changes in revenue (i.e. -20% in mussel price) and costs (i.e. +20% in operating costs, and doubling of depreciation and capital costs) are assumed
- Bad operating costs: where revenue and capital costs stay constant but operating costs are increased by 20%
- Worst case with base depreciation: where the worst-case scenario is assumed but no changes to capital costs are made
- In-between case: where mussel price (or revenue) and operating cost are both increased by +20%

The best- and worst-case scenarios are designed to provide upper and lower bound impacts to Net Present Value (NPV) over the 25 year period of the analysis, while the worst case and bad operating cost scenarios provide sensitivity examples for a more precautionary outlook. Finally, the in-between case presents an example scenario for a growing economy in which prices of outputs and inputs are both increasing. Judging by the historical prices (in real 2018 values) for mussels sold at auctions in the Netherlands, considerable fluctuations in prices are not uncommon (see Figure 5). In contrast, there is generally less variability in terms of CAPEX and OPEX for a given level of production, compared to the revenue side[7].

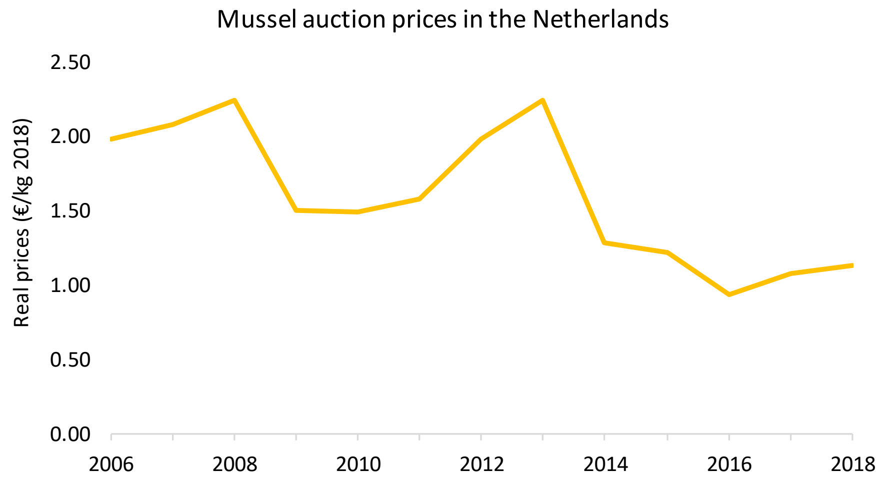

Figure 5 Real prices for mussel sold at Dutch auctions, prices expressed in 2018 values

[7] Based on confidential farm level data collected as part of the socio-economic study of mussel farming transition in the Netherlands. The latest report as part of the research publication series is available at https://edepot.wur.nl/446741

Figure 6 illustrates the ratios of final NPVs relative to the base case, which is set to 1, and splits these ratios by the impacts from discounted cash revenue (DCR), discounted cash cost (DCC), and discounted capital cost (DKC). For example, under the best-case scenario, the total NPV after 25 years is 8.09 times that of the base case and 63% of the impact is the result of an improvement in price. The remaining 27% of the positive contributions to a higher NPV is from a reduction in DCC (i.e. operating cost and financial costs).

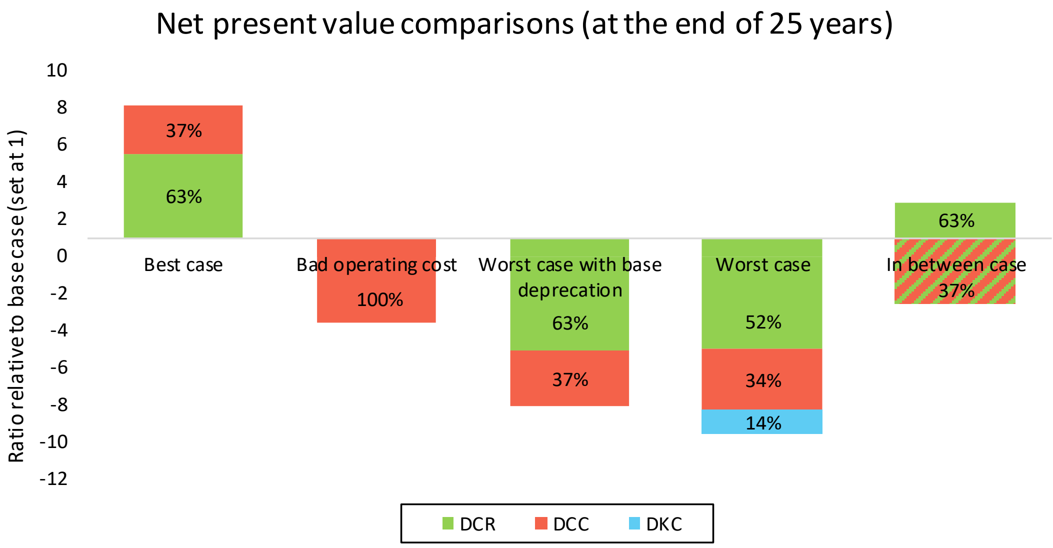

Figure 6 Sensitivity analysis of changes in price and cost components against the base case.

In contrast, under the worst-case scenario, the total NPV after 25 years is -9.59 times that of the base case and 52% of the impact is the result of a decline in price. Increase in DCC (i.e. operating cost and financial costs) make up 34% of the negative contributions to a lower final NPV compared to the base case and increase in DKC accounts for the remaining 14% of the impacts.

This suggests that factor with the largest impact on total NPV over the 25 year period, or the factor NPV is most sensitive to, is price. A small change in price can have a significant impact on the financial performance of the offshore Space@Sea farm. Therefore, it is imperative to ensure healthy markets are sustained, and innovative products with higher value added can be supplied.

In terms of discounting, any decrease in the real discount rate represents a decline in the opportunity cost of investing in the Space@Sea offshore mussel farming project, and hence an increase in the value of discounted net profit (i.e. NPV). As suggested by the IRR, once the real discount rate exceeds 7.4%, the NPV of profit falls below zero. Therefore, the final NPV is becomes less than -100% for discount rates of 8%, 9% and 10% in Figure 7 – that is, more than 100% of the discounted profit are lost.

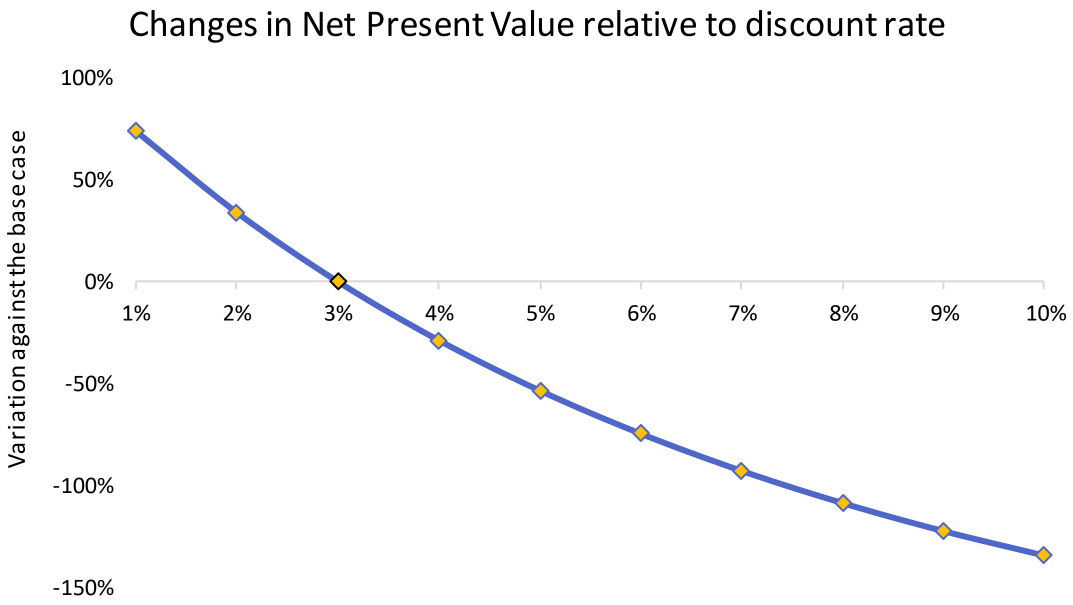

Figure 7 Sensitivity analysis of changes in discount rate relative to the base case, evaluated at the end of the 25 year period

5.2 Business Risk Register

In the business risk register, qualitative risks are identified and its level is assessed on the basis of the expected size of impact and the probability of occurrence. The risk is then calculated by multiplying the probability with the impact. The evaluation scheme to assess the risk level in a semi-quantitative way is shown in the table below.

Impact	High	3	6	9
	Medium	2	4	6
	Low	1	2	3
		Low	Medium	High
				Probability

A number of cost categories were identified by a small number of experts involved in the development of this business case, other than those described in the previous section which were evaluated on the basis of a sensitivity analysis. For each of the identified type of risk, its impact and probability was assessed by each expert independently according to the criteria described below.

Impact	Low (1)	The hazard impacts the total annual cost or revenue by less than 10%
	Medium (2)	The hazard impacts the total annual cost or revenue by 10-50%
	High (3)	The hazard impacts the total annual cost or revenue by more than 50%

Probability	Low (1)	The likelihood of the hazard occurring is less than once in every 5 years
	Medium (2)	The likelihood of the hazard occurring is at least once in every 1-5 years
	High (3)	The likelihood of the hazard occurring is at least once per year

The scores designated by each expert for impact and probability were averaged and multiplied to calculate the risk level. A high score for risk means that the average score is ≥ 5, medium is in between <5 and ≥ 2.5, low is <2.5. Because of rounding off the values, medium scores for both impact and probability can still result in a high level of risk.

It was found that high mussel mortality and storm incidents have the highest risk on the costs. Mussel mortality is quite unpredictable since it is caused by natural factors which may vary during the season and in between years. Predation by starfish and crabs are the cause of high mortality rates on the bottom cultures in the Dutch Wadden Sea. Their predation is less likely to occur on longlines in the water column of the North Sea, since starfish are bound to the seafloor and cannot reach the mussels. However, other predators including swimming crabs may predate substantially on the mussels.

