Business Case Space@Sea

D**1.1**

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List of abbreviations

Automated Guided Vehicle	AGV
Capital Expenditure	CAPEX
Cost and Benefit Analysis	CBA
Capital Recovery Factor	CRF
Discounted Cash Flow	DCF
Energy Hub at Sea	EH@Sea
European Commission	EC
European Union	EU
Farming@Sea	F@S
Financial Net Present Value	FNPV
kilowatt hour	kWh
Living@Sea	L@S
Meter	m
Member State	MS
Net Present Value	NPV
Operation and Maintenance	O&M
Operational Expenditure	OPEX
Port of Antwerp	PoA
Return on Investment	ROI
Ship-to-Shore	STS
Transport&LogisticSpace@Sea	T&L@Sea
Twenty-foot Equivalent Unit	TEU
Work Package	W.P

Executive Summary

The goal of this report is to analyse the economic feasibility of floating islands developed in the 3-year project Space@Sea, part of the HORIZON 2020 program [Figure 0-1]. This project's mission is to provide for smart and sustainable growth based on future needs, by the development of standardized, affordable modular islands with a low ecological impact.

This deliverable presents a combined analysis of the four applications: Living@Sea [1], EnergyHub@Sea [2], Transport&LogisticSpace@Sea [3], and Farming@Sea [4]. These four applications are represented in two modular floating islands: The North Sea and Mediterranean islands. Their creation would promise to deliver growth and job opportunities as per *Europe 2020*'s strategy. Improving Europe's competitiveness and productivity along with encouraging a spur in sustainable social market economies are part of the long-term goals of Space@Sea.

The North Sea and Mediterranean modular islands acquire key technology that is both sustainable and efficient. The islands provide competitive marketing with respect to renewable energy and create work opportunities. They provide the European market with green opportunities and are expected to counter competitive threats.

The financial analysis described in this report is composed of quantifying the combined financials of the individual applications along with their costs for each modular island. Non-quantifying benefits provided by the creation of the modular islands such as a relief in increasing needs of maritime throughput are listed in section 4.3.1.

Conclusions made from comparing the Space@Sea islands to their industry competitors, the jacket platform and land reclamation, show that the expansion by use of modular islands is a costly, yet beneficial solution. A strong correlation between cost and water depth was found, as Space@Sea is more economically feasible in the deeper Mediterranean Sea than in the shallower waters of the North Sea [18].

The main recommendations are to obtain governmental funding [5] and private financial assistance, for the initial capital expenditures of floating modular islands. Other recommendations, suggested by the "Do-Better Scenario" include applying a 30% module cost, if discount rates are available, thereby reducing the initial capital expenditures [62]. Where for single-use applications the party responsible for the investment is more clear, multi-use applications may require a larger role for governments to bring together stakeholders and provide affordable space at sea.

This report validates that both capital and operational expenditures can be reduced for a more economically feasible option by decreasing the construction and module costs for capital expenditures. This will also include a possible synergy between the different modules based on functionality for operational expenditure.

Figure 0-1 Space@Sea and the Horizon 2020 Program

1. Introduction

1.1 Motivation and Purpose

The Space@Sea research project was launched on November 1st, 2017, and coordinated by MARIN along with 16 other partners. Its main motivation was and still is, to establish the concept of floating islands, that would merge multiple activities/functions such as farming, transport, logistics and energy hubs, and living amenities.

The main objective is to provide a "sustainable and affordable workspace at sea by developing a standardized and cost-efficient modular island with low ecological impact". The main goals are space creation, accommodation, access to operations, and maintenance. Additionally, Space@Sea provides an alternative solution for the de-congestion of container port terminals, which is a growing issue.

Figure 1-1 List of Partners for Space@Sea

The effort to implement research as the "future" and to utilize the marine environment as an extension for resources has the commitment and political backing of Europe's leaders and the members of the European Parliament. The teams with each application contributed to producing solutions for the economics (cost/benefit/risks), for the configuration of each multi-use modular island.

The goal of this report is to demonstrate how two multi-use floating islands, with functionalities provided by each Work Package, can be merged into feasible alternatives that would solve the faced issues. The goal is to summarize the previous scopes and deliverables discussing the single-use application business cases and combining them into two multi-use modular islands, as well as to establish the feasibility and potential of the Space@Sea modular floating islands as a future concept.

The objective of this document is to assess the business potential of the North Sea and Mediterranean multi-use islands with the obtained final configurations. Each application WP (WP 6-9) involved was responsible for determining individual purposes and functionality for each module and the financial analysis and outcome as per the Deliverables [1] [2] [3] [4].

It is relevant to list the previous work accomplished throughout the three years that the project took place. Each application had specific pre-defined goals and assessed various scenarios, including industry standards, to select the most feasible way to achieve these goals.

1.2 Subject

The main considerations were to assemble cohesive, economically feasible, and profitable modular islands that would include the findings and financial results of each application. The decision to include two modular islands based on the available potential and resources has concluded in the consideration of a North Sea modular island as well as one located in the Mediterranean island. Both multi-use islands would comprise various combinations of the proposed applications.

The main objective of Space@Sea providing multi-use modular islands with various applications such as support infrastructure for renewable offshore energy, provision of living space out at sea, production of food (in the case of seabreams and mussels), and offshore ports.

The Mediterranean island configuration is in the Bay of Montpellier with a mean significant wave height $H_s = 1.0$ m. The exact location can be seen in Figure 1-2, indicated by the red locator, and is to be approximately 43°N, 4° E. The following applications will be represented in the multi-use floating island: Living@Sea, Energy@Sea, and Farming@Sea, although it is shown in [4] that Farming@Sea's seabream model is not a profitable business venture on the Mediterranean island as an individual application.

Figure 1-2 Location of the Mediterranean island courtesy of Google Maps

The location for the modular North Sea island is shown in Figure 1-3 and is configured for a water depth of 20-25 meters and significant wave height $H_s = 2.2$ m, shielded by a floating breakwater. The offshore modular floating islands proposed are composed of Energy@Sea, Living@Sea or Transport&LogisticSpace@Sea, and Farming@Sea.

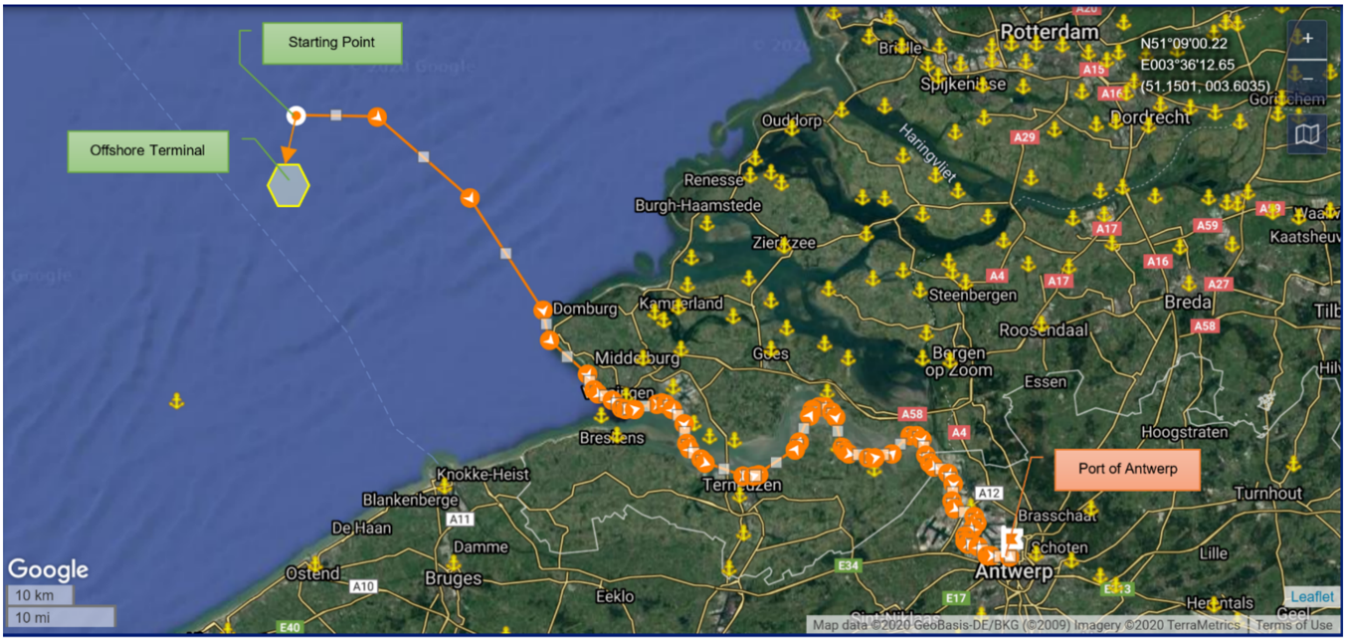


Figure 1-3 Location of the North Sea modular island

The choice of applications for each island was made by a comparison of various scenarios, concerning feasibility, sociologically with emphasis on economical. The overall and kept scenarios are shown in Table 1-1.

Table 1-1 Kept Scenarios for the modular island

Business Case	Represented Work Cases
North Sea	Energy@Sea Living@Sea Transport&LogisticSpace@Sea Farming@Sea
Mediterranean	Living@Sea Energy@Sea Farming@Sea Transport&LogisticSpace@Sea

Figure 1-4 Living@Sea rendering for Space@Sea

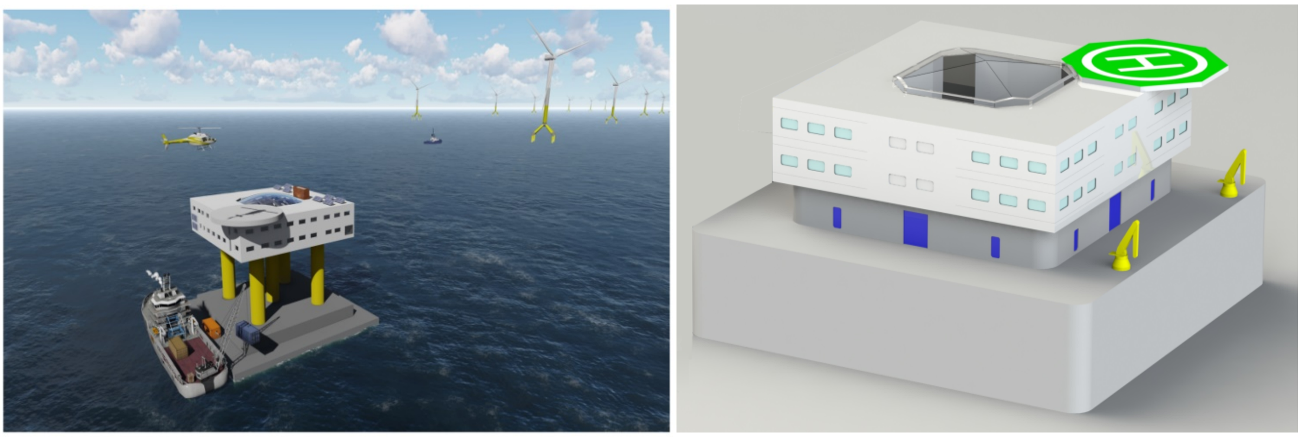


Figure 1-5 EnergyHub@Sea renderings for Space@Sea

Some of the renderings of the Space@Sea concept are shown, Figure 1-4 showing Living@Sea. Similarly, EnergyHub@Sea can be seen in Figure 1-5.

MOCEAN has also initiated renderings at the time of this report, and hence at a later stage of development. As can be seen in Figure 1-6 for Transport&Logistics@Sea and Figure 1-7 for Living@Sea.

Figure 1-6 Rendering of a possible layout for the modular islands, courtesy of MOCEAN

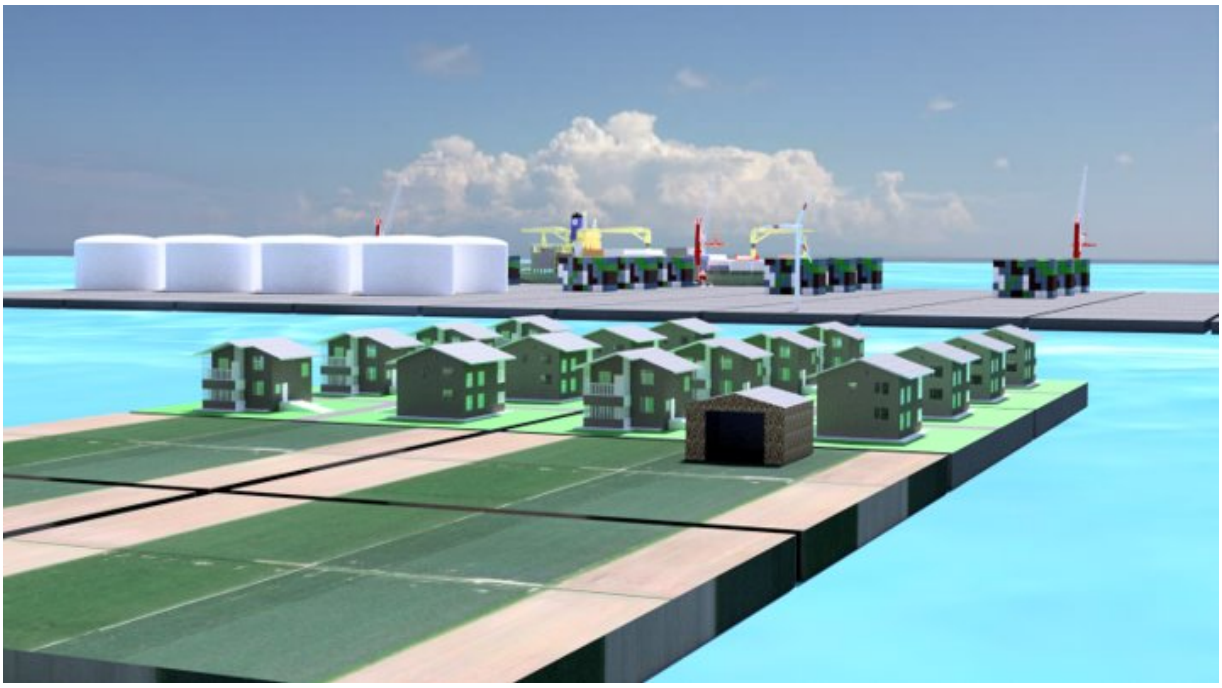


Figure 1-7 Rendering for Space@Sea, courtesy of MOCEAN

1.3 Stakeholders

For each of the applications a panel of stakeholders had to be defined. For each subcategory or incorporated application, the stakeholders vary, depending on the functionality of the modules. A stakeholders' analysis, or compilation of known stakeholders, is combined in Table 1-2.

Due to the total costs required for initial investments, each of the stakeholders will have to account for their respective CAPEX and their OPEX [5].

Table 1-2 Summary of Stakeholders for each programme

PROGRAMME	STAKEHOLDERS
Living@Sea	Policy makers Investors End-Users
	Technical Community (designers + engineers) Wind park owners
Transport and Logistics@Sea	Operations and maintenance workers Service partners Contributing authorities and partners
Energy@Sea	Policy Makers Investors End-users
Farming@Sea	Marine space users: commercial freight companies National Defense Marine safety enforcement Policy makers
	Scientists and researchers Public

This stakeholder committee is responsible for cost as well as decision making for the floating islands. It is general business practice to involve a stakeholder committee, and stakeholder meetings ensure proper communication between these decision-makers for the financial decisions regarding the merged business ventures. For this business case evaluation, no stakeholder meetings/interviews were coordinates at this preliminary stage of Space@Sea.

By combining the SWOT matrices of each business case, a compiled SWOT for the cases is created as seen in Table 1-3.

INTERNAL FACTORS	
STRENGTHS (+)	**WEAKNESSES (–)**
Living@Sea : Flexibility, adaptability and cost efficiency **Transport&Logistics@Sea** : Attractive opportunity for growth, modular scalable concept and less environmental impact **Farming@Sea** : Biological potential for offshore mussel culture present, high nutritional content in mussel meat, lower risk of disease and parasites **EnergyHub@Sea** : Competitive prices, accepted by general public and CO_2 neutral	**Living@Sea** : Unknown willingness of clients to develop **Transport&Logistics@Sea** : Large vessels increase port congestions, unproven concept, high costs, highly dependent on environmental conditions and personnel conditions **Farming@Sea** : High costs for technology, and ships that can withstand offshore conditions. **EnergyHub@Sea** : Subsidy dependence and high construction and maintenance compared to onshore wind.
EXTERNAL FACTORS	
OPPORTUNITIES (+)	**THREATS (–)**
Living@Sea : Combine both land reclamation and floating development **Transport&Logistics@Sea** : Attractive for ULCVs- Flexibility to adapt port traffic expected to increase new solutions are needed **Farming@Sea** : Netherlands is an expert on mussel cultivation, company reward, new growing technology available in other countries. Development of other cultures (oysters, algae) possible. Little predation for cultures, opportunities for benefits for staff, infrastructure and transport within wind farms. **EnergyHub@Sea**: Europe's goal to use more renewables and improvement in technology enable more remote locations	**Living@Sea** : lack of references, competition with existing offshore technologies and land reclamation. **Transport&Logistics@Sea** : Stakeholders interests might not line align, qualitative benefits may not be enough and unproven concept. **Farming@Sea** : Ten years needed for technique development, little trust between mussel farmers and government, intellectual properties challenges, little interest for collaboration from wind sector, conflicts between government, wind and mussel cultivation, unknown biological impact. **EnergyHub@Sea** : Possible increase of interest rates, high construction and maintenance costs compared to Onshore wind.

Table 1-3 SWOT Matrix for the combined application cases

1.4 The strategy of BC assessment

Each application [1] [2] [3] [4] provided their data and documentation which was used as input for the research described in this deliverable. The sources listed in this section serve as the basis for this deliverable. Further analysis was done to compile all available data.

The four business cases followed a bottom-up approach whereas the analysis described in this report follows a top-down approach as seen in Figure 1-8. The bottom-up approach, also known as a quantitative analysis approach, focuses on making reasonable valuations, evaluates costs, and focuses on future growth expectations. On the other hand, the top-down approach is referred to as a qualitative analysis where the macroeconomic picture, including the industry growth and global opportunities, are at the forefront.

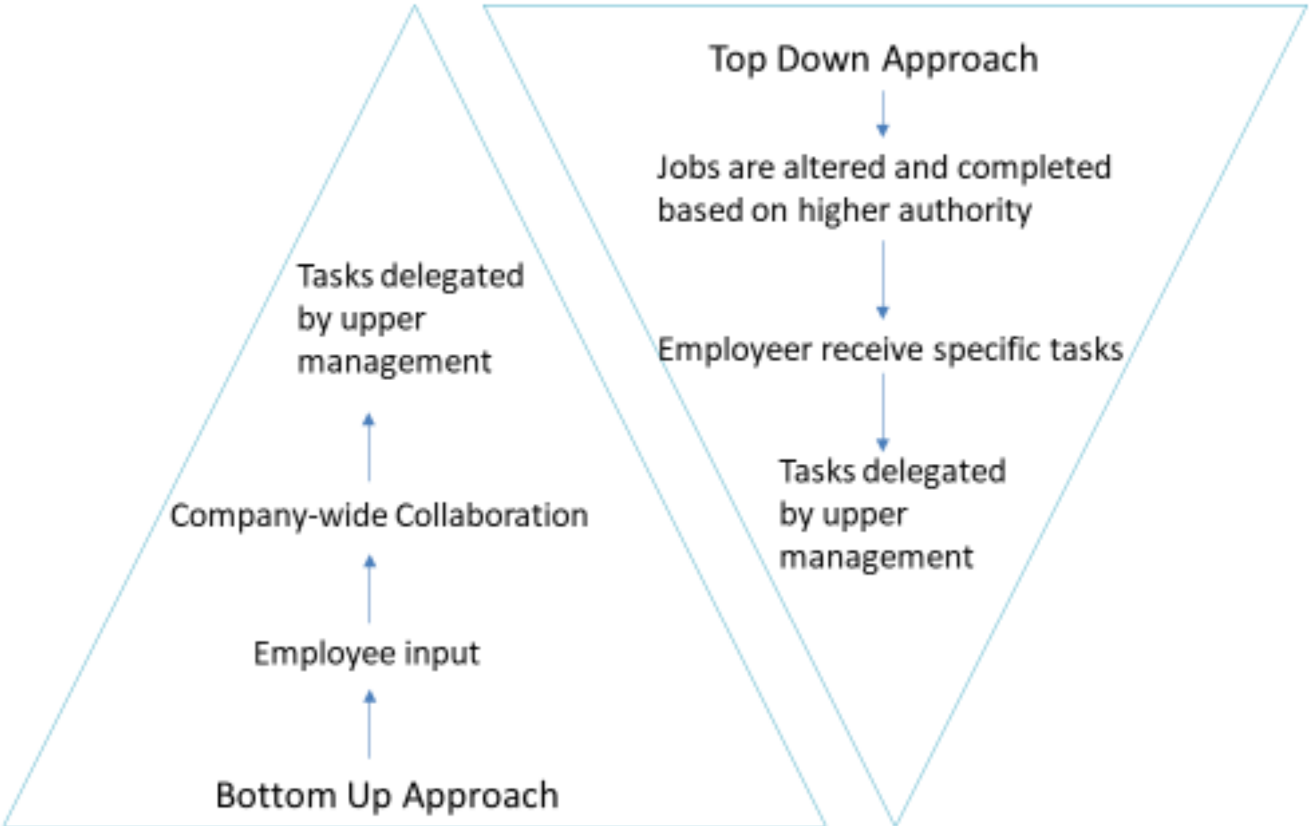


Figure 1-8 Bottom-up vs Top-down approach

All cost data used in this business case evaluation have been procured via the previous deliverables on the individual applications, extensive literature review, (annual) reports of port authorities, and online sources. Individual sources for each case can be found in the detailed cost in the Bibliography.

1.5 Summary of individual business cases

During this three-year-long project, various individual business cases were executed and provided their deliverables [1] [2] [4] [3]. Each business case covered one aspect of the Space@Sea project/business and provided two comparative scenarios on how to implement these innovative ideas. To assess the purpose of multi-use applications on each island, each studied application had to come up with individual purposes which are summarized in Table 1-4.

Living@Sea (WP 7) investigated the technical feasibility of using the floating modular island for housing and recreation. Two cases were used as a baseline for the study: an offshore industrial floating accommodation and a nearshore urban extension floating community.

The purpose was to get an insight into the initial capital expenditure (CAPEX) of creating space, either for urban or offshore context and through floating land or land reclamation. The OPEX or operational expenditures were also assessed for 4 years.

EnergyHub@Sea's (WP6) purpose was to establish a business case that evaluates the service of floating living quarters for offshore workers combined with an operation/maintenance platform for wind parks. The hub(s) offers living and working space for the maintenance employees as well as storage for the place [2]. The offshore business is primarily dominated by the oil and gas industry, this business case focuses on increasing the harvesting and use of renewable energy for a greener future, well-aligned with the goals of HORIZON 2020.

Transport & Logistics @Sea's (WP9) main goal was assessing the business potential of various forms of transport and logistics solutions, to assess the potential of the T&L@Sea hub serving as a container terminal [3]. Comparisons with existing container onshore terminals and correlations to existing throughput of a major port (Port of Antwerp) were made.

Farming@Sea's (WP 8) main purpose was to assess the economic potential of two recirculating aquaculture systems (RAS), to expand production, and to transpose it from the nature conservation area of the Wadden Sea to the coastal North Sea by growing mussels offshore. The low ecological impact is one of the main objectives of this application. Similarly, the Gilthead seabream business case was evaluated for the Mediterranean. These actions, ultimately fill the long-term objective to obtain more food [4].

The combined business cases assess the economic feasibility of the development of two modular islands located in varied environments comprised of different numbers of floating modules. This document aims to merge in a quantifiable way, all the conclusive deliverables to form two modular islands as explained aforehand.

The final scenarios chosen for each application are now used for the combined multi-use business cases of the North Sea, and the Mediterranean Sea as seen in Table 1-4. The following section addresses the financial assumptions and methods that are used in the combining last business case deliverable.

Table 1-4 Summary of the Work package results

WORK PACKAGE	GOALS	SCENARIOS	KEPT SCENARIO
Living@Sea	Provide living accommodations for offshore workers --> Provision of Living Amenities	1. Offshore Accommodation barges (off the port of Antwerp Belgium) 2. Nearshore Land Reclamation (Bay of Montpellier, France)	Offshore Accommodation off the Port of Antwerp
Transport& Logistics@Sea	Provide transportation of Cargo/Crew/Production	1.Modular floating T&L offshore platform 2. Onshore Terminal Containers	Modular floating offshore platform
Energy Hub@Sea	Provide operation and maintenance services for the offshore wind energy industry	1.Fictional wind park (100 turbines) ~3500 GWh 2. Fixed Platform 3. Energy Hub @Sea 4. Mothership Approach	EnergyHub at Sea
Farming@Sea	Produce Mussels (offshore), seabream (onshore)Food production and work opportunities	1. Offshore production of mussels (inexistent in the Netherlands for now) 2. Onshore production	Offshore Production

2. Methods and assumptions

2.1 Scope of work

The costs and benefits in this section were merged from the North Sea and the Mediterranean Sea business cases and are representing an analysis period of 25 years.

The role of these combined modular islands is to define which costs and benefits are relevant, and what the business goal for both modular islands is. This section serves as a summary of the combined applications, and therefore it is essential to define a common set of metrics and financial criteria.