Storms are frequently occurring in the North Sea, and may seriously damage offshore constructions, including longline systems with mussels. Mussels may also drop from the lines and sink to the sea floor. It takes at least two years before full grown mussels can be brought to the market, meaning a high loss of revenues for the damaged part of the culture system.

A lot of other risks were assessed as having a median risk on the costs, including risks on the performance of mussel production, like a reduced growth rate because of e.g. low water temperatures, of low food levels, diseases in mussels caused by e.g. viruses, and the presence of toxins such as tetrodotoxin (TTX probably produced by bacteria) that make mussels unsuitable for consumption. This may also be high pollution levels, e.g. resulting from incidental spills from ships. The quality of the mussel flesh in general may be low because of low levels or low quality of available food in the form of plankton.

The aquaculture system is exposed to rough offshore conditions and may be damaged by waves, strong currents, storms, and by collisions with ships. Weather conditions may also result in a reduced accessibility of the system to perform O&M activities. Risks related to the use that is made of the floating modules scored relatively low.

COST CATEGORIES	Impact	Probability	**Risk level**
Mussel performance			
Mussel growth rate	Medium	Medium	Medium
Diseases in mussels	Medium	Low	Medium
Toxins	High	Medium	Medium
Pollution due to incident (e.g. oil spill)	High	Low	Medium
Quality of mussels	Medium	Medium	Medium
High mussel mortality	Medium	Medium	High
Aquaculture system			
Unexpected partial breakdown of system	Medium	Medium	Medium
Complete breakdown of system	High	Low	Low
Equipment failure	Medium	Medium	Medium
Damage by collisions (ships)	Medium	Medium	Medium
Storm incidents	Medium	Medium	High
Reduced accessibility due to bad weather	Medium	High	Medium
Modules			
Installation of equipment	Medium	Low	Low
Interrupted processing of harvest	Medium	Medium	Low
Labour	Medium	Medium	Medium

6. Conclusions & Recommendations

This business case on mussel production in the shallow North Sea aims to assess its economic feasibility, as compared to current culture practices at inshore locations.
Other objectives are to produce mussel seed to enable increased mussel culturing in the southern Delta region of the Netherlands, and the production of full grown mussels for consumers. Another benefit of producing mussels offshore, is to release the nature protection area of the Wadden Sea from activities related to current mussel production. Also, more space is available and mussels grown offshore have high quality and high growth rates as a result of favourable environmental conditions. The business case described here takes advantage of these strengths and opportunities.
High costs for culturing technology and ships that can withstand offshore conditions is considered one of the bottlenecks for the further development of offshore culturing. Floating modular as developed within Space@Sea could remove part of these constraints by providing suitable workspace in the operation and maintenance of mussel culturing.

Based on the assumptions made in this study, and the highly relevant information that has been collected, it appears that over the period of 25 years that is considered, the annually total cash cost amounts to €12.6 million, before taxes, depreciation and amortisation. These costs for the installation and use of the floating modules is not accounted for in this cost assessment. The annually total cash income from the farming of mussel seed, juveniles and consumption sized mussels and the processing and sale of packaged consumption sized mussels amount to €14.5 million. The total NPV of income of the activities amounts to €247 million, whereas the NPV of costs, including capital investments, amount to €236 million. So, over the entire 25 year period, the NPV of profit amount to €11 million.
This means that there is only a small margin from which the use of the four required floating modules van be financed. Currently, the costs for the construction of one module is estimated to be at least 3 to 4 million each. This would mean that only if the modules can be re-used after the 25 year time period, the overall business may be profitable.

The sensitivity analysis reveals that NPV is most sensitive to the price of mussels, i.e. a small change in price can have a significant impact on the financial performance of the offshore Space@Sea farm. A high quality of offshore grown mussels needs to be retained in order to ensure high enough revenues to cover overall costs. Therefore, factors that negatively affect the growth and quality of mussels pose a risk to the business case. Based on expert assessment, a high mussel mortality was identified for having the highest risk. This mortality may result from consumption of mussels by naturally occurring predators, such as crabs, birds, or certain species of fish. I addition, also diseases, natural occurring toxins, and pollution may negatively impact the growth and quality of mussels. Furthermore, the exposure to offshore conditions and especially storm incidents were thought to from a major risk by increasing the costs on the technology and (partially) loss of the aquaculture system. The risks related to the activities making use of the modules were assessed low or medium.

Since no operations for offshore mussel culturing do exist at the moment, information was obtained from ongoing bottom culture and nearshore longline culturing. Therefore, assumptions had to be made that could further be discussed with stakeholders that are willing to invest in offshore production of mussels, and in sharing information. By making use of modular floating platforms, part of the costs may possibly increase while others may decrease, for instance by sharing operation and facilities with other user functions on a multi-use island. These factors include e.g. transport, energy supply, labour, and sharing of workspace, equipment and facilities. An improved assessment of cost specified for the multi-use island, may further clarify the potential for these type of islands for including the culturing of mussels.

Part B Gilthead Seabream Business Case Mediterranean Sea

1. Introduction to Seabream Business Case

1.1 Background and motivation

Gilthead Seabream and Sea bass are the most important finfish species farmed in the Mediterranean Sea. Until the 1980s, Seabream was only fished from wild populations, but successful reproductions and intensive rearing resulted in a rapid increase in production. Already in 1993, culturing in cages exceeded that of open sea fishing.

Seabream is the largest marine farmed fish in the Mediterranean, they usually weigh between 400 and 600 g and are sold fresh, whole or eviscerated. The major producing countries within the EU are Greece, Spain, and Italy. France is the fourth largest producer of seabream juveniles. Turkey is the second major producer in the Mediterranean. In 2015, seabream accounted for 12% of the total production, in terms of value and volume for the EU marine aquaculture.

Recently, the volume in the production of seabream fry and juveniles has increased, and costs reductions were achieved by automation. The finfish aquaculture industry has heavily invested in farming technologies and automation to improve quality, food safety and traceability of produced fish. A further increase in production volumes rely on environmentally friendly approaches to aquaculture, which are mandatory for production licences and commercially viable production.

The ambition for the business case developed here in the Space@Sea project for Sea bream aquaculture is to increase sustainable food production at large scale production in offshore conditions by making use of modular floating islands.

An increase of food production at sea fits to the EU Blue Growth strategy. An important aspect also is to reduce the environmental footprint by making use of a closed type of aquaculture system, minimising interactions (water intake and discharge) with the marine environment. Closed systems also enable to keep out parasites and to control disease outbreaks.

1.2 Subject

No seabream culturing, to date, takes place in Recirculating Aquaculture Systems (RAS) and there are currently no RAS facilities located on floating platforms. The option for culturing Seabream on top of the modules therefore explores the possibility to do so. An upscaling of Seabream production in the Mediterranean Sea, using current practices, would increase the spatial claim in the more intensely used coastal zone, and also increase the environmental footprint. Offshore production would reduce the claim for space in the coastal zone, and the use of closed RAS system would significantly reduce the environmental footprint.

There are many uncertainties in the technical set-up of such a culturing system, and the behaviour and welfare of fish under conditions with motions. Therefore, the application of this set-up would not be possible at the moment but maybe later in the future.

1.3 Purpose

The purpose of the business case is to assess the costs and revenues of the exploitation of a RAS system on top of floating modules, by producing a widely cultured and marketed species, i.e. the Gilthead Seabream. The assessment is made from the view of a sea farm company.

A main goal is to achieve an increase in the overall production volume of cultured fish in an offshore area where space is available and conditions and pre-conditions can be met, including supply of electric power and transport facilities, offered by a modular floating island.

Within Space@Sea, a location is proposed for an Energy Hub in the Mediterranean Sea (*Figure 8*), and this area is also suitable for the culturing of Seabream. A RAS system on top of floating modules is selected as it has lower environmental impacts on the surrounding sea as compared to the open cage systems that are currently in use in the coastal waters of the Mediterranean Sea. Additional functions of the modular floating island may facilitate requirements of aquaculture, including energy supply and transport facilities.

Figure 8 Considered area for the offshore culturing of Seabream.

2. Methods & Assumptions

2.1 Scope

The costs and benefits of a potential farmer are considered in this business case. The financial figures used are based on the current situation, but the development of the system may take at least a decade to tackle all the technological challenges to successfully culture seabream in the RAS considered here.

Financial figures for the culture system are based on information on land-based systems, whereas information on prices for fish are based on the current market situation. Information is applied in a bio-economic model called AquaVlan[8], a generic and flexible model that was adjusted for use in Space@Sea.

Currently, little information is available on floating RAS. Developments are starting however, focusing mainly on the technical aspects, and on fish welfare and growth under conditions with motions. Consequently, there are many uncertainties considering the feasibility of these floating systems.

2.2 Metrics & Decision criteria

2.2.1 Financial Metrics

The financial metrics used in the Space@Sea business case is summarised as the following:

- Annual financial profit
- Return on Investment (ROI)
- Discounted Cash Flow (DCF) and Net Present Value (NPV)
- Payback Period
- Internal Rate of Return (IRR)

The most basic metric for assessing the financial feasibility of a business case is the **annual financial profit**, which is calculated as revenue less expenses. Expenses include both operating costs for day-to-day activities of the farm, and capital costs of financing borrowings and depreciation. The latter is not a cash expense or outflow, but needs to be accounted for in the financial performance of the business case as it captures the loss in value in the capital investment, which needs to be recovered or replaced over time. More specifically, annual financial profit is calculated as:

$$Financial\ profit_t = Revenue_t - Operating\ cost_t - Capital\ cost_t$$

Or

$$Financial\ profit_t = Revenue_t - Cash\ cost_t - Depreciation_t$$

The next metric that needs to be considered is the **Return on Investment (ROI)**, which measures the annual return as a percentage of initial capital investment. This is calculated as:

$$ROI_t(\%) = \frac{Capital\ gains_t + Net\ profit\ or\ dividend\ yield_t}{Captial\ investment_t} \times 100$$

For the purpose of this study, we do not assume that any capital investments are sold during the period of operation, so that the ROI simplifies to:

$$ROI_t(\%) = \frac{Net\ profit_t}{Captial\ investment_t} \times 100$$

[8] Unpublished report; Bioeconomic model of Aquaculture feasibility – Application to four species in AquaVlan, 2012. Hamon K & A. Kamstra, LEI Wageningen UR.