2.2 Financial metrics and decision criteria

2.2.1 Financial Metrics

Each single-use application provided a cost analysis and therefore determined their financial metrics and cash flow statements over the determined lifetime project. Costs and cash flows are determined for the individual need for the combined business cases and a summary of the costs comprised is listed below:

For the case of Living@Sea**:**

- The preliminary costs of development include both construction and additional costs.
- Module price, mooring, towing installation, building costs, bridges, pavements/and or public spaces are included in the building costs.
- Building costs, as the name implies, define any costs used for the building of the gross area. Additional costs estimated at 35% were added to the total construction cost and include engineering (fees, certificates, permit applications…).

EnergyHub@Sea main financial assumptions included:

- Operational costs, including labour, energy, and other expenditures.

Farming@Sea's main metric used was:

- The production rate of output in tons of mussels and seabream, respectively, per year.

Finally, Transport&Logistics@Sea used:

- The throughput per year as their main metrics. For maritime ports, port throughput is measured in the number of cargo tons (TEU) that are moved through the port.

2.2.2 Financial Assumptions

To properly calculate a cost-benefit analysis, each WP had to state which underlying financial assumptions were used to quantify the analysis.

For Living@Sea, the main assumption is that it will provide all the living spaces required for the staff of the multi-use islands, including Transport & Logistics, farming, and energy maintenance support, providing amenities close to the wind farms [1] .

EnergyHub@Sea: cost data based on assumptions, mainly fitting the financial data with existing floating projects. The main assumption being the energy demand of 280 MWh. The use of these costs is also included as an opportunity net energy price of 0.14 $\frac{€}{kwh}$ is considered. The initial costs are largely based on the square meter [m^2] price for the cabins, the mooring costs, installation costs (platform towage, anchor installation, platform anchoring). The main cost component is the concrete price, and this will be set to increase as per 0.5% per year [2] .

Farming@Sea costs are broken down into operating costs including expenditures related to day-to-day mussel farming and capital cost which includes wear and tear of machinery as well as the cost of financing capital (interest rates) [4].

Transport&Logistics@Sea's main financial assumptions are that the complete investments and operational as well as maintenance costs of the terminal development are costs. Projected gains/cash inflows were not considered, only cash outflows, discounted cash flows (DCF) and net present value (NPV) are included [3].

Each application case provided its cash flow and cost analysis. For a case like Farming@Sea, the metric used was the net production of mussels (or sea bream), while for Transport&logistics@Sea the metric used was the shipping container throughput per year, EnergyHub@Sea main cost item was chosen to be the net energy production, Living@Sea, the area of living spaces in m^2 as summarized in Table 3-1.

The cash flow analysis is a quantifiable measure of profitability and the long-term outlook of a business. Cash flow can also be computed into future values as future cash flow, which is a useful predictor for future liquidity value. This indicator is computed as follows [3]:

$$Net\ Cash\ Flow = Cash\ Inflows - Cash\ Outflow$$

This measurement is a good indicator if the business sees cash flowing *in* or ***out*** and therefore, is an indicator of profitable or non-profitable businesses. A result of the analysis is the net present value (FNPV) for all the applications for both multi-use modular islands is obtained.

For the North Sea and Mediterranean islands, the net cash flow was assessed for 25 years, considering the cash fluctuations with rates and time variation of liquidity. Some of the applications, due to the nature of the application, and the building time, (i.e. Living@Sea for example [1]), analysed 4 years, based on construction times.

Applications such as the EnergyHub@Sea show periods of "2,10 and 24" of the life of the project: right at the project start, middle of the project lifespan, and operating costs at the end of design life, respectively. For the case of Transport&LogisticSpace@Sea, three periods were also chosen, but with different timeframes. Year 2, or right after the original investment while year 12 represents the middle timeframe and year 24 right before decommissioning costs [3].

Overall, computation of these individual costs was made and the combined cash flows of the two modular islands were realized. The process was like the individual applications, first obtaining Discounted Cash Flows (DCF) for each application.

This parameter can be computed as follows:

$$DCF = \frac{(Future\ Value)}{(1 + Interest\ Rate)^N}$$

The cash flow summary, which has been adjusted to reflect the time value of money, was calculated for both the North Sea modular island and the Mediterranean island. The discounted values of the cash flow stream for each combined application were added together, the total sum represents the Net Present Value (NPV). By using the discounted values methods, the values representing past periods are associated with their associated rates (discount, tax rates, inflation, depreciation, etc), and the cash flow is linearized to its present value.

2.3 Scenario design(s)

The scenario design(s) for each business case had to be assessed to establish its requirements. This section presents the configurations for both multi-use modular floating islands.

2.3.1 North Sea Island

2.3.1.1 Space@Sea and Configuration

This configuration represents the scenario of and “Offshore Industrial Floating Community”. The location chosen for the North Sea island is located off the port of Antwerp as seen in Figure 1-3. The conditions here include an approximate water depth of 25 m, adequate for the use of the module with an 11-meter height, used in the application design of Transport & Logistics [3]. The wave climate can be described by a wave height $H_s \sim 2.2$ meters and an up crossing zero period of $T_z = 9.9$ s.

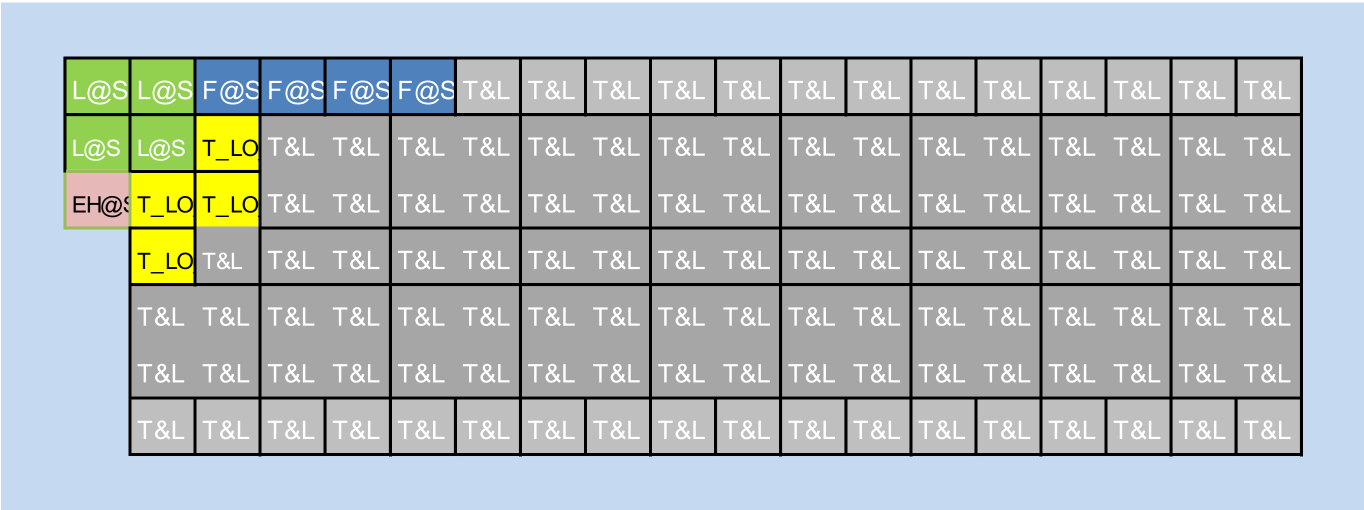


Figure 2-1 North Sea modular island configuration

As can be seen in the layout in Figure 2-1, the North Sea modular island is close to a rectangular shape. This facilitates efficient access to the T&L@Sea, the 96 grey modules, and enables easy vessel traffic from and to the island. This case also includes four yellow-coloured modules that serve the T&L@Sea with supplies, maintenance service, and traffic/control for the island. The red module represents the Energy Hub @Sea as it could prove beneficial and efficient to provide a platform with a transformer available for nearby wind parks.

The Farming@Sea modules are in blue and are conveniently located in the north-western corner of our modular island, for the long-lines to be deployed into the open-sea. In addition to these, four modules of Living@Sea are also included nearby, with its associated population.

For the calculations, it is assumed that all used modules are 45 m x 45 m and that on average one module can host at the most capacity 246 people for the Living@Sea modules. This number refers to the estimated maximum number of people living on one module of the Living@Sea [1].

The North Sea modular island would comprise a total of 109 modules, for a total area of ~221,000 m^2 and could host a total of 1353 people. The example of the mooring configuration and summary of the cost per module are provided in section 2.3.2 for the Mediterranean case and extrapolated for the North Sea. A reduction of equipment cost for the catenaries was taken linearly into account due to the lower water depth of the North Sea compared to the Mediterranean Sea.

Table 2-1 Total number of modules, areas, and the population total

North Sea Case			
Item	**Module Nr.**	**Total area [m²]**	**Total Population**
Living@Sea	4	8100	984 [max capacity]
T&L@Sea	96	202500	65
T&L@ Sea – Supp. + Maintenance	4		
Farming@Sea	4	8100	58
EnergyHub@Sea	1	2025	32
Total	109	220725	1353

2.3.1.2 Land reclamation - Industry-standard alternative

The use of an industry-standard, or alternative scenario, allows for the comparison of the modular island with another scenario and obtaining the difference or "Delta results". The use of land reclamation has been an industry standard for special creation. It is the process of creating new land from oceans, seas, riverbeds, or lake beds [6]. The deliverable on the Transport&LogisticSpace@Sea single-use business case [3], has used this option as a standard alternative to the modules.

The most common way to fill the intended area is with large amounts of heavy rock and/or sand - cement then filling with clay and soil until the desired height is reached, through the process of infilling. Alternatively, a dike is built in the water, enclosing the future land. Once the dike is complete, water is pumped out and new land is created. Several instances of land reclamation were previously created notably for the use of human activities, these include the rapidly expanding city of Jakarta, which is still ongoing the creation of the project "Golf island" [6]. Another example of land reclamation is the Flevopolder in the Netherlands as seen in Figure 2-2.

Figure 2-2 Flevopolder in the Netherlands

The Flevopolder in the Netherlands is a polder which is a piece of low-lying land reclaimed from the sea and protected by dikes. This piece of land is the largest reclaimed artificial island in the world. A proposed alternative scenario of a land-reclaimed island will be shown in section 3.

2.3.2 Mediterranean Island

The Mediterranean modular island is located off the bay of Montpellier, France, as seen in Figure 2-3. This location is elaborated for the scenario of deliverable 5.2 (O&M Lifecycle scenarios).

Figure 2-3 Location of the Mediterranean modular island

2.3.2.1 Space@Sea and Configuration

The Mediterranean islands configuration, shown in Figure 2-4, includes the applications EnergyHub@Sea, Living@Sea, Farming@Sea, and a small section for Transport&Logistic@Sea.

The EnergyHub@Sea consists of 27 modules in the configuration to provide and comprehend sufficient service for the Mediterranean growing wind industry. Seven modules are comprised to provide accommodation to current local workers for Living@Sea, T&L@sea, and Farming@Sea. The module numbers account for the possibility of having future recreational inhabitants, as an additional business, and/or a growing number of local workers. The Farming@Sea uses fifteen modules to accommodate the production of seabream farming, as determined by the individual business case. To establish a form of transport and logistics service for Space@Sea, two modules have been chosen from T&L@Sea to provide this necessity.

WP 3 [7] provided a rendering of the mooring layout for the Mediterranean island as seen on the left in Figure 2-4. The layout has been used for estimating the cost of the mooring lines of the Mediterranean Sea islands. Using the material list for the required mooring, in [7], combined with the installation procedure and cost estimation from D5.2 an average mooring cost per module was determined. An approximate average cost per module of €3,59M was obtained for the Mediterranean case and €1,91M for the North Sea. The difference in average cost is mainly related to the required catenary length, i.e. cost of catenary, the number of modules the shape of the island.

As elaborated in Table 2-2, the Mediterranean Sea modular island would comprise a total of 51 modules, for a total area of ~100,000 m^2 and could host a total of 1977 people.