As the value of money declines with time, it is important to establish the worth of cash flows in today's dollars, or present value, so that it can be accurately weighed against the capital investment needed upfront. The present value of cash flows is reflected by the metric **Discounted Cash Flow (DCF)** and the cumulative sum of all DCF over the period of interest is defined by the **Net Present Value (NPV)**. The two metrics can be calculated as the following:

$$DCF = Present\ Value = Net\ cash\ flow_t/(1+i)^t$$

$$NPV = \sum_{t=0}^{n} \frac{Net\ cash\ flow_t}{(1+i)^t}$$

where *i* is the discount rate or the return that could be earned in alternative investments, and *t* is the time period (with the maximum number of periods set to *n*).

Related to the concept of NPV are the **Payback Period** and **Internal Rate of Return (IRR)**. The Payback Period is specified as the number of years for the NPV to become positive – that is, the number of years for initial investment to be recuperated or paid back with discounted cash inflows. On the other hand, the IRR corresponds to the discount or interest rate that will equate to a NPV of zero. It is used to evaluate the attractiveness of various business cases against others, or against a company's minimum threshold rate to take on an investment. For example, if the IRR falls below the desired rate of return, the project may be rejected. As mentioned earlier, the IRR is calculated by setting NPV to zero:

$$NPV = \sum_{t=0}^{n} \frac{Net\ cash\ flow_t}{(1+IRR)^t} = 0$$

The combination of financial metrics outlined here provides a comprehensive assessment of the attractiveness of the Space@Sea business case for farming seabream in the Mediterranean.

2.2.2 Other Decision Criteria

This business case basically explores the financial factors of the business case. The RAS further reduces the environmental footprint of aquaculture fish production as compared to open cage systems, since water exchange with the marine environment is reduced to a minimum, preventing the potential enrichment of the sea with organic matter, and nutrients (nitrogen and phosphorous). Furthermore, an increase of food production from the sea contributes to the general food security and is one of the societal goals as expressed in the EU Blue Growth Strategy[9]. With respect to this strategy, the business case contributes to the two out of four of the identified priority areas, i.e. [1)] improve access to space and water, as provided by the floating of modules being developed within Space@Sea, and [2)] exploiting competitive advantages due to high quality, health and environmental standards. By bringing the production facilities offshore, pressure on the coastal ecosystem and its other users will be decreased.

2.3 Scenario Design

The proposed set-up for culturing Seabream on top of floating modules would substantially increase the production of Seabream in the western Mediterranean Sea and would supply the markets of France for further distribution. The location for the culturing of Seabream is relatively far offshore (*Figure 8*), and cultured fish may therefore be distributed to several harbours in its vicinity. The high production volume may lower the market price for Seabream. The product is more environmentally friendly produced than the fish currently cultured in open cages and may profit from a greener image.

[9] https://ec.europa.eu/fisheries/cfp/aquaculture/

2.4 Major Assumptions

Although the high production volume might affect the market price of seabream, it is assumed that current prices are valid. The sensitivity to changes in price is part of the sensitivity analysis in the section on the sensitivity analysis.

The production plan for the culturing of Seabream forms the basis of the RAS design. It quantifies the amount of fish (standing stock) and associated feed load given the production target of 50.000 ton of seabream per year. Production characteristics of the species form the basis to quantify the production. The amount of fish in the culture system determines the dimensions of the facilities required to house the fish in the RAS. The feed load determines the waste production by the fish and thus the design of the water treatment facilities, see also D8.3 of Space@Sea.

The production scheme is built up from several batches of fish that are cultured in parallel. Each batch consists of a single group of fish that is grown from seed to market sized fish, which takes one year. Batches of seed fish are stocked once per week. The weekly stocking combined with a total rearing period of 52 weeks from seed to market size results in the presence of 52 different batches of fish in the production system once the system is fully stocked. The total biomass in the system in any given week or standing stock of approximately 500 ton then results from the sum of the biomasses of the 52 batches. This allows a continuous delivery of Seabream to the market throughout the year.

The production of this amount of Seabream takes considerable space. It is assumed that about 150 modules of 45x45 m are needed to house all facilities. This figure is primarily based on the space needed for housing the fish tanks and water filtration units. In addition, modules will be needed for the storage of feed, processing, pumps and accommodation. Per 1000 tons of seabream production per year, a fish tank volume of 8,500 m^3 is required. When using tanks with a height of 3 m a surface of 2833 m^2 is required. Some 25% of additional space is required in between and surrounding the tanks. The same applies to the filtration units, which would account for a total surface area of 1958 m^2. When using modules measuring 45x45 m with a surface area of 2025 m^2, a number of 2.36 modules are required for 100 tonnes of fish production, or 118 modules for 50,000 tonnes of production. For this, about 87 modules are required for storing feed, and 2 for processing. Approximately 20% additional area is needed for installing pumps and accommodation. This results in a total figure of 153 modules required for 50,000 tonnes of Seabream production per year.

An overview of the basic parameter values for this scenario is presented in *Table 8*.

Table 8 Scenario design for production of 1000 tons of seabream, farming component

Input	Unit	Space@Sea case	Comments/reference
Juveniles (8.5g)	Number/year	3,600,000	From model design
Feed	Tons/year	1250	From model design
Oxygen	Tons/year	920	From model design
Electricity	kWh/year	4,780,000	From AquaVlan model[8]
Water renewal	m^3/year	793,520	Average of 860 to 3500 m^3/d for 364 days from model design
Gas	m^3/year	1,231,771	Based on 1.45 m^3 gas/m^3 input water (at ~17°C) and 5 m^3 gas/m^2 building, from AquaVlan model
Chemical and medicine	Euros/kg fish	0.09	From AquaVlan model[8]
Tank area	m^2	5,682	Based on tank volume of 6,818 from design and assumption of 1.2m water level in tank
Building area	m^2	16,233	Based on assumption of tank to building ratio of 35% from AquaVlan model[8]
Platform area	ha	3	Based on assumption that farming building is 60% of platform space
Output	**Unit**	**Space@Sea case**	**Comments/reference**
Fish harvest	Tons/year	1000	Per Space@Sea unit
Dead fish	Tons/year	184	From model design
Solid waste	Tons/year	59.16	From model design

Fish slaughter waste	Tons/year	90	From FAO guidelines[10]
Carbon dioxide	Ton/year	1267	From model design
Nitrate	Ton/year	65	From model design

2.5 Data Sources

Data for the design of the culture system are based on deliverable 8.3 of Space@Sea. Financial information was collected from several open sources, and is dealt with in section 3.

2.6 Data Structure

A full value approach is used for the cost revenue assessment in section 3. That is, total revenues and costs for the business case in order to present a benchmark measure of financial feasibility for setting and operating a Recirculating Aquaculture System (RAS) to culture Seabream on top of floating modules ate sea. Financial sensitivity analysis in section 0 is presented in incremental values (e.g. ratios or percentages) against this benchmark to illustrate the deviations from the base case from changes in the underlying assumptions.

[10] FAO (2020), Indicative factors for converting product weight to live weight for a selection of major fishery commodities, Coordinating Working Party on Fishery Statistics (CWP), Handbook of Fishery Statistics, available online: http://www.fao.org/cwp-on-fishery-statistics/handbook/capture-fisheries-statistics/conversion-factors/en/

3. Cost-Revenue Assessment

3.1 Annual Financial Performance, Farming

The seabream farming model is based on data from a combination of data sources and methods. These include data from the AquaVlan model[8], as well as STECF data for seabream cage system farming in Spain and trout RAS farming in Finland[11]. The latter was selected because it was the closest proxy for RAS farming that STECF reported financial information for. That is, there was no information for other RAS farming systems (e.g. seabream, salmon, other marine aquatic animals), and nor did any other country report data for trout RAS farming besides Finland. Therefore, Finnish trout RAS farming was selected to provide some insight into the costs of RAS operations. Where possible, the cost structure of RAS farming in Finland was adapted to Spanish economic conditions. For example, while labour productivity (tonnes per employee) is derived from the Finnish data, annual salary per employee is assumed to reflect the Spanish seabream cage farming case. The reason is twofold: 1) the economic conditions for the Space@Sea case study is more likely to resemble seabream cage farming in Spain, and 2) the Finnish data for RAS farming reports considerable losses (more than 50% of revenue), primarily attributable to high labour cost and other operational costs. This seems unrealistic for farms to continue operation.

The AquaVlan model, on the other hand, is a bioeconomic model from an Interreg project about aquaculture in Flanders and the Netherlands developed by LEI (now named Wageningen Economic Research) in collaboration with IMARES (now named Wageningen Marine Research)[8]. The model was built from a set of aquaculture models applied in previous projects and utilises cost components collected from literature review and expert consultations[12]. The final Space@Sea model is the average of RAS farming based on STECF data, adapting the Finnish trout RAS cost structure to economic conditions of Spanish seabream cage farming, and the AquaVlan model for RAS farming. The only exception is capital investment, which is purely based on the AquaVlan model because it contains detailed information breakdown of capital investment (see *Table 9*).

For STECF data, average earnings and cost for seabream cage farming in Spain over the 3 years from 2014 to 2016, inclusive, are used to establish the economic conditions applicable to Space@Sea. As data for trout RAS farming in Finland is only available for 2015 and 2016, the average cost structure of those years is considered in the model. More specifically, in terms of operating cost, energy and repairs and maintenance are sourced from Finnish RAS data as these relate to the farming practice. Feed uses the combination of feed conversion from Finnish RAS data, due to the low feed loss within the enclosure, and feed cost per kilogram specific to seabream farming from Spain. Livestock cost for juvenile seabream is purely sourced from Spanish data, as was other operational costs. For capital costs, the rate of depreciation is averaged using both Finnish and Spanish data, while the interest rate for financing is derived purely from the Spanish data due to its location proximity to the Space@Sea site. The per tonne cost of capital investment is taken from the Finnish case for the reason that investment is dependent on the farming system. However, as noted previously, this is not included in the final Space@Sea model and is only used for the calculation of finance and depreciation costs.

[11] STECF (2019), Aquaculture economic data tables.xlsx (Version 1.0), accompanying Economic Report of the EU Aquaculture sector (STECF-18-19). Publications Office of the European Union, Luxembourg, 2018, ISBN978-92-79-79402-5, JRC114801, available online: https://stecf.jrc.ec.europa.eu/reports/economic
[12] Rothuis, A., van Duijn, A.P., Dejen, E., Kamstra, A., van der Pijl, W., Rurangwa, E., and Stokkers, R. (2012) Business opportunities for aquaculture in Ethiopia. LEI report.

Table 9 Annual revenue and expenditures for the seabream farming model

	ES cage system	RAS adapted	AquaVlan	Space@sea
Income per enterprise				
Turnover	6,748,665	6,748,665	6,600,000	6,600,000
Subsidies	344,965	344,965	0	0
Other income	106,149	106,149	0	0
Total income	**7,199,779**	**7,199,779**	**6,600,000**	**6,600,000**
Operating costs per enterprise				
Wages and salaries	804,759	1,698,936	1,000,000	1,349,468
Imputed value of unpaid labour	1,975	4,169	0	0
Energy	75,319	993,915	1,019,979	1,006,947
Feed	3,103,544	1,386,873	1,568,789	1,477,831
Livestock	1,048,822	1,048,822	1,447,074	1,247,948
Repair and maintenance	86,160	200,741	176,910	188,826
Other operational costs	1,503,756	1,503,756	1,339,828	1,421,792
Total operating costs	**6,624,333**	**6,837,212**	**6,552,580**	**6,692,811**
Capital costs per enterprise				
Depreciation	254,982	1,386,206	829,018	829,018
Financial costs	150,348	599,807	198,179	198,179
Total capital costs	**405,330**	**1,986,014**	**1,027,197**	**1,027,197**
Net result per enterprise	**170,116**	**-1,623,446**	**-979,777**	**-1,120,009**
Capital investment	7,748,073	30,910,616	8,845,488	8,845,488
Employment	**27**	**57**	**20**	**39**
Female FTE	4	9	na	na
Male FTE	23	48	na	na
Production				
Volume of production (tonnes)	1,000	1,000	1,000	1,000
Volume of feed (tonnes)	2,473	1,105	1,250	1,178
Volume of livestock (tonnes)	22	22	31	26
Income/kg output	6.75	6.75	6.60	6.60
Operating cost/kg output	6.62	6.84	6.55	6.69
Profit/kg output	0.17	-1.62	-0.98	-1.12

Looking at the annual revenue and expenditures reported in *Table 9*, it can be observed that the RAS model using STECF data and the AquaVlan model yields comparable results. This indicates the assumptions made are relatively robust. The key differences lie in the investment cost, as discussed earlier, and the turnover or revenue. For the AquaVlan and Space@Sea model, the price of €6.60 per kilo is sourced from gilthead seabream price structure report for Italy, the biggest market for seabream[13]. Moreover, the report also provides the price for seabream after gutting which is required for the next segment of the feasibility analysis. No subsidies or other income were assumed for the AquaVlan and Space@Sea model.

As alluded to earlier, the breakdown of capital investment for the farming component of the Space@Sea model is estimated based on the AquaVlan model and this is displayed in *Table 10*.

[13] EUMOFA (2017), Case study: Gilthead seabream in Italy – price structure in the supply chain, available online: https://www.eumofa.eu/documents/20178/107625/EN_Gilt-head+seabream+in+IT.pdf

Table 10 Breakdown of capital investment for seabream RAS farming, based on AquaVlan model

Capital breakdown	Unit	Quantity	Price (€)/unit	Value
Tanks				
Tank area	m^2	5,682	68	386,353
Biofilter material	m^2/m^3	150	200	30,000
Piping	$m^3.h$	13,635	15	204,528
Drums	$m^3.h$	13,635	60	818,110
Pumps	$m^3.h$	13,635	35	477,231
Oxygen reactor	$m^3.h$	13,635	20	272,703
Oxygen dose regulator	$m^3.h$	13,635	10	136,352
Total power (recirc:rest = 0.4)	kW	1,082	400	432,862
Building				
Building	m^2	16,233	200	3,246,667
- Ground preparation	m^2	16,233	5	81,167
- Heating	m^2	16,233	15	243,500
- Ventilation	m^2	16,233	5	81,167
- Lighting	m^2	16,233	15	243,500
- Electra	kW	1,082	400	432,862
Other initial set up costs				
- Permits	#	1	1,361	1,361
- Hook up electra	#	1	2,269	2,269
- Hook up gas	#	1	1,361	1,361
- Hook up water	#	1	1,000	1,000
- Hook up waste system	#	1	2,269	2,269
Other costs				
Emergency power aggregate	kW	1,082	400	432,862
Measurement and control	m^3	6,818	15	102,270
Alarm	Piece	1	2,269	2,269
Septic tank	ton/Y	243	100	24,316
Feeding equipment	m^3	1,250	15	18,750
Weighing equipment	piece	1	4000	4,000
Sorting equipment	piece	1	4000	4,000
Cooler/freezer	piece	1	2,000	2,000
High pressure cleaner	piece	1	1,000	1,000
Office	piece	1	5,000	5,000
Extraordinary costs	%	15	7,691,729	1,153,759
Total capital investment				**8,845,488**

3.2 Annual Financial Performance, Processing

For processing calculations, data from several sources are used to provide a guide for the cost per kilo of processing seabream:

- STECF processing data for Greece[11]
- Supply chain price transmission for seabream sold in Italy[13]
- Revenue breakdown in the supply chain for seabream and seabass across the EU[14]

The choice of STECF processing data for Greece is made based on the fact that Greece is the largest producer of gilthead seabream in the European Union, accounting for more than two thirds of total production in 2015 and more than 4 times that of Spain, the second largest producer[13,15]. Furthermore, gilthead seabream and seabass make up the bulk of aquaculture production in Greece, constituting 45% and 35% of total aquaculture output in 2017, respectively[16]. However, as STECF processing data does not provide information on species composition, it is impossible to know whether the species processed are in the same proportions as that of the country's aquaculture production. Therefore, by using the cost per kilo calculated from STECF data for Greece, it is implicitly assumed that the per unit cost for processing seabream and seabass does not differ from that to process other fish species, potentially sourced from wild-capture fisheries or imported catch.

Supply chain data for seabream in Italy is selected owing to Italy's large market share in the apparent consumption of seabream within the European Union, at over 31 kilotons in 2015 or 29% of EU28[13]. The report provides prices at different levels of the supply chain but has limited itemisation of processing activities along the chain. For example, the itemisation is only available for whole seabream sales but not for seabream fillets, and the net margin is only applied at the retail level with no margin estimated at the wholesale level.

While the study by Prins et al.[14] on revenue breakdown in the supply chain for seabream and seabass across the EU estimates price transmission for both whole fish and fillets, it lacks details on itemisation of processing activities. Given that prices reported by EUMOFA[13] and Prins et al.[14] do not differ significantly, information from the two sources are combined, and where appropriate, itemised ratios for intermediate costs are translated from the EUMOFA report. These are expressed in per kilo terms alongside the Greek data in *Table 11*, for the options gutted whole fish and fillet processing.

The final Space@Sea model is constructed using the amalgamation of the Greek data and the 'combo data' from EUMOFA[13] and Prins et al.[14]. For example, wages for gutting only operations at Space@Sea takes the cost per kilo input from 'combo gutted', which reflects that reported in EUMOFA[13], while filleting operations assumes the labour cost per kilo from the average Greek processing plant. This is because it is assumed that the labour required for gutting fish is relatively close to simply packaging whole un-gutted fish, and that the Greek data is more indicative of a higher degree of processing. Both labour costs are also then discounted by a factor of 0.5 to account for the possibility to mobilise workers from the farming division to assist in processing on the platform as required.

Similarly, for the cost of energy, cleaning and packaging, the Greek data is used for the Space@Sea filleting scenario because it is a more accurate depiction of higher processing. The scenario of only gutting fish uses the average of the Greek data and that reported for the Italian price transmission. This is due to the fact that the cost of €0.05 reported in EUMOFA[13] is only the cost of packaging, and does not account for energy or cleaning costs. Repairs and maintenance are calculated by applying the ratio to capital investment found in the AquaVlan model for farming seabream. There was no information provided in any of the data sources. This cost is then removed from the other operational cost, which is the average of Greek and Italian data, as to avoid double counting.

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[14] Prins, H., Stokkers, R. Hoste, R. and Immink, V. (2016). Farm economics and competitiveness of organic aquaculture, part of Assessment of organic aquaculture for further development of European regulatory framework, Funded by the EC (Grant No: 613547), available online: https://www.oraqua.eu/content/download/110481/file/OrAqua%20D%203_2.pdf

[15] EU Commission (2012), Sea bream fact sheet, Fisheries and Aquaculture in Europe, No. 59, December 2012, available online: https://ec.europa.eu/fisheries/marine_species/farmed_fish_and_shellfish/seabream_en

[16] FAO (2019), Fisheries and aquaculture statistics yearbook 2017, ISBN 978-92-5-131669-6, Rome, available online: http://www.fao.org/fishery/static/Yearbook/YB2017_USBcard/navigation/index_intro_e.htm

For capital costs, the Space@Sea scenario for filleting uses the cost per input data from the average Greek processing plant, and the scenario for gutting only is assumed to be half of this. Depreciation and financing cost is taken from the average AquaVlan rate of depreciation and the Spanish interest rate for the farming division, respectively. The Greek rate of depreciation appear too low for a useful life of 10 to 20 years, and while the financing rate is not dissimilar to the Spanish data, the rate from the farming division is used for consistency.