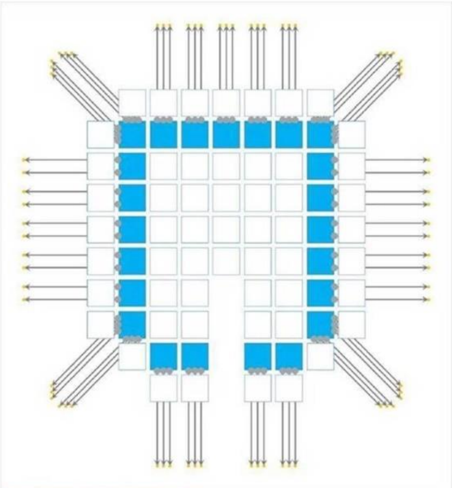
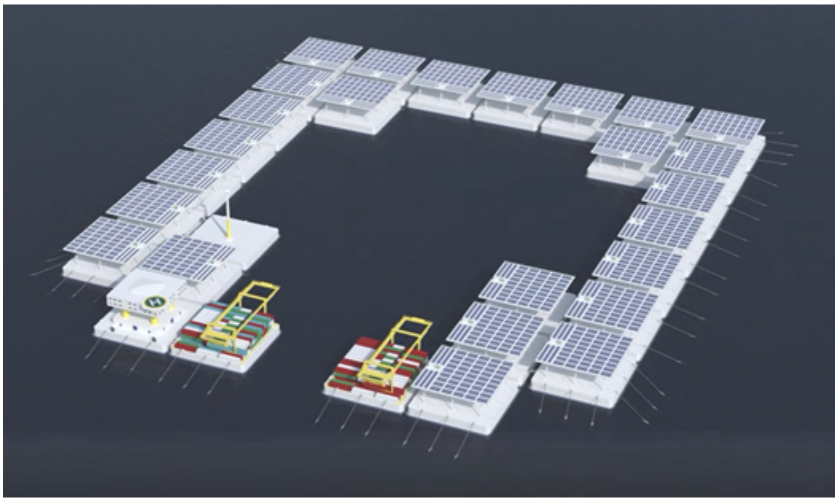



Figure 2-4 Mediterranean Sea modular island configuration and mooring layout

Table 2-2 Total number of modules, areas, and the population total

Mediterranean Sea Case			
Item	**Module Nr.**	**Total area [m²]**	**Total Population**
Living@Sea	7	14175	1722
T&L@Sea T&L@ Sea – Supp. + Maintenance	2	492	6
Farming@Sea	15	30375	217
EnergyHub@Sea	27	54675	32+
Total	51	99717	1977

2.3.2.2 Fixed Jacket – Industry-standard alternative

The use of an industry-standard allows for the comparison of the modular island with another scenario and obtaining the difference or "Delta results". The industry-standard alternative for the Mediterranean Sea is the jacket platform. The jackets platforms have been readily used since the 1950s with the spur in the oil and gas industry. The jacket term refers to the steel frame supporting the deck and the topside in a fixed offshore platform. Figure 2-5 shows an example of a recent jacket platform installation off the coast of Iran. This jacket platform, the South Pars Phase 13 project, involved a 1500-Ton jacket. The topside element to the jacket was not installed yet in the picture.

Figure 2-6 Jacket platform example for South Pars Pars 13

2.4 Major Assumptions

As seen in section 2.2, economic assumptions were made to evaluate the costs for each application. The current section covers other assumptions including the project lifetime. Each application has established its own general and financial assumptions. The assumptions presented in the individual single-use business cases [1] [2] [3] [4], have been applied to designated modular islands and are listed in the section below.

2.4.1.1 General and financial assumptions from business cases

The assumptions of Transport&Logistics@Sea, included an analysis of 25-years, a throughput of 4,690,000 TEU/year, and 6200 operating hours, including 100 modules of 11 meters height [3]. The business case was assumed to receive a 50% EU assistance on initial costs, with the rest of the investment costs split between public contribution, private equity, and private loan. The same assumptions were used for the multi-use islands as it was deemed to be a realistic scenario. Besides this general assumption, the 100% private venture, was assessed to elaborate on the difference.

Farming@Sea's assumptions were made based on the production rates of mussels and seabream, considering their growth period and the monetary value of larvae stages [4]. This business case was assessed as a 100% private venture, and therefore no public assistance was considered.

Living@Sea [1] also established its own set of general assumptions, based on the basic design performed by WP4 and the Living@Sea design process. Among these, for the case of the North Sea island the assumptions used were:

- 246 residents per platform;
- The building is constructed of 4 floors;
- The platform size remains 45m x 45m.

The general assumptions for EnergyHub@Sea were that an income tax rate of zero percent was taken, and only net costs were considered. Also, no equity capital costs were assumed, and the loan will be paid off in 10 years [2]. This business case was assessed as a 100% private venture, and therefore no public assistance was considered.

As a summary, for both multi-use islands, the total number of modules per application can be found in Table 2-3. In the case of joint modular islands, each assumption is relevant and added to a final list of assumptions for each application.

Table 2-3 Summary of module type for each modular island

Module type Business	Subtype	North Sea	Mediterranean Sea
Living@Sea		4	7
Transport&Logistics@Sea		100	2
	T&L @Sea Supply chain modules	*96*	*1*
	T&L Operation and Maintenance modules	*4*	*1*
Farming@Sea		4	15
EnergyHub@Sea		1	27
Total		109	51

The financial assumptions that were made vary for each application and represent the financial constraints of each application. It is assumed that the modules that are initially considered for the modular floating islands are fully decommissioned and have no residual value, i.e. they will be recycled and no longer will be used. More detailed elaboration and overview of the financial assumptions for each of the business cases are listed in section 3.

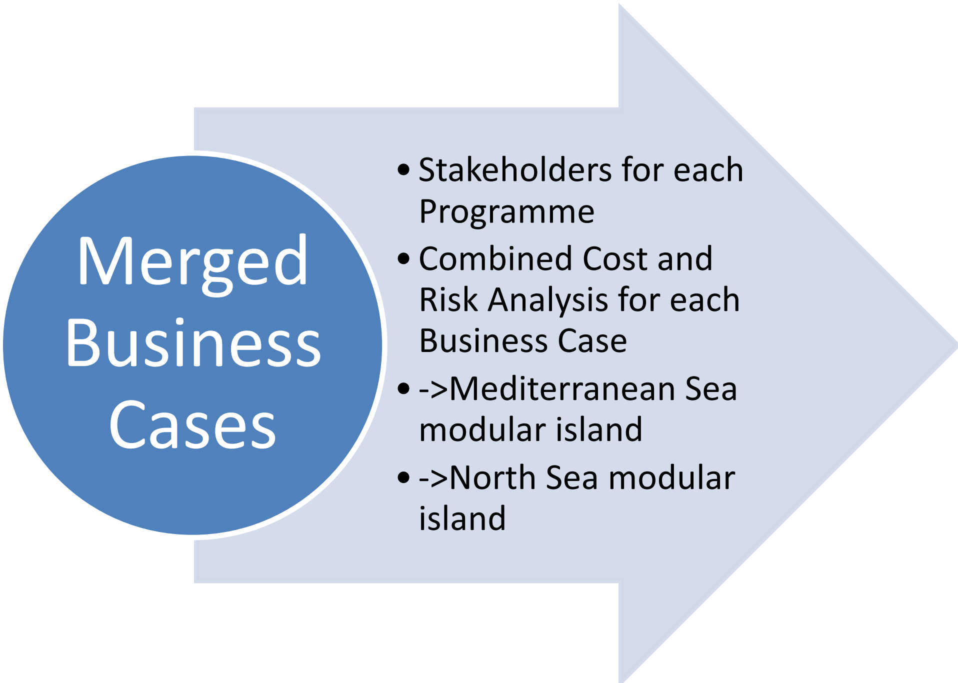
3. Cost analysis

A Cost-Benefit Analysis (CBA) was conducted for both modular islands. The results were used to extract a unit-price for linear extrapolation or interpolation. The combined costs were then merged for the Space@Sea modules or industry-standard islands and the results are presented in this chapter.

3.1 Cost Model

For any major economic and financial project, a CBA must be realized to assess its economic feasibility. The CBA is defined as "a systematic approach to estimating the strengths and weaknesses of used alternatives, to determine options which provide the best approach to achieving benefits while preserving savings" [8].

According to the CBA-Guide, the results of the cost-benefit analysis should demonstrate if the project:



- Generates *employment*, contributes to the reduction in carbon dioxide (CO_2) or other greenhouse gases, and contributes to the priority axis of the program and policy goals
- Needs Co-financing (as can be shown in the later section), which would be shown in the Financial Net Present Value (FNPV) and the Financial Rate of Return of the Investment (FRR(C))
- Is desirable in terms of socio-economic aspects, shown by a positive Economic Net Present Value (ENPV)

The cost model is a structured list, grouping together *cost items,* and arranging them in *cost item categories*. Each single-use business case was responsible for the proposal of its cost model and *had different metrics, as seen in* Table 3-1. This cost model also includes the costs related to acquisition and implementation, operational and growth. In the case of a merged multi-use modular island, the costs of the individual business cases were added, along with joined costs pertaining to being a part of Space@Sea island. Missing data for individual business cases were extracted from other businesses using interpolation or extrapolation and which were found to have the best approach for the missing value(s),

Table 3-1 Cost Items for each WP of Space@Sea

Business Case	Cost Item
Living@Sea L@S	Area - Space for a living (m²)
EnergyHub@Sea EH@S	Net Energy Production
Transport&LogisticSpace@Sea T&S@S	Throughput/year
Farming@Sea F@S	Net production of mussels

The cost model adds the dimension of time by analysing costs for the lifetime of the project. Resources can either be resource-based or activity-based, and cost items will constitute the lines of costs in the cash flow statement.

3.1.1 CAPEX

The initial investment data for the modular islands were taken from each single-use application and merged into two combined cost analyses and indicated the costs for the Space@Sea business cases. Please note the unit for all costs are Million Euros [M €]. The summary results for each working case are presented below.

The North Sea configuration contains one EnergyHub@Sea module. Therefore, the total monetary value numbers reflected in Table 3-1 are equal to the unit price extracted from [2].

The Living@Sea module construction costs are primarily divided into the substructure and the superstructure. The unit cost for these components is respectively 6.5 M.€ and superstructure of 6.6 M.€, [1], using the 11-meter module height.

As seen in Table 3-2 through Table 3-5, the functionality of each application dictated the listed initial costs and is specific for each Space@Sea business case. Each cost category is listed as follows:

- Substructure/ Superstructure
- Installation
- Business Investments
- Financial Cost
- S@S O&M costs

The civil works for T&L@Sea, consisting mainly of lifting equipment, amount to 548,7 Million Euros, whilst other individual business cases do not require this high initial expenditure for their equipment. The civil works for T&L@Sea cost 647.4 Million Euros and will consequently be different for Living@Sea for which only living amenities must be taken into consideration. Similarly, the initial costs of Living@Sea simply included the construction of the superstructure and substructure of the Living@Sea module [1].

In this specific case, T&L@Sea, the maintenance costs are also module-specific and include the energy required for the modules' infrastructure and machinery. The labour costs include the annual salaries for T&L employees [3].

In the case of EnergyHub@Sea, the main construction costs include a detailed breakdown of the area of the interiors based on functionalities, such as kitchens, conference rooms, and so on. The combined pricing of this design, which consists of the cabins, along with the weight of base platforms and living platforms were used to assess initial costs [2].

As mentioned previously, for Farming@Sea the cost of module construction was added during the making of this assessment, but the processing and production were based on the AQUAVLAN. AQUAVLAN is an Interreg project coordinated through a collaboration of a variety of partners which enables the knowledge development between research institutes and companies for the production of fish, shellfish, and silty vegetables. The goal is to establish the fundamentals of an economic, social, and ecologically sustainable agricultural sector within the Netherlands and Belgium.

The energy required to maintain the farming process, as well as other operational costs were included. It will be seen in this section, that these costs are used and combined, as well as included with other Space@Sea operational and maintenance costs [4].

Some additional costs were included with the single-use applications. An example of these was a contingency, which is a fixed percentage (often including schedule delays and significant deviation in scope and functionality), based on the desired level of confidence that the owner of the business would like to have on a project. This estimate was extracted from EnergyHub@Sea [2].

Table 3-2 CAPEX for T&L@Sea for the modular Islands

T&L@Sea			
North Sea BC		Med. Sea BC	
Item	Cost [M. €]	Item	Cost [M. €]
Civil works	548,70	Civil works	10,97
Equipment	513,40	Equipment	10,27
Other infrastructure	19,29	Other infrastructure	0,39
Installation	191,32	Installation	7,17
S@S O&M	3,90	S@S O&M	0,17
Contingency	162,21	Contingency	4,35

Table 3-3 CAPEX for EnergyHub@Sea for the modular islands

EnergyHub@Sea			
North Sea BC		Med. Sea BC	
Item	Cost [M. €]	Item	Cost [M. €]
Steel/concrete carcass	9,61	Steel and concrete carcass	259,50
Living module interior	3,86	Living module interior	104,34
Machinery	0,62	Machinery	16,87
Development/ consenting	1,28	Development/consenting	34,52
Installation	1,91	Installation	96,85
S@S O&M	0,04	S@S O&M	2,25
Contingency	1,05	Contingency Reserve	28,48

Table 3-4 CAPEX for Living@Sea for the modular Islands

Living@Sea			
North Sea BC		Med. Sea BC	
Item	Cost [M. €]	Item	Cost [M. €]
Substructure	26,01	Substructure	45,52
Superstructure	26,47	Superstructure	46,32
Contigency	18,37	Contigenecy	32,14
Installation	7,65	Installation	25,11
S@S O&M	0,16	S@S O&M	0,58

Table 3-5 CAPEX for Farming@Sea for the modular Islands

Farming@Sea			
North Sea BC		Med. Sea BC	
Item	Cost [M. €]	Item	Cost [M. €]
Substructure	26,01	Substructure	97,55
Installation	7,65	Installation	53,80
S@S O&M	0,16	S@S O&M	1,25
Business investments	18,72	Business investments	11,36
Financial Cost	0,48	Financial costs	0,25

3.1.2 OPEX

The OPEX is directly related to the operational maintenance of each module. However, these operational costs must be incurred at regular intervals for the maintenance of the infrastructures.

Living@Sea's OPEX comprised of energy costs, CTV O&M, platform maintenance, furniture for the accommodation as well as supplies for the crew. This total operational cost amounts to 3.5 Million Euros per year.

The EnergyHub@Sea OPEX calculations are also function-specific and include the operational costs energy consumption, energy costs, and work shifts. OPEX costs are restricted to the maintenance of the hub and cover the costs of the required personnel including maintenance technician, CTV crew, office, organizational staff, boarding, and lodging staff [2].

The OPEX for the Transport&Logistics@Sea modules comprised of the energy required for the infrastructure and equipment of the modules as well as fuel for the Automated Guided Vehicles (AGVs). The complete breakdown of the necessary cranes to transport and place the containers in the hub is added, including Large ship-to-shore, as well as rail-mounted gantry cranes (single or double spreaders) [3].

Table 3-6 OPEX for T&L@Sea for the modular Islands

T&L@Sea			
North Sea BC		Med. Sea BC	
Item	Cost [M. €]	Item	Cost [M. €]
Platform maintenance	25,4	Platform maintenance	0,5
Equipment O&M costs	28,2	Equipment O&M costs	0,6
Infrastructure O&M costs	0,7	Infrastructure O&M costs	0,0
Labour costs	2,9	Labour costs	0,1
Other expenses (Insurance/computer sys.)	16,2	Other expenses (Insurance/computer sys.)	0,3
S@S O&M	2,7	S@S O&M	0,1

Table 3-7 OPEX for EnergyHub@Sea for the modular islands

EnergyHub@Sea			
North Sea BC		Med. Sea BC	
Item	Cost [M. €]	Item	Cost [M. €]
Energy	0,04	CTV O&M	74,41
CTV O&M	2,76	Platform maintenance	5,25
Platform maintenance	0,19	Furniture	0,98
Furniture	0,04	Crew supply	13,47
Crew supply	0,50	Labor costs	64,05
Labor costs	2,37	S@S O&M	0,84

Table 3-8 OPEX for Living@Sea for the modular Islands

Living@Sea			
North Sea BC		Med. Sea BC	
Item	Cost [M. €]	Item	Cost [M. €]
Energy	0,2	Energy	0,3
Platform maintenance	0,8	Platform maintenance	1,4
Furniture	0,1	Furniture	0,3
Crew supply	2,0	Crew supply	3,5
Labor costs	0,8	Labor costs	5,5

Table 3-9 OPEX for Farming@Sea for the modular Islands

Farming@Sea			
North Sea BC		Med. Sea BC	
Item	Cost [M. €]	Item	Cost [M. €]
Wages and salaries	€ 3,59	Wages and salaries	€ 1,55
Energy/cleaning/packaging	€ 2,50	Platform maintenance	€ 2,92
COGS: fish and other raw materials	€ 4,27	Energy	€ 1,31
Repair and maintenance	€ 1,73	Feed	€ 1,48
Other operational costs (e.g. transport)	€ 4,30	Livestock	€ 7,85
Platform maintenance	€ 1,02	Repair and maintenance	€ 0,24
S@S O&M	€ 0,11	S@S O&M	€ 2,90

3.1.3 Module costs

Figure 3-1 shows the summary of the average initial expenditure per individual application within Space@Sea. The average module cost was derived from the construction cost. Living@Sea and EnergyHub@Sea are relatively more expensive than the T&L@Sea and Farming@Sea, since T&L@Sea spread their high civil works investments over relatively more modules and Farming@Sea did not require any expensive equipment for their business.

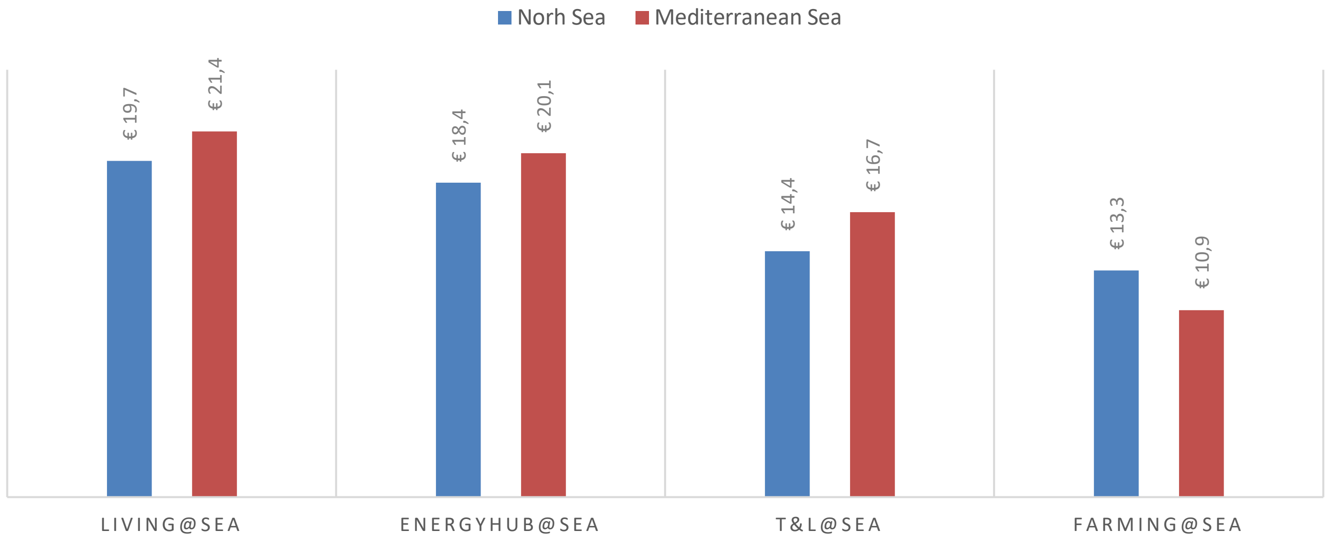


Figure 3-1 Approximated average module CAPEX

3.2 Industry-standard alternative

3.2.1 Land reclamation

The land reclamation is the foremost business case competitor to the Space@Sea modular island for the North Sea. The port expansion of the Port of Rotterdam, Maasvlakte II, is the most recent example of land reclamation as can be seen in Figure 3-2. Before Maasvlakte II emerged, the sea was approximately 17 meters deep. A lot of sand was required to spray new land to approximately 5 meters above sea level. For the Maasvlakte II, the amount of sand required to obtain 2000 hectares of usable land was 325 million m^3. Another example, which is globally more renowned and focussed on the real estate and more recreational business is the Palm Jumeirah, Figure 3-3, located in Dubai. It is comprised of 94 million m^3 of sand and 7 million tons of rock from the Hajar Mountains at an approximated price of 12 Billion Dollars in 2001-2004. These examples indicate the scale of the current land reclamation industry and the prices that Space@Sea must compete with.

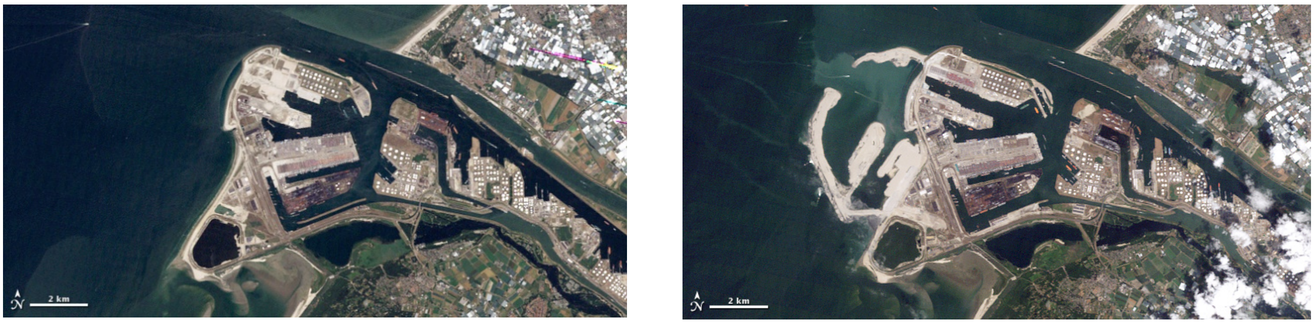


Figure 3-2 Maasvlakte II land reclamation example – before and after

Figure 3-3 Construction of Palm Jumeirah

3.2.1.1 CAPEX

The land reclamation is going to replace the CAPEX of the foundation/substructure for all the businesses, but keep the above water investments the same, i.e. facilities, crane, etc. The CAPEX difference is shown in Table 3-10 through Table 3-13. A comparison is made between what would be required in terms of dredged rocks and sand and other materials to create the equivalent port facility with modules.

Table 3-10 CAPEX for T&L@Sea using land reclamation

T&L@Sea	
Item	Cost [M. €]
Land reclamation/foundation	€ 158,29
Equipment	€ 513,40
Other infrastructure	€ 19,29
Contingency	€ 103,65

Table 3-11 CAPEX for Living@Sea using land reclamation

Living@Sea	
Item	Cost [M. €]
Land reclamation/foundation	€ 1,58
Superstructure	€ 26,47
Additional Cost	€ 9,82
O&M	€ 0,58

Table 3-12 CAPEX for EnergyHub@Sea@Sea using land reclamation

EnergyHub@Sea	
Item	Cost [M. €]
Land reclamation/foundation	€ 1,58
Superstructure construction	€ 2,91
Living module interior	€ 3,86
Machinery	€ 0,62
Development and consenting	€ 0,55
Contingency Reserve	€ 0,45
O&M	€ 0,04

Table 3-13 CAPEX for Farming@Sea using land reclamation

Farming@Sea	
Item	Cost [M. €]
Land reclamation/foundation	€ 6,33
Business investments	€ 18,72
O&M	€ 0,16
Financial Cost	€ 0,48

Landfill calculation

The CAPEX for the sand land reclamation is primarily dependent on:

- Volume of fill
- Average Price per volume of fill including transit cost for fill pick up and deposit
- Price of the vessel (including personnel)
- Mob/demobilization equipment
- Compaction and finishing sealine with stone breakwater barrier

Figure 3-4 shows an isotopic view on how geometrically the volume for the landfill was constructed. The parts were divided into two separate components, the first being the cube meant for the business space occupation and the second the additional volume required for stability/reinforcement of the island. The volume V_2 is dependent on the friction angle, ϕ, of the loose sand used as fill material. The friction angle is assumed to be approximately equal to 30 degrees.

$$Volume = V_1 + V_2$$

$$V_1 = [\mathrm{L \; x \; W \; x \; (H}_{wd} + \mathrm{H}_{Freeboard})] = [\mathrm{L \; x \; W \; x \; H}_{fill}] * N_{mod}$$

$$V_2 = 4 * H_{fill}^3 \tan^2(\phi) + (L + B) * \mathrm{H}_{fill} \tan(\phi)$$

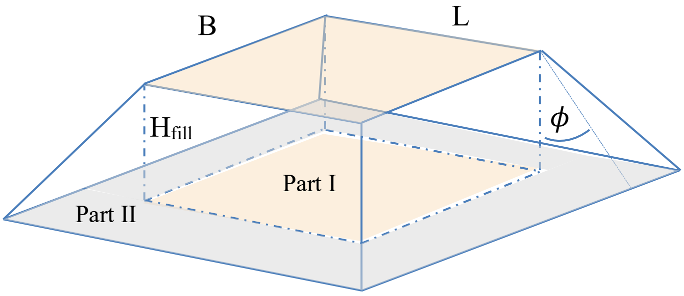


Figure 3-5 Lanfill volume

Table 3-14 Financial assumptions and associated cost for sand - land reclamation

Item	Unit	Value	Financial Assumptions
AVG. price Landfill	€/m³	17.0	Assuming transit distance for sand distribution of 50 KM and average dredger price
Mob/demob equipment	€	1,000,000	Price for one vessel mobilization
Compaction of soil	€/m²	247	Approximated at 500,000 for one module size
L	M	855	
B	M	315	
H_{wd}	M	25	
$H_{freeboard}$	M	6	
N_{mod}	M	129	
Volume	M³	8,16E+06	One vessel to finish the job

3.2.1.2 OPEX

In Table 3-15 to Table 3-18 it can be seen that each cost is based on the functionality and individual applications. The operational expenditures were found to be lower compared to Space@Sea, as no platform and mooring maintenance are required.