Table 11 Annual revenue and expenditures for the seabream processing model

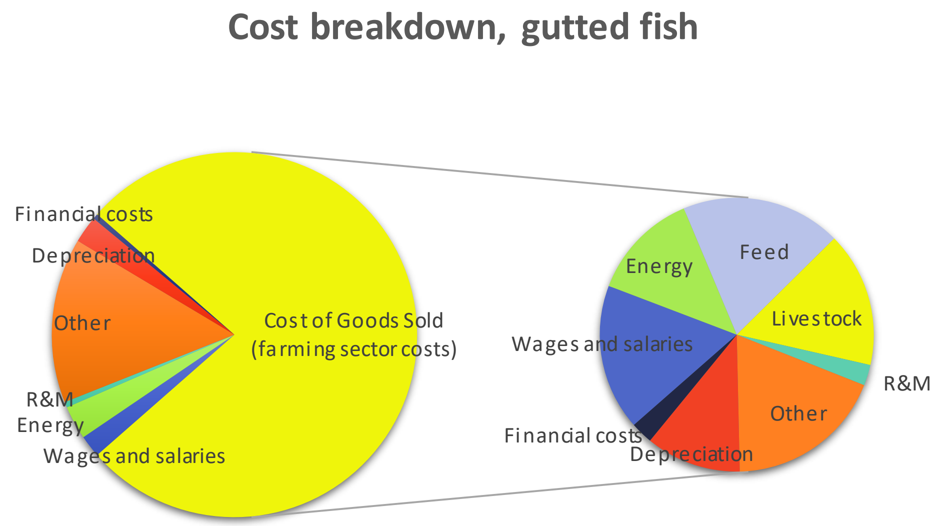
	Greece	Combo gutted	Combo filleted	S@S gutted	S@S filleted
Income per enterprise					
Turnover	5.64	7.09	7.47	7,090,909	7,470,000
Other income	2.38	0.00	0.00	36,123	103,018
Total income	**8.01**	**7.09**	**7.47**	**7,127,032**	**7,573,018**
Operating costs per enterprise					
Wages and salaries	0.51	0.40	0.40	200,000	255,637
Imputed value of unpaid labour	0.02	0.00	0.00	0	0
Energy/cleaning/packaging	0.55	0.05	0.05	301,754	553,509
COGS: fish and other raw materials	2.76	6.60	6.60	6,600,000	6,600,000
Repair and maintenance	0.00	0.00	0.00	50,280	100,561
Other operational costs (e.g. transport)	2.62	0.45	0.45	1,482,612	1,482,612
Total operating costs	**6.45**	**7.50**	**7.50**	**8,634,647**	**8,992,318**
Capital costs per enterprise					
Depreciation	3%	9%	9%	235,620	471,240
Financial costs	3%	2%	2%	48,784	97,567
Total capital costs	**0.30**	n.a.	n.a.	**284,403**	**568,807**
Net result per enterprise	**1.26**	**-0.41**	**-0.03**	**-1,792,018**	**-1,988,107**
Capital investment	5.03	n.a.	n.a.	2,514,025	5,028,050
Employment (workers/100 ton)					
Total FTE	n.a.	n.a.	n.a.	6	8
Production					
Volume of raw materials (tonnes)	1.00	1.00	1.00	1,000,000	1,000,000
Volume of output (tonnes)	0.82	0.91	0.40	909,091	400,000
Income/kg output	5.64	7.80	18.68	7.80	18.68
Operating cost/kg output	7.92	8.25	18.75	9.50	22.48
Profit/kg output (from seabream)	-1.37	-0.45	-0.07	-1.97	-4.97

On the income side, the prices for gutted whole fish and fillets are taken from EUMOFA[13] and Prins et al.[14]. The conversion factor for gutted fish is sourced from the FAO Handbook of Fishery Statistics[10]. For fillets, the conversion factor is based on the Space@Sea Design Document as no information was available from the Handbook of Fishery Statistics. Other income is derived from estimates of utilising fish waste from processing to further refine to fishmeal and fish oil as a rough guide[17,18].

[17] Huntington, M. D. T., Curr, C. and Joensen, J. (2004). 'Evaluation of Fish Waste Management Techniques'. Report to the Scottish Environment Protection Agency SEPA. Poseidon Aquatic Resource, Hampshire, UK, available online: https://www2.gov.scot/Publications/2005/03/20717/52860

[18] Jackson (2009). Fish in – fish out: ratios explained, Aquaculture Europe, Vol. 34 (3), Featured article, September 2009

Visual illustration of cost breakdown throughout the integrated production and processing chain is displayed in *Figure 9*.



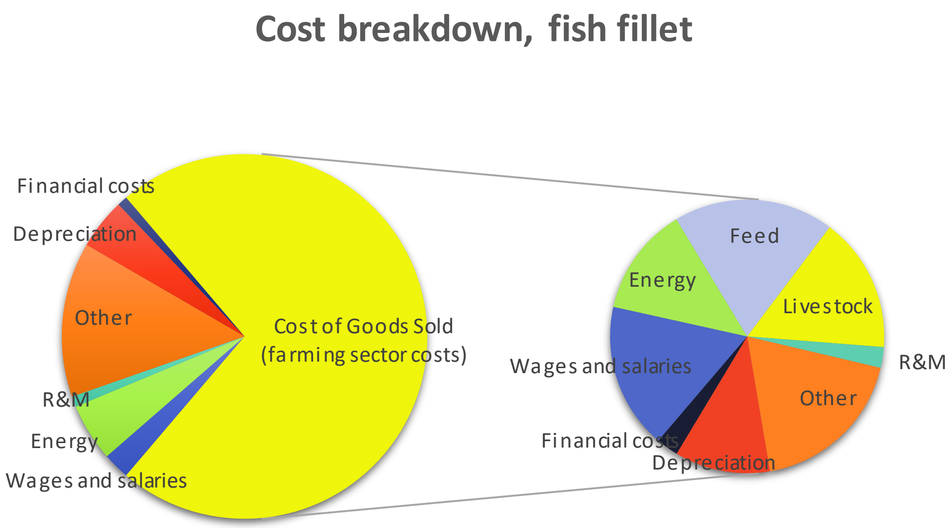


Figure 9 Cost breakdown throughout for the integrated production and processing chain for gutted fish (above) and fish fillet (below).

One observation that can be made from Table 11 is that the seabream processing industry is not particularly profitable. For an output price of €5.64, the average Greek processing company makes a financial loss of €1.37 per kilogram of seabream output in the absence of other income. This result has two possible explanations. The first is that the seabream market is highly competitive in Greece, and for a relatively homogenous product the Bertrand model suggests price competition would leave price equal to marginal cost (i.e. very low or no profit margin). Considering the volume of production, export and market share Greece has in Europe for seabream, this is a very plausible explanation.

The second explanation may be that seabream from open cage farms in Greece are mostly sold and exported whole without even simple processing (i.e. gutted). The limited market for product value addition and development is also suggested by the case study of gilthead seabream price structure in Italy[13]. However, from July 2016 filleted, and even marinated, products have started to appear more on the market. As discussed earlier, the processing data from STECF for Greece does not make the distinction on species composition. Therefore, the only conclusion that can be drawn from the STECF data, assuming that the weighted recovery rate from processing for seabass and seabream of 82% is applicable to the species processed, is that the fish processing sector in Greece is highly competitive. A secondary implication of using the data for Greece in this feasibility analysis is that the operating costs for Space@Sea may be much higher, especially in the beginning before the platform acquires the necessary specialisation in skills or economies of scale.

4. Business Case Results

4.1 Cash Flow projections

Cash flows and net present values (NPVs) projections are computed for a vertically integrated model, inclusive of both the farming and processing divisions. These are displayed in *Table 12* and *Table 13* for the options of simple processing (i.e. gutted fish) and more complex processing (i.e. fish fillets), respectively. Under the two scenarios, the annual cash profit, revenue less operating cost and financing cost, is around −€1.8 million for the integrated simple processing model and −€2.0 million for the more complex processing model. The losses only deteriorate further over time as more investment is required, and in turn, greater financing cost. As such the initial and ongoing investment costs are never recuperated.

Over the 25 year period of operating on the Space@Sea platform, the total NPV accumulated under the integrated simple processing model is −€59.9 million. If the depreciated capital could be sold for €5.7 million, then the total discounted loss is estimated to be −€54.2 million. Similarly, the total NPV accumulated under the integrated fillet processing model is −€65.6 million, and if the depreciated capital could be sold for €7.6 million then the total loss could be minimised to is −€58.0 million. These losses are estimated for the production of 1000 tonnes of whole fish. Therefore, it should be multiplied by a factor of one hundred for a production of 100.000 tonnes. From a business perspective, neither of these two scenarios are ideal as an investment option, unless additional funding would be made available, e.g. in the form of subsidies.

Furthermore, the cash flow projections and cost revenue models presented here in the study are relatively optimistic. For example, insurance cost is only explicitly calculated for the farming component, based on the AquaVlan model. This is likely to be an underestimate given the significantly higher risk of damages, and hence insurance premiums, of operating offshore as well as the lack of explicit modelling for insurance in the processing division. Similarly, the cost of transport is taken to be 150% to that of transporting from seabream cage platforms to wholesale markets. If the Space@Sea platform is to be more than 50% further offshore than the average seabream cage farm, the additional costs are not considered.