Table 3-15 OPEX for T&L@Sea using land reclamation

T&L@Sea	
Item	Cost [M. €]
Equipment O&M costs	28,16
Infrastructure O&M costs	0,74
Labor costs	2,87
Other expenses (Insurance/computer sys.)	16,21
Building maintenance	0,06
S@S O&M	1,02

Table 3-16 OPEX for Living@Sea using land reclamation

Living@Sea	
Item	Cost [M. €]
Energy	0,15
Building maintenance	0,24
Furniture	0,15
Supply	2,00
Labor costs	0,79
S@S O&M	0,04

Table 3-17 OPEX for EnergyHub@Sea@Sea using land reclamation

EnergyHub@Sea	
Item	Cost [M. €]
Energy	0,04
CTV O&M	2,76
Building maintenance	0,06
Furniture	0,04
Crew supply	0,50
Labor costs	2,37
S@S O&M	0,01

Table 3-18 OPEX for Farming@Sea using land reclamation

Farming@Sea	
Item	Cost [M. €]
Wages and salaries	3.59
Energy	2.50
Livestock	4.27
Building maintenance	4.30
Other operational expenses	0.24
S@S O&M	0.04

3.2.2 Fixed platform

Due to the water depth, the most feasible business alternative for the Mediterranean island is a fixed platform. The evaluation is similar to the approach elaborated in EnergyHub@Sea [2]. The Space@Sea modular island was compared to an island with jacket platforms as a base foundation. These are mostly used in the offshore industry, notably in the oil and gas since the 1950s, and are hereby compared to the floating module option. The comparable scenario to the Mediterranean modular island would resemble the offshore platform structure seen in Figure 3-6. It is expected that this industry-standard alternative will have a reduced level of functionality compared to S@S, for example, due to the complexity of T&L@Sea vessel (off)loading capability. However, for this research, the functionalities were assumed to be similar. If the fixed jacket is found to be a relevant competitor a more in-depth study should be initiated on the costs aiming for similar functionality and improved results.

Figure 3-6 Jacket Platform Island configuration

3.2.2.1 CAPEX

Below is the summary CAPEX for an alternative scenario for each application if a jacket was to be constructed in place of the modular island. The initial costs were divided into the following categories: jacket foundation, which replaces the module foundation, development for a jacket, additional equipment required during the construction and installation, O&M as well as a contingency on infrastructure and equipment costs. Using the same approximation for the initial costs of the fixed platform, versus the initial costs of the module platform, Table 3-19 through Table 3-22 show the steps used in calculating the CAPEX of the alternative scenario with a similar configuration to the Mediterranean configuration.

Table 3-19 CAPEX for &L@Sea for the jacket alternative

T&L@Sea	
Item	Cost [M. €]
Jacket Foundation	41,06
Development/consenting for jacket	5,81
Equipment	10,27
Installation	10,88
O&M	0,17
Contingency on Infrastructure/equipment	1,60

Table 3-20 CAPEX for Living@Sea for the jacket alternative

Living@Sea	
Item	Cost [M. €]
Jacket Foundation	143,72
Development/consenting for jacket	20,34
Superstructure	46,32
Contingency	9,47
Installation	38,09
O&M	0,58

Table 3-21 CAPEX for EnergyHub@SEa for the jacket alternative

EnergyHub@Sea	
Item	Cost [M. €]
Jacket Foundation	554,37
Superstructure	78,45
Living Module interior	104,34
machinery	16,87
Development and consenting	78,34
Installation	146,90
O&M	2,25
Contingency	45,05

Table 3-22 CAPEX for Farming@Sea for the jacket alternative

Farming@Sea	
Item	Cost [M. €]
Jacket Foundation	307,98
Development/consenting for jacket	43,58
Equipment cost for production	132,68
Installation	81,61
O&M	1,25
Contingency on Civil works for a jacket	13,86

Fixed Platform/Jacket extraction

The jacket platform is composed of jackets, joints, legs, and braces, but unlike the modular combined island with its concrete storage structure, this is counted as an addition (or superstructure) to the jacket. This addition weighs 970T and its cost was estimated to be ~17,670 €/Ton and the cost of steel was approximated to be 3000 € / Ton. The costs were calculated in the EH @ Sea's deliverable [2] and are calculated first by determining the price per ton of upper structure and meters of water depth. Using these approximations, and the following equation was used for the cost approximation in [2]:

$$W_{Fpjacket} = \frac{W_{turbine}}{W_{tjacket}} * \frac{\mathrm{d}}{30}$$

Where $W_{Fpjacket}$ is the weight of the platform's jacket

$W_{turbine}$ is the weight of the turbine

$W_{tjacket}$ is the weight of the turbine's jacket

d is the water depth

This price is for the construction of one alternative jacket type platform and its additional superstructure. As calculated by EnergyHub@Sea's alternative scenario, the $FNPV_C$'s of the fixed platform account for more CAPEX as seen in [2].

As shown in Table 2-1, the modular island off the coast off of Montpellier comprises a total of 51 modules, each with its own four functionalities. The same reasoning was used to compare the initial costs of a comparable island but with jacket foundations. As can be seen in Figure 2-6, the module is now replaced with a jacket foundation, with a base price of 20.53 Million €, for a total of 148 Million €.

The superstructure was calculated with the cost of the Living@Sea superstructure including the accommodation. As construction costs include specific costs relating to functionalities of each application, it is useful to define some of the specific costs that are included, which defer mainly due to the function foreseen.

The construction of the seabream systems of the Farming@Sea section includes equipment such as measurement and control equipment, alarms, weighing equipment, septic tanks, coolers and freezers, high-pressure cleaners, and sorting equipment. an office as well as other costs related to the farming. These costs, therefore, include all construction, apparatus, and machinery related to seabream farming. The transport and Logistics section of the island would comprise construction costs related to the various cranes needed to transport and place the containers, assuming a similar scenario/functionality as T&L@Sea.

3.2.2.2 OPEX

In the previous section, OPEX was associated with moorings to keep the modules in place within the sea environment. With the case of jacket foundations, the physical characteristics of the steel-based structure, the operational costs are computed accordingly. Operations such as pile driving and anchoring as well as scouring of the jackets are included in the cost.

Table 3-23 OPEX for T&L@Sea for the Island reclamation

T&L@Sea	
Item	Cost [M. €]
Equipment O&M costs	0,56
Infrastructure O&M costs	0,01
Labor costs	0,06
Other expenses (Insurance/computer sys.)	0,32
S@S O&M	0,11

Table 3-24 OPEX for Living@Sea for the Island reclamation

Living@Sea	
Item	Cost [M. €]
Energy	0,27
Platform maintenance	1,36
Furniture	0,25
Crew supply	3,49
Labor costs	5,54
S@S O&M	0,40

Table 3-25 OPEX for EnergyHub@Sea for the Island reclamation

EnergyHub@Sea	
Item	Cost [M. €]
Energy	1,04
CTV O&M	74,41
Platform maintenance	5,25
Furniture	0,98
Crew supply	13,47
Labor costs	64,05
S@S O&M	1,55

Table 3-26 OPEX for Farming@Sea for the Island reclamation

Farming@Sea	
Item	Cost [M. €]
Wages and salaries	1,55
Platform maintenance	2,92
Energy	1,31
Feed	1,48
Livestock	7,85
Repair and maintenance	0,24
S@S O&M	2,90

4. Business Case Results

The total CAPEX is a summation of each single-use application's business case scenario and is obtained by deconstructing each cost analysis to make the final combined CAPEX and OPEX for each modular island. An example of this cost deconstruction is multiplying the initial costs of Living@Sea by 4 since we will have four Living@Sea modules.

Table 4-1 below summarizes the total CAPEX cost or initial investment for each working case and modules present. The total CAPEX for the combined North Sea modular island is 1589 Million Euros. The obtained CAPEX for the Mediterranean Sea island is 890 Million Euros. This is based on the financial assumptions, a precalculated module rate, and including construction costs for each application. Similarly, operational expenditures were calculated at a total of 190,7 Million Euros for the Mediterranean modular island and 103,4 Million Euros for the North Sea modular island, and are summarized in Table 4-2.

This chapter elaborates on the functional aspects of each module assembly, representing each application and its estimated costs. Additional costs are related to the assembled modular islands as the following results show. The total CAPEX of the North Sea modular island is comprised of each CAPEX related to each application. The construction costs for each module, and the number of modules, and the mooring installation costs were included. An additional fee relating to "belonging to the Space@Sea island" would be payable by each application, meant for general O&M for Space@Sea.

The total CAPEX cost for the North Sea is estimated to be ~ 1,589 Million Euros. This amount includes a total of the cost of Transport&LogisticSpace@Sea and based on the 100 module cost calculations. The second-largest component of the CAPEX is Living@Sea, with around 79 Million Euros. This cost is due to the construction of the superstructures and substructures. The Farming@Sea WP comes next with a cost of 53 Million Euros, mostly due to a high number of modules necessary to produce mussels.

The total CAPEX of the Mediterranean consists of 27 modules of EnergyHub@Sea, for a CAPEX of 542.8 Million Euros, and the second-largest contributor of CAPEX is Farming@Sea, with 15 modules and 164.2 Million Euros. T&L@Sea and Living@Sea 's contributions to the capital cost are 169.7 and 33.3 Million Euros respectively.

Table 4-1 shows the repartition of CAPEX contribution per business case. Similarly summarizes the combined operational expenditures for the combined North Sea island. Also, in Table 4-2, the combined operational expenditures for the Mediterranean island are shown.

An important aspect of this financial analysis was to assess each system for the individual methodologies of the cash flow estimation. As defined in section 4.2, the net cash flow is calculated by deducting the cash income (or revenue) from the cash outflows (here costs). Most individual applications did not include income or cash in, as the metrics for determining a revenue, defined in Table 3-1, were not translatable to Euros. Therefore, only costs were considered hence resulting in a negative net cash flow for Space@Sea.

4.1 Evaluation of results

The following sections present the results of the financial analysis of both modular islands. This involves the tabulation of both investment costs such as CAPEX as well as the operational expenditures in a second separate table. It is important to note that each modular island scenario is compared to its alternative industry standard for sake of relativity and comparing costs.

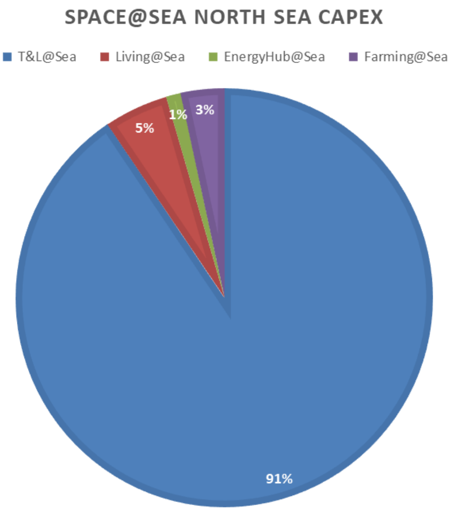
4.1.1 North Sea Business Case

The following section shows the combined capital expenditure (CAPEX) of the modular islands, as well as their alternative scenarios and a delta column indicating the difference between each cost.

The CAPEX calculations in Table 4-1 represents the results for the North Sea modular island and the landfill alternative. The results show a CAPEX of approximately 1589 Million Euros and 869 Million Euros, for floating modular and landfill, respectively. The difference is about 720 Million Euros and is defined as the Delta in CAPEX between the two options. The values in the delta scenario containing negative values show that land reclamation is a more attractive alternative, but it will be shown in the following sections that it is parameter dependent.

Table 4-1 North Sea BC comparison

North Sea business case Comparison				
	CAPEX			
Module Type	S@S [M. €]	Landfilled [M. €]	Delta [M. €]	Ratio [-]
T&L@Sea	1438,8	794,6	**-644,2**	**1,81**
Living@Sea	78,7	38,5	**-40,2**	**2,05**
EnergyHub@Sea	18,4	10,0	**-8,4**	**1,84**
Farming@Sea	53,0	25,7	**-27,3**	**2,06**
Total	1588,9	868,8	**-720,1**	**1,83**



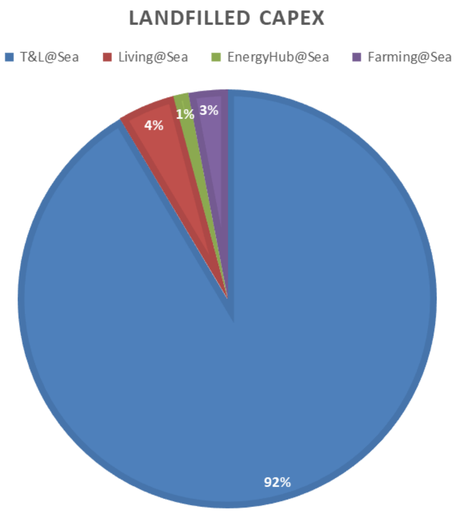
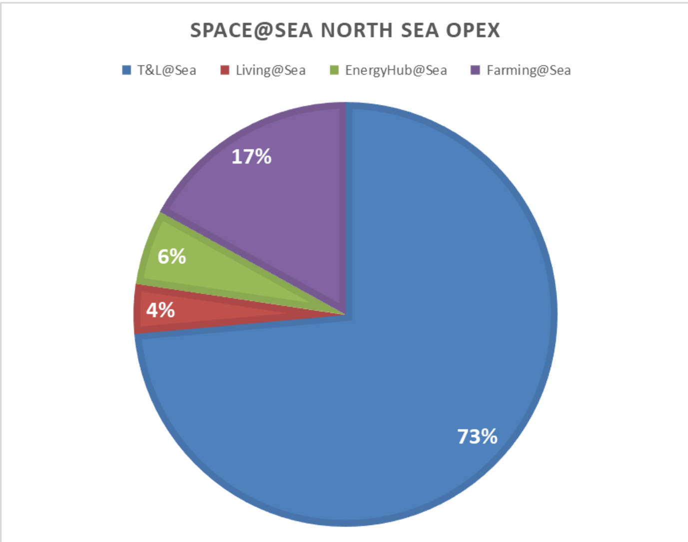
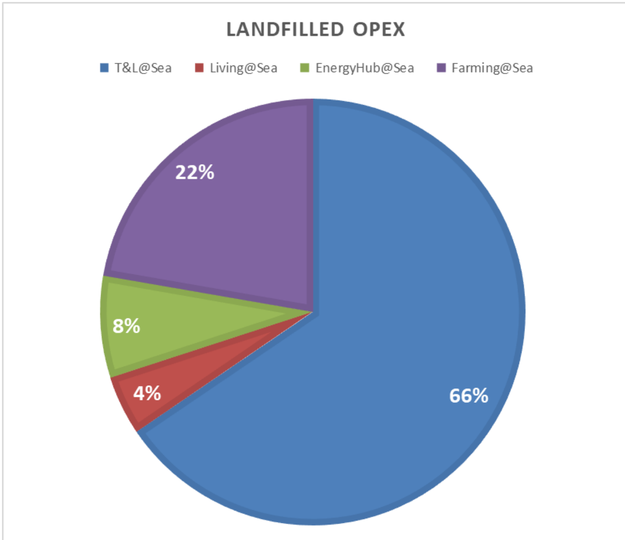


Table 4-2 summarizes the differences in OPEX of the Space@Sea North Sea modular island, its industry alternative competitor, the landfilled scenario, and the Delta is the differences of these costs per business case. The T&L section of the OPEX ranges at approximately 47 Million Euros, versus ~ 49 Million Euros for its landfilled competitor. The difference between the two is approximately 55%.

Table 4-2 Comparison between Space@Sea and landfilled scenarios

North Sea business case Comparison				
	OPEX			
Module Type	S@S [M. €]	Landfilled [M. €]	Delta [M. €]	Delta [-]
T&L@Sea	76,1	49,1	**-27,0**	**1,55**
Living@Sea	3,9	3,4	**-0,5**	**1,15**
EnergyHub@Sea	5,9	5,8	**-0,2**	**1,03**
Farming@Sea	17,5	16,7	**-0,8**	**1,05**
Total	103,4	74,9	**-28,5**	**1,38**





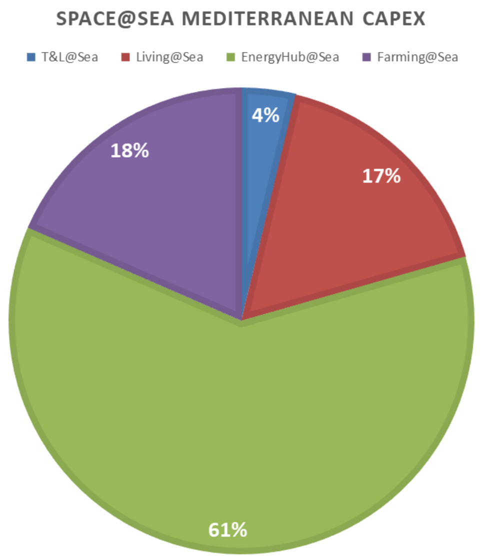
4.1.2 Mediterranean Sea Business Case

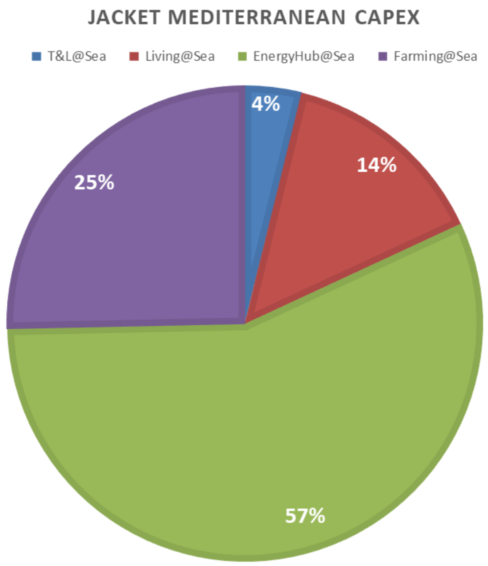
As can be seen in Table 4-3, the combined initial expenditure of the Space@Sea modular island compared to the standard industry scenario, jacket fixed platform, is economically advantageous. The T&L, Living@Sea, EnergyHub@Sea, and Farming@Sea's additions are 0.49 times less costly to invest compared to industry-standard scenario.

Calculations have shown that for this case, the EnergyHub@Sea alone constitutes 50% for both options in terms of CAPEX.

Table 4-3 Summary CAPEX for Space@Sea Mediterranean Sea business case

Mediterranean Sea business case Comparison				
	CAPEX			
Module Type	S@S [M. €]	Fixed Platform [M. €]	Delta [M. €]	Ratio [-]
T&L@Sea	33,3	69,8	**36,5**	**0,48**
Living@Sea	149,7	258,5	**108,8**	**0,58**
EnergyHub@Sea	542,8	1026,6	**483,8**	**0,53**
Farming@Sea	164,2	459,6	**295,4**	**0,36**
Total	890,0	1814,5	**924,5**	**0,49**

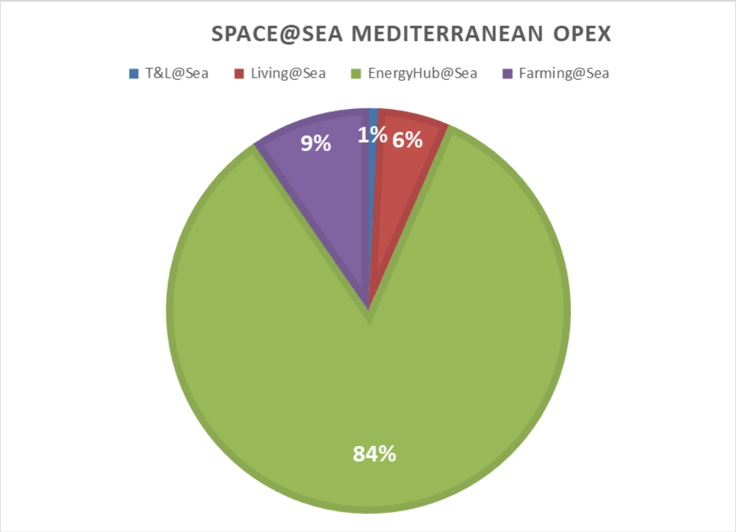


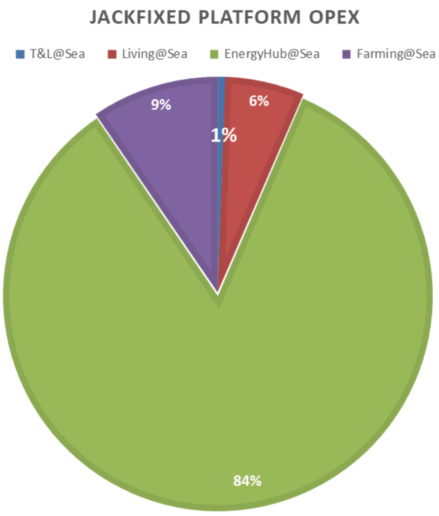


The OPEX for the Mediterranean modular island are listed in Table 4-4, as well as the most competitive industry standard, the fixed jacket platform, and the difference in cost displayed as the Delta columns.

Table 4-4 Summary OPEX for Space@Sea Mediterranean Modular Island

Mediterranean Sea business case Comparison				
	OPEX			
Module Type	S@S [M. €]	Fixed Platform [M. €]	Delta [M. €]	Delta [-]
T&L@Sea	1,5	1,1	-0,5	1,42
Living@Sea	10,9	11,3	0,4	0,96
EnergyHub@Sea	160,0	160,8	0,7	1,00
Farming@Sea	18,2	18,2	0,0	1,00
Total	190,7	191,4	0,7	0,997





In section Module costs, the modules having the same function share the same costs. When combining the multi-use islands, the costs for each module were deconstructed, multiplied by the number of modules needed, and recombined concerning the island configuration.

As can be seen in Table 4-4, the T&L@Sea, Living@Sea, EnergyHub@Sea, Farming@Sea, respective operational expenditures are entered for the Space@Sea modular island and the fixed platform competitor.

The average trend observed is that the T&L@Sea OPEX is 42% higher for Space@Sea, but other costs are relatively identical except for the Living@Sea modules. These would be 4% more beneficial as a modular island, due to the additional cost of the superstructure and base on the jacket to build it on.

It can be seen by the last line of each CAPEX table, that the price of modules may differ between each business case. This is explained by the detailed costs linked to the function provided by the module. The price of the module per business case once combined into the modular island is shown in Figure 3-1.

The sensible financial explanation is that the average price of the module is not the same per:

- Assumption based on the primary calculation of concrete module (approximately 3.5 Million Euros)
- Each application made specific assumptions with regards to rates such as the VAT for Living@Sea or contingency reserve for EnergyHub@Sea.

In this chapter, the Cost Model developed in Chapter 3.1 along with the assumptions presented in section 2.4, set the base for deriving cash flow projections, financial metrics, and non-financial results, as they are used to predict the costs for running each of the three alternatives. The results presented in this section will be used for drawing conclusions and making recommendations in Chapter 0.

When merging four applications into one multi-use floating island, the important aspect was to properly combine cash flow, and that is especially true when reporting periods deviated. One of the challenges that erewere encountered when combining different business cases with divergent metrics was that the cash flow projections did not have the same period in the Cost-Benefit Analysis, each was incorporated as is.

The outcome of the combined cash flows is in Appendices A through D. The financial assumptions including discount rates, interest rates, energy increase rates, salary increase, loan interest rates, and maintenance increase rates are merged**.** For each of these cases, three periods were analysed. The starting period involving investing costs, year 12 at the project's half-life, and year 24-year before decommissioning. The indicator calculated for each modular island is the FNPV and is defined as:

$$FNPV = \sum_{N=1}^{N=max} \frac{(Future\ Value)}{(1 + Interest\ Rate)^N}$$

The assessment of expected cash flows for the combined modular islands included the separate cash flows of each business case.

4.1.3 Conclusion on Business Cases

In the case of Space@Sea, the individual measures should be added together when they have a common goal and clarify the financial assumptions which belong to each module, based on functionality.

In the case of Living@Sea, the cash flow calculations were performed for a total of six modules (for a total cost of 128 Million Euro). The cash outflow discounted cash flow (DCF), as well as the net present value, must be redefined for the 4 modules needed.

The following summarizes the new cash flow for four modules of Living@Sea, which will be integrated into the combined cashflow. The financial assumptions do remain the same with a 6% discount rate, but the initial cost is lowered from 1.06 Million Euros to 0.7 Million Euros.

Table 4-5 Cashflow for Living@Sea initial 7 module

Year	Costs	Revenues	Cashflow	Cumulative Cashflow	Interest costs	Present value
1	€ 1,2	€ 0	-€ 1,2	-€ 1,2	-€ 0.74	-€ 1,12
2	€ 0.26	€ 0	-€ 0.336	-€ 1,57	-€ 0.943	-€ 0.277
3	€ 0	€ 0.395	€ 0.301	-€ 1,27	-€ 0.75	€ 0.225
4	€ 0	€ 1,58	€ 1,50	€ 0.232	€ 0	€ 1,0.3

Table 4-6 Cashflow for Living@Sea with 4 modules

Year	Costs	Revenues	Cashflow	Cumulative Cashflow	Interest costs	Present value
1	€ 0.8	€ 0	(€ 0.705)	(€ 0.705)	(€ 0.424)	(€0. 06412)
2	€ 0.15	€ 0	(€ 0.192)	(€ 0.89)	(€ 0.538)	(€ 0.158)
3	€ 0	€ 0.226	€ 171,782	(€0. 726)	(€ 43,581)	€ 0.129
4	€ 0	€ 0.902	€ 0.859	€ 0.133	€ 0	€ 586,777

Living@Sea (Figure 4-1) chose to evaluate their cash flow for the first 4 years, which differs from the three other applications, which presented a challenge in merging the costs, and notably the cashflow and its financial assumptions.