Table 12 Summary of combined cash flows and NPVs for the seabream farming and simple processing (i.e. gutted fish)

Assumptions								
Discount rate	3%							
Depreciation	9%							
Interest rate	2%							
Year	**1**	**2**	**3**	**6**	**11**	**16**	**21**	**25**
Revenue	13,727,032	13,727,032	13,727,032	13,727,032	13,727,032	13,727,032	13,727,032	13,727,032
Operating cost	15,327,458	15,327,458	15,327,458	15,327,458	15,327,458	15,327,458	15,327,458	15,327,458
Capital costs								
Depreciation	0	1,045,773	1,045,773	1,045,773	1,045,773	1,045,773	1,045,773	1,045,773
Finance	246,963	246,963	246,963	286,251	429,286	468,574	624,265	624,265
Initial investment farming	8,845,488	0	0	2,024,661	4,857,198	2,024,661	5,509,395	0
Building and platform	3,246,667	0	0	0	0	0	0	0
20 year investments	652,197	0	0	0	0	0	652,197	0
10 year investments	2,832,537	0	0	0	2,832,537	0	2,832,537	0
5 year investments	2,024,661	0	0	2,024,661	2,024,661	2,024,661	2,024,661	0
Initial investment processing	2,514,025	0	0	0	2,514,025	0	2,514,025	0
Depreciated amount	*11,359,513*	*10,313,740*	*9,267,967*	*8,155,308*	*10,297,665*	*7,093,460*	*9,888,014*	*5,704,920*
Cash profit	-1,847,389	-1,847,389	-1,847,389	-1,886,677	-2,029,712	-2,069,000	-2,224,691	-2,224,691
Total operations								
Net Cash flow	**-13,206,902**	**-1,847,389**	**-1,847,389**	**-3,911,338**	**-9,400,935**	**-4,093,661**	**-10,248,111**	**-2,224,691**
Discounted Cash flow	**-13,206,902**	**-1,793,581**	**-1,741,341**	**-3,373,954**	**-6,995,179**	**-2,627,565**	**-5,674,130**	**-1,094,400**
Cumulative Net Present Value	**-13,206,902**	**-15,000,484**	**-16,741,825**	**-23,447,783**	**-36,492,404**	**-44,733,889**	**-55,344,371**	**-59,922,935**

Table 13 Summary of combined cash flows and NPVs for the seabream farming and more complex processing (i.e. fish fillets)

Assumptions								
Discount rate	3%							
Depreciation	9%							
Interest rate	2%							
Year	**1**	**2**	**3**	**6**	**11**	**16**	**21**	**25**
Revenue	14,173,018	14,173,018	14,173,018	14,173,018	14,173,018	14,173,018	14,173,018	14,173,018
Operating cost	15,685,129	15,685,129	15,685,129	15,685,129	15,685,129	15,685,129	15,685,129	15,685,129
Capital costs								
Depreciation	0	1,281,393	1,281,393	1,281,393	1,281,393	1,281,393	1,281,393	1,281,393
Finance	295,747	295,747	295,747	335,034	526,853	566,141	770,616	770,616
Initial investment farming	8,845,488	0	0	2,024,661	4,857,198	2,024,661	5,509,395	0
Building and platform	3,246,667	0	0	0	0	0	0	0
20 year investments	652,197	0	0	0	0	0	652,197	0
10 year investments	2,832,537	0	0	0	2,832,537	0	2,832,537	0
5 year investments	2,024,661	0	0	2,024,661	2,024,661	2,024,661	2,024,661	0
Initial investment processing	5,028,050	0	0	0	5,028,050	0	5,028,050	0
Depreciated amount	*13,873,538*	*12,592,145*	*11,310,752*	*9,491,234*	*12,969,517*	*8,587,213*	*12,717,693*	*7,592,121*
Cash profit	-1,807,858	-1,807,858	-1,807,858	-1,847,146	-2,038,965	-2,078,253	-2,282,727	-2,282,727
Total operations								
Net Cash flow	**-15,681,397**	**-1,807,858**	**-1,807,858**	**-3,871,807**	**-11,924,213**	**-4,102,914**	**-12,820,172**	**-2,282,727**
Discounted Cash flow	**-15,681,397**	**-1,755,202**	**-1,704,080**	**-3,339,855**	**-8,872,734**	**-2,633,504**	**-7,098,219**	**-1,122,951**
Cumulative Net Present Value	**-15,681,397**	**-17,436,599**	**-19,140,679**	**-25,741,239**	**-40,536,665**	**-48,809,683**	**-60,866,329**	**-65,564,336**

4.2 Financial Metrics

The financial metric results for the entire vertically integrated farming and processing operations are summarised in the following:

- Annual financial profit: −€2,9 million for gutted fish output and −€3,1 million for filleted fish output, accounting for depreciation
- Return on Investment (ROI): not applicable for negative returns.
- Discounted Cash Flow (DCF) and Net Present Value (NPV): graphed in *Figure 10* and *Figure 11* below
- Payback Period: never
- Internal Rate of Return (IRR): not applicable for negative returns

As illustrated in *Figure 10*, Discounted Cash Flow (DCF) is negative for the entire time period of 25 years, with spikes of larger losses in years of new capital investment, which occurs at 5, 10 and 20 year intervals depending on the capital item. The gradual decline in annual cash flow loss over the period is due to the discounting of future losses, which become less as the cost of money declines. By year 25, the total cumulative NPV for the integrated farming and simple processing seabream model reaches −€59.9 million in today's value. For the integrated fish filleting model, the total cumulative NPV is −€65.6 million. These results are calculated for the production of 1000 tonnes of whole fish. For 100.000 tonnes of seabream production, the losses should be multiplied by a factor of one hundred. The IRR, the rate in which positive NPV returns equals zero over the 25 year period, and the annual ROI cannot be calculated as returns are negative over the entire period.

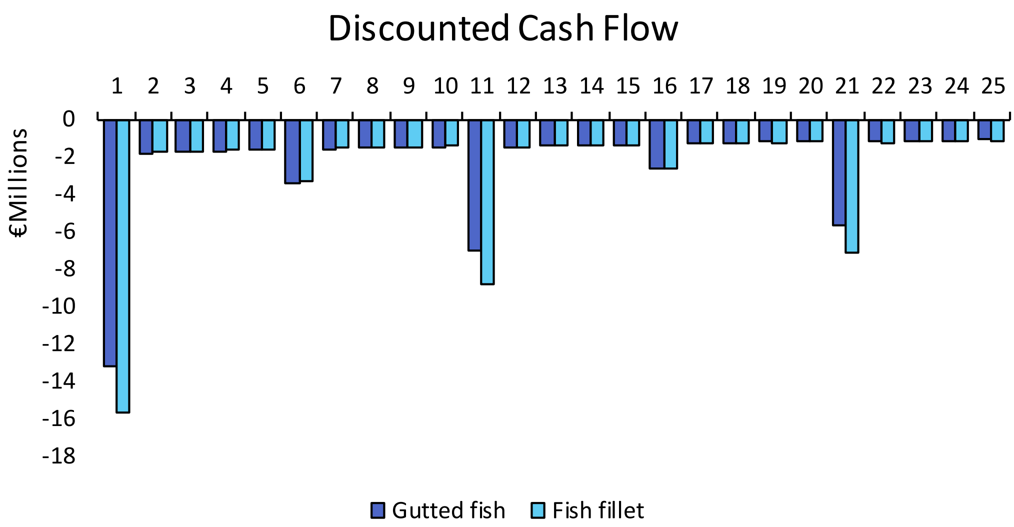


Figure 10 Discounted cash flow over a time period of 25 years.

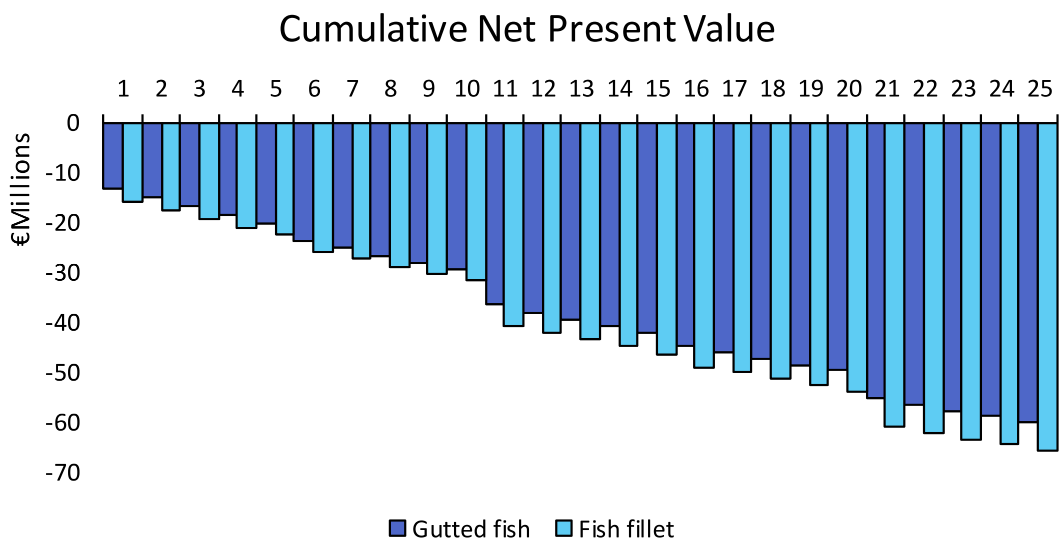


Figure 11 The cumulative net present value over a time period of 25 years.

4.3 Non-Financial Results

Non-financial goals were described in section 2.2 and an evaluation is presented in *Figure 12*. By transposing the activities to an offshore location, pressure on the requirement of space in the coastal area is reduced. Thereby, effects on the ecosystem caused by the aquaculture activities are consequently also diminished, as is competition for space with other user functions in the coastal zone, such as fishing activities, tourism and shipping.

The substantial increase in fish production considered in this business case also provides food security to feed the increasing human population. Frozen fish can be transported over a wide area directly from the culture facility or via onshore fish markets.

Since the RAS is by definition making use of closed systems, discharges of waste are negligible as compared to a similar production size produced in open cages.

There may also be some negative consequences for society by offshore fish. Rough weather conditions may increase the risk of the loss of materials that are then released into the environment. This would result in the creation of litter, i.e. non-organic waste that may persist in the environment for decades and cause effects on marine organisms.

The offshore location also requires higher rates of transport in comparison with coastal location. As a result, the carbon footprint caused by increased shipping activities will be higher.

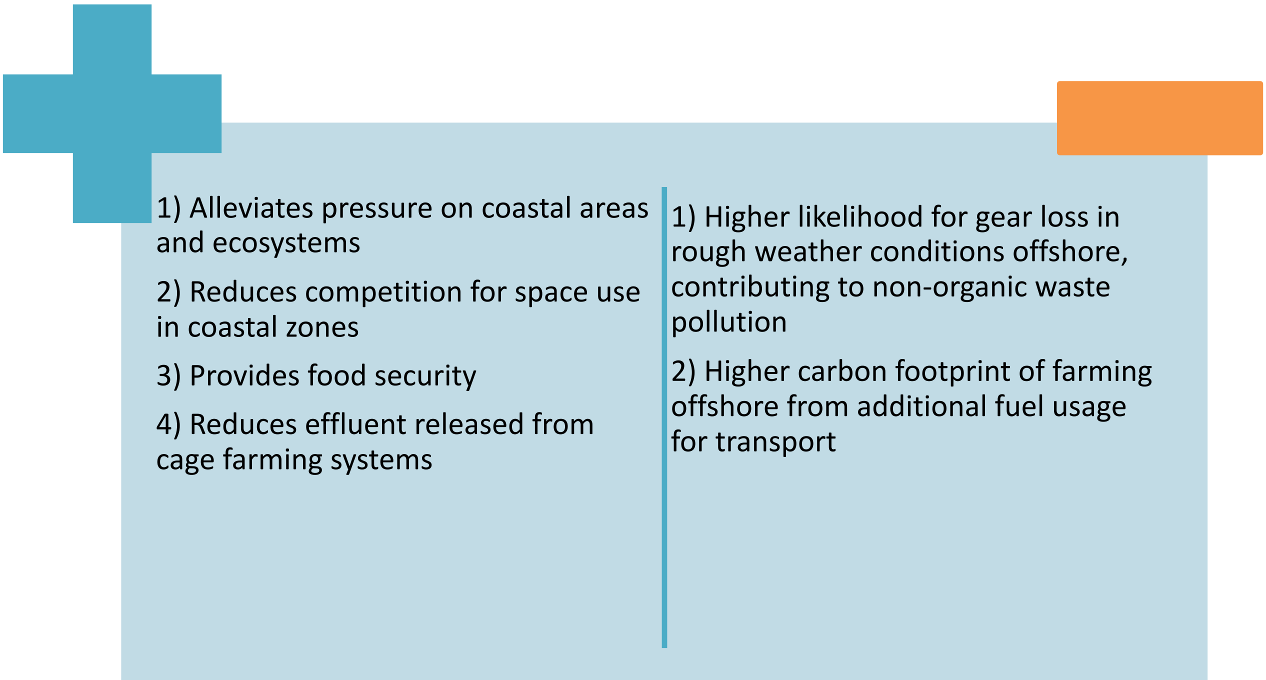


Figure 12 Overview of positive (left) and negative (right) impacts for society by offshore Seabream farming in Recirculating Aquaculture Systems.

5. Risk Analysis

Costs have been financially estimated in the preceding chapter on the basis of assumptions, made on several aspects. Uncertainty ranges in the quantitative assumptions contribute to the financial risks of the business case. These will be analysed below with a sensitivity analyses wherein assumed main factors in the financial results will be varied. In addition, also non-financial risks will be inventoried and listed in a risk register. The risk levels will be assessed semi-quantitatively. Where possible, risk management measures are proposed.

5.1 Sensitivity Analysis

5.1.2 Financial data

For sensitivity analysis on the financial performance calculations, the following changes relative to the base case were applied:

- Revenue:
  - Base price of seabream was adjusted by ±20%, to reflect historical variations in price. That is, no demand and supply impacts from the increased production of the offshore platform is explicitly accounted for
- Operating costs:
  - Fuel costs (including the proportion of transport attributed to fuel) are adjusted by ±20%, to account for variability in the global fuel price
  - Energy costs are adjusted by –30% and +0% to account for potential saving opportunities from utilising energy generated in adjacent wind farms
  - Labour costs are adjusted by ±20% to account for any improvements in productivity (i.e. reduction in labour cost) or higher costs of employing more skilled labour (e.g. additional training necessary to manage RAS facilities)
  - Feed conversion is varied by –20% and +0% from the current baseline of 1.25 FCR. This is based on the observation that RAS facilities tend to have a lower FCR of around 1 compared to open cage systems[19]
  - Feed cost is varied by ±20% from the current price of €1.26/kg. This translates to a range for feed cost per kilogram of between €1.00 to €1.51, and is designed to account for changes in economic conditions more generally
- Discount rate:
  - Real discount rate is examined for the range between 1% to 10%, against the base case assumption of 3%. The lower end of the real discount rate is to account for deep recession periods while the higher end of the discount rate captures not only economic booms but also increased options of investment options in the future that may yield higher returns. This is examined separately to the alterations to financial factors.

Using the combination of these changes relative to the base case, 3 scenarios are examined:

- Best case scenario: where positive changes in revenue (i.e. +20% in price) and costs (i.e. largest fall in operating costs) are assumed
- Worst case scenario: where negative changes in revenue (i.e. -20% in price) and costs (i.e. largest increase in operating costs) are assumed
- Good feed scenario: where only the best assumptions to feed (i.e. low price and good conversion rate) are assumed and no other variations to the base case

[19] Bregnballe, J. (2015), A guide to recirculating aquaculture: an introduction to the new environmentally friendly and highly productive closed fish farming systems, Published by the Food and Agriculture Organization of the United Nations (FAO) and EUROFISH International Organisation, available online: http://www.fao.org/3/a-i4626e.pdf

- Bad feed scenario: where only the worst assumptions to feed (i.e. high price and poor conversion rate) are assumed and no other variations to the base case

The best- and worst-case scenarios are designed to provide upper and lower bound impacts to Net Present Value (NPV) over the 25 year period of the analysis, and the two feed cases provide sensitivity examples for an in-between outlook. *Figure 6* illustrates the variations in cumulated NPVs as a percentage change from the base case, and splits these by the impacts from discounted cash revenue (DCR) and discounted cash cost (DCC). For example, under the best-case scenario, the total NPV after 25 years is 87% higher compared to the base case for seabream farming and simple processing (i.e. gutted fish). Of this improvement in NPV, 49% is attributable to the 20% increase in price. The remaining 51% of the positive contributions to a higher NPV, relative to the base, is more or less evenly distributed between the operating cost items (i.e. lower labour, feed, energy and fuel costs). The case for seabream farming with more complex processing (i.e. filleting) in not considerably different to the simple processing case in relative terms. The best-case scenario finds an 84% improvement in total NPV for fish filleting, with price contributing to 49% of the improvement.

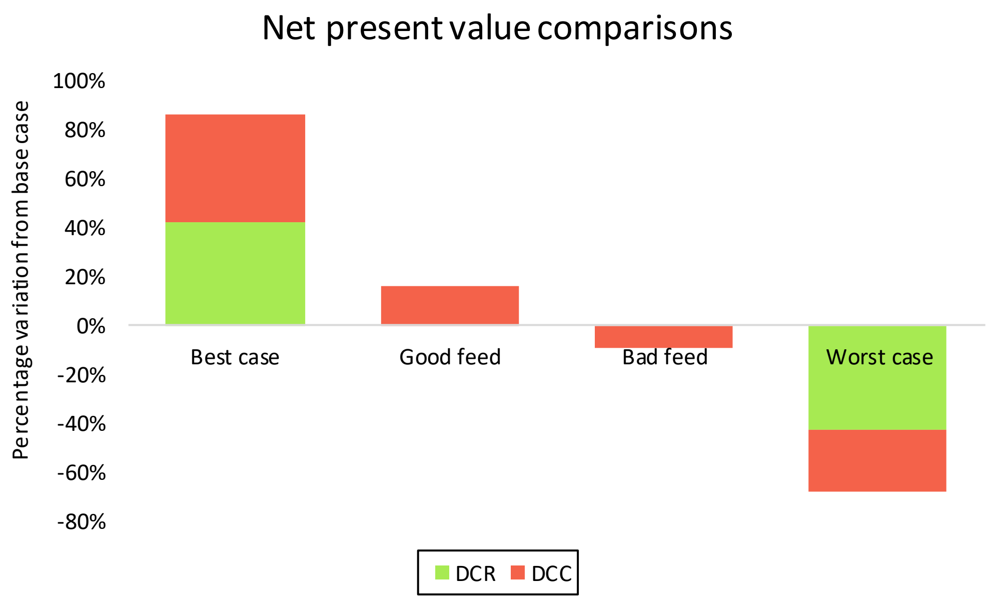


Figure 13 Sensitivity analysis of changes in price and cost components against the base case.

In contrast, under the worst-case scenario, the total NPV for seabream farming with simple processing after 25 years is 68% worse than the base case. The decline in price accounts for 63% of the total variation with increase in DCC (i.e. operating cost and financial costs) making up the remaining 37% of negative contributions to a lower final NPV compared to the base case. For more fish fillet processing, the decrease in cumulated NPV after 25 years under the worst-case scenario is 65%, with 64% of the total decline attributed to a fall in price.

The results suggest that factor with the single largest impact on total NPV over the 25 year period, or the factor NPV is most sensitive to, is price. A small change in price can have a significant impact on the financial performance of the offshore Space@Sea farm. It should also be noted that even under the best-case scenario, the improvement in total NPV over 25 years is less than 100%. For a base case of negative cumulative NPV, this means that even under the best-case scenario, the overall project still generates a financial loss and is not worthwhile pursuing. Furthermore, it should be reiterated that the losses reported under the base case is for 1000 tonnes of seabream production. For 100.000 tonnes of production, the losses should be multiplied by one hundred.

In terms of discounting, the general interpretation is that any decrease in the real discount rate represents a decline in the opportunity cost of investing in the Space@Sea offshore seabream project, and hence an increase in the value of discounted cumulative net profit (i.e. positive NPV). This is because as the discount rate increases, the opportunity cost of forgoing alternative investment (i.e. the cost of capital/money) increases, driving down the value of NPV.

However, in the case of negative NPV the opposite is true. The reason is that as the cost of money decreases, the value of losses incurred also decreases. Hence, changes in total NPV over 25 years, as illustrated in *Figure 7*, declines as the discount rate relative to the base case becomes higher. Nevertheless, regardless of the discount rate used, the cumulative NPV over 25 years remains negative for Space@Sea seabream farming with both the simple and complex processing business model.

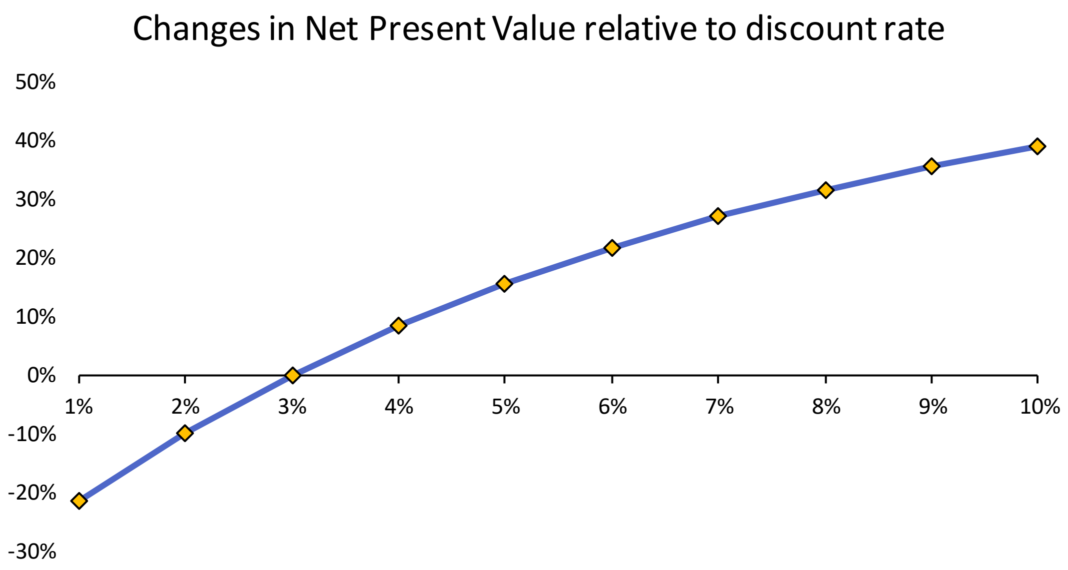


Figure 14 Sensitivity analysis of changes in discount rate relative to the base case.

5.2 Business Risk Register

In the business risk register, qualitative risks are identified and its level is assessed on the basis of the expected size of impact and the probability of occurrence. The risk is then calculated by multiplying the probability with the impact. The evaluation scheme to assess the risk level in a semi-quantitative way is shown in the table below.

Impact	High	3	6	9
	Medium	2	4	6
	Low	1	2	3
		Low	Medium	High
				Probability

A number of cost categories were identified by a small number of experts involved in the development of this business case, other than those described in the previous section which were evaluated on the basis of a sensitivity analysis. For each of the identified type of risk, its impact and probability were assessed by each expert independently according to the criteria described below.

Impact	Low (1)	The hazard impacts the total annual cost or revenue by less than 10%
	Medium (2)	The hazard impacts the total annual cost or revenue by 10-50%
	High (3)	The hazard impacts the total annual cost or revenue by more than 50%

Probability	Low (1)	The likelihood of the hazard occurring is less than once in every 5 years
	Medium (2)	The likelihood of the hazard occurring is at least once in every 1-5 years
	High (3)	The likelihood of the hazard occurring is at least once per year

The scores designated by each expert for impact and probability were averaged and multiplied to calculate the risk level. A high score for risk means that the average score is ≥5, medium is in between <5 and ≥2.5, low is <2.5. Because of rounding off the values, medium scores for both impact and probability can still result in a high level of risk.

Overall, it was assessed that the performance of Sea bream in RAS runs low to medium risks. Although impacts of diseases and mortality may have a large effect on the costs, the conditions in a RAS can be controlled relatively well in order to reduce the probability of occurrence. Consequently, risks are expected to be low to medium.

Bad weather conditions from storms resulting in severe motions and damage to constructions and equipment used in the culturing of Sea bream are expected to cause the main risks on the overall costs. A batch-wise culture system is used, meaning that every week a new batch of juvenile fish is stocked to become commercial size fish in one year. Batches can be spread over different modules, thereby reducing the risk of a complete breakdown of the culture system, including water treatment facilities.

COST CATEGORIES	Impact	Probability	**Risk level**
Sea Bream performance			
Growth rate	Medium	Medium	Medium
Food Conversion ratio	Medium	Low	Low
Diseases	High	Low	Medium
High mortality of fish	High	Medium	Medium
(Food) quality	Medium	Medium	Low
Aquaculture system			
Unexpected partial breakdown of system	High	Medium	High
Complete breakdown of system	High	Low	Low
Equipment failure	Medium	Medium	Medium
Damage by collisions (ships)	Medium	Low	Low
Storm incidents	Medium	Medium	High
Reduced accessibility due to bad weather	Low	Medium	Low
Modules			
Installation of systems	Medium	Low	Low
Inappropriate functioning of systems	Medium	Low	Low
Failures in transport/logistics	Medium	Medium	Medium
Labour	Low	Medium	Low

6. Conclusions & Recommendations

A business case was selected for culturing Gilthead Sea Bream in the offshore Mediterranean Sea, based on the use of floating modular islands in the future, and taking account of more sustainable environmental practices as compared to current open cage culture systems. These open systems are currently deployed in coastal zones of the Mediterranean Sea, where space is also in use for tourism, shipping and other human activities. The fish in the open cage systems are in close contact with the natural marine environment, and surplus of added feed will therefore enter the natural ecosystem, which may lead to an undesired enrichment with nutrients and organic matter. The environment may also affect the fish, by exposure to natural occurring parasites and diseases. Therefore, recirculating aquaculture systems (RAS) were considered here, that have less interactions with the local environment. Discharges of feed and excretion products of fish are very limited since seawater is recirculated in the production systems. Also, the refreshment with sea water from the environment is very limited, reducing the exposure to parasites and diseases. In case of fish health problems, measures can be taken in the closed systems.

In addition to the tanks containing fish, facilities required for water treatment makes up considerable part of the space and needed. Therefore, the designed aquaculture facility requires a large number of modules. It is estimated that about 150 modules each measuring 45x45 m are required for the production of the aimed 50.000 tonnes of sea bream per year. Even without taking into account the costs for modules (either rent or purchase), the business case appears not to be profitable.

Over the entire 25 year period considered here, the NPV of profit (income less operating and capital costs) amount to −€59.9 million for the integrated simple processing model for producing “whole fish”, and −€65.6 million for the more complex processing model where fish is processed to fillet. These financial results are estimated for 1000 tonnes of whole fish production and should be multiplied by 50 to assess results for the aimed 50,000 tonnes of production (assuming linearity of costs with production volume).

The business case is based on many assumptions and uncertainties, and there are many risks involved that may affect the outcome of the business case. The results indicate that it is unlikely that culturing of seabream on floating modules in offshore areas will become profitable in the future.

Problem	Strategic design	Key stakeholders	Strengths	Weaknesses
1) Lack of coastal areas available for aquaculture farming amidst growing demand for food, and other competing uses. 2) Impact to water quality, biodiversity and the environment from intensive uses of coastal areas.		Other users of marine space such as cruise ships, commercial freight companies, fishing vessels, national defence and maritime safety enforcement. Policy makers, scientific researchers and the general public.	Year round availability of produced fish Low environmental footprint Available space in offshore areas Low vulnerability to natural diseases and parasites	A lot of (expensive) space is required to house all systems and installations Uncertainty about the performance of fish and culture systems under conditions of motions High costs for offshore resistant technology Increased shipping distance
Solution		**Economics**	**Opportunities**	**Threats**
Design platform modules that can be used offshore, away from coastal areas. This reduces the competition and intensity of coastal area uses and allows for other goals, such as food security, to be achieved.			Availability of facilities and services by other activities on a multi-used island A market is existing in the area, and so is expertise	Technical developments are needed that will take considerable time High production volumes may reduce the market price of seabream and consequently the revenues
Costs		**Benefits**		
Annually, total cash cost (including operating cost and finance cost) amounts to €8.7 million for the integrated simple processing model and €9.1 million for the complex processing model. Cash costs are net of COGS and calculated before taxes, depreciation, and amortisation.	Over the period of 25 years, total NPV of costs, including capital investments, amount to €187.8 million for the integrated simple processing model, and €201.4 million for the complex processing model.	Annually, total cash income from the farming and processing of gilthead seabream in the Mediterranean amount to €7.1 million for the integrated simple processing model, and €7.6 million for the more complex processing model.	Over the period of 25 years, total NPV of income of the aforementioned activities amounts to €127.8 million for the integrated simple processing model, and €135.8 for the more complex processing model.	Over the entire 25 year period, the NPV of profit (income less operating and capital costs) amount to −€59.9 million for the integrated simple processing model, and −€65.6 million for the more complex processing model. All financial results are estimated for 1000 tonnes of whole fish production.

Table @@:

Problem	Strategic design	Key stakeholders	Strengths	Weaknesses
1) Lack of coastal areas available for aquaculture farming amidst growing demand for food, and other competing uses. 2) Impact to water quality, biodiversity and the environment from intensive uses of coastal areas.		Other users of marine space such as offshore wind farmers, fishing vessels, national defence and maritime safety enforcement. Policy makers, scientific researchers and the general public.	• Biological potential for offshore mussel culture present • Mussels found have high meat content • Lower risk of diseases and parasites • More available area and increase of total production •18 months consumption mussels production without socking and / or move	• High costs for technology and ships that can withstand offshore conditions • Uncertainty about the most appropriate method • No need for offshore mussel cultivation in the sector
Solution		**Economics**	**Opportunities**	**Threats**
Design platform modules that can be used offshore, away from coastal areas. This reduces the competition and intensity of coastal area uses and allows for other goals, such as food security, to be achieved.			• The Netherlands has the expertise and the companies necessary to develop mussel cultivation at sea • "Rewarding" of companies that invest by granting rights • New mussel cultivation technologies are already used in other countries • Development of mussel farming in combination with other products (oysters and algae) • Little predation of starfish and crab • Opportunities for benefits for staff, infrastructure and transport within wind farm	• 10 years needed for development new techniques • Little trust between mussel farmers and government • Too few opportunities to claim results of pilot projects as intellectual property (patents) • Little interest in collaboration between companies from the wind sector and the mussel farms • Conflicts between wind, government and mussel cultivation • Ecological impacts are unknown
Costs		**Benefits**		
Annually, total cash cost (including operating cost and finance cost) amounts to €12.6 million before taxes, depreciation, and amortisation.	Over the period of 25 years, total NPV of costs, including capital investments, amount to €236 million.	Annually, total cash income from the farming of seeds, juveniles and consumption sized mussels; and the processing and sale of packaged consumption sized mussels amount to €14.5 million.	Over the period of 25 years, total NPV of income of the aforementioned activities amounts to €247 million.	Over the entire 25 year period, the NPV of profit (income less operating and capital costs) amount to €11 million.

PU=Public, CO=Confidential, only for members of the consortium (including the Commission Services), CI=Classified, as referred to in Commission Decision 2001/844/EC.