As mentioned in section 2.2.1, the cash inflows are unknown, so cannot be taken into account. A starting period, a half-life period, and the end period of the project's lifetime were used for most work cases.

For the case of the EnergyHub@Sea, three periods were included in the cash flow calculations: right after the original investment or "Year 2", "Year 12" distinguishing the middle timeframe and "Year 24", or right after the decommissioning costs as can be seen in Figure 4-2.

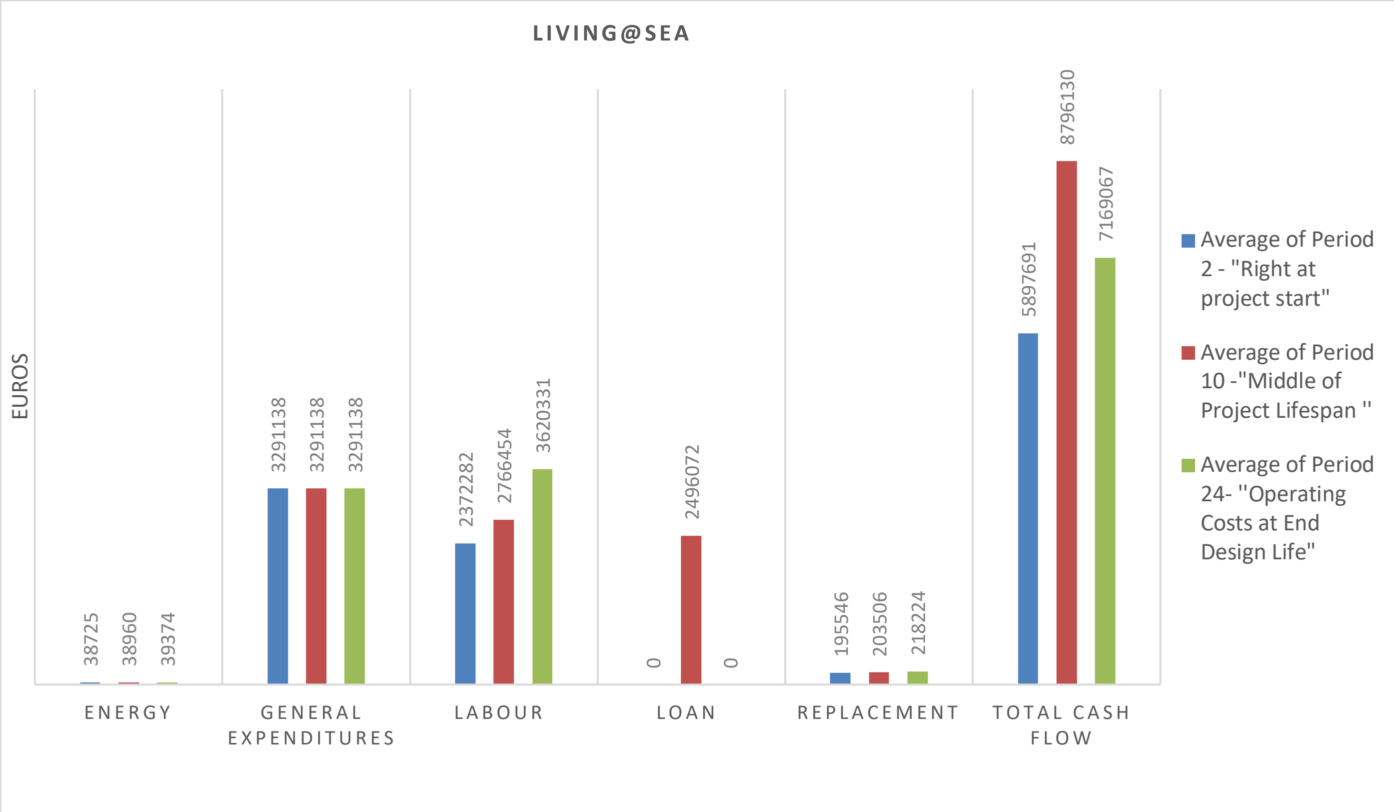


Figure 4-1 Four years detailed cash flow for Living@Sea

For Farming@Sea, the main metric used is the production rate (and processing) of mussels/seabream. The main cost indicators used were Germany and Denmark's cost per kilogram of mussels [4].

The net cash flow calculations of the combined modular North Sea island included financial assumptions such as an integrated 3% discount rate for Farming, 5% for T&L, and 4% For Energy Hub @Sea, No discount was incorporated for the calculations of the Living@Sea, and similarly in the North Sea modular island. Depreciation rates were used solely in the case of Farming@Sea which included a rate of 4% depreciation rate and an interest rate of 5%.

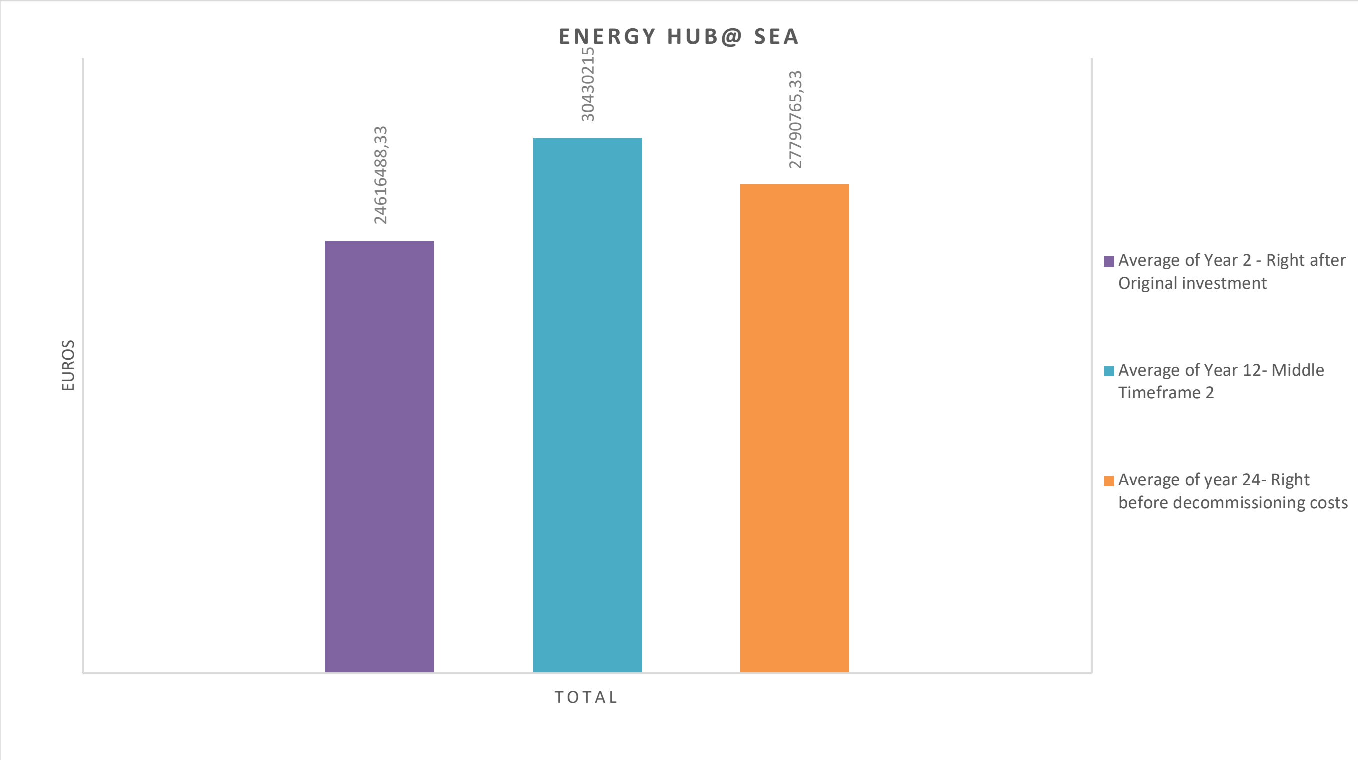


Figure 4-2 Energy Hub Cash flow

Transport&Logistics@Sea, costs included initial investments, installation costs, operating costs, maintenance costs, and remaining (residual or salvage) value at the end of ownership or its useful life. In this single-use business case, the assumption was that there is no residual value at the end of the lifetime of the terminals (25 years), so the only costs incurred at the final period are the decommissioning costs. All these costs were discounted to present-day value.

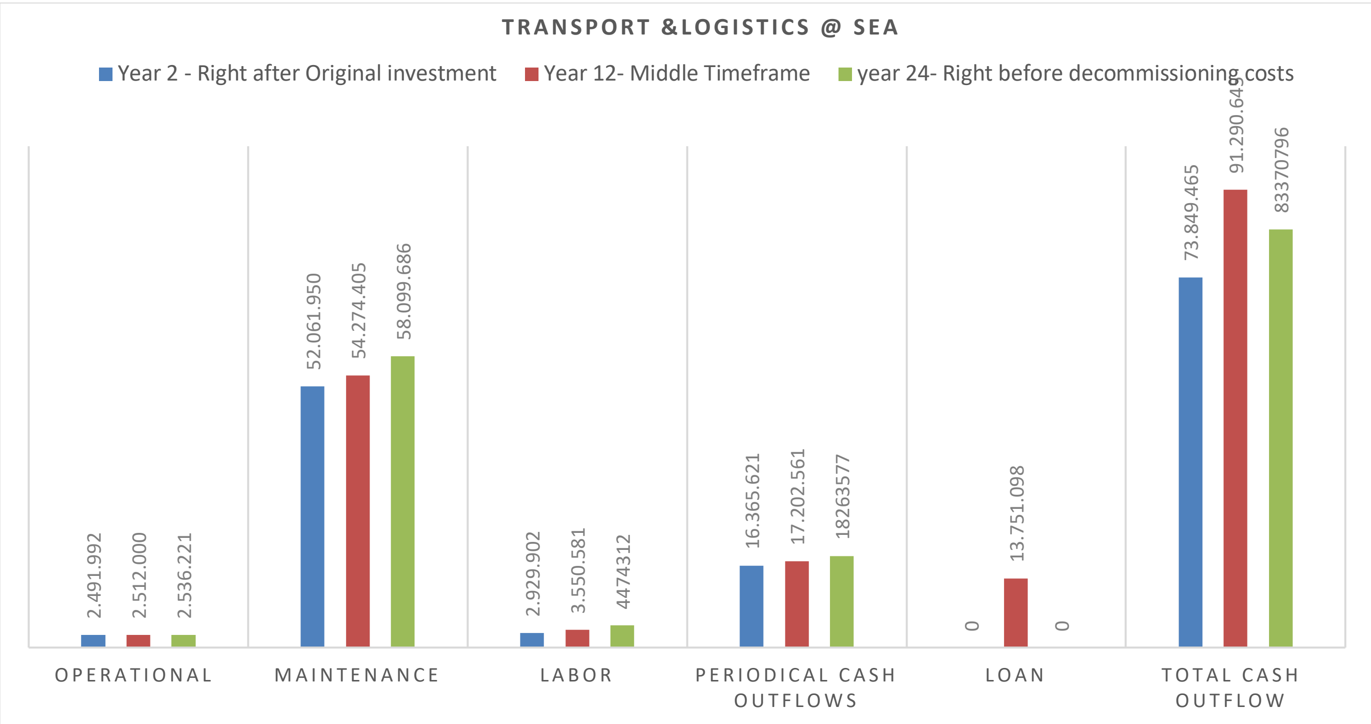


Figure 4-3 Transport&LogisticSpace@Sea detailed Cashflow

For Farming@Sea, the initial assumption for the seabream model was based on literature and the Greek market, which is highly competitive and results in negative overall total numbers in the cash flow. This set of assumptions make for a breakeven only after 15 years [4] **.** Assumptions were made before calculating the cash flow of the combined modular islands such as:

Transport&LogisticSpace@Sea CAPEX was divided linearly to accommodate two modules for the Mediterranean island. EnergyHub@Sea OPEX was reduced tenfold to match the appropriate module number. The initial EnergyHub@Sea financial investment of €4,881,003 was paid before the analysis (as indicated in the deliverable [1])**.** The detailed cash flow analysis for the North Sea case and the Mediterranean case is listed in Table 4-7:

Table 4-7 Financial Assumptions for Cashflow Projections

Financial Assumptions				
Working Case rate	Living@Sea	EnergyHub@Sea	Transport&LogisticSpace@Sea	Farming@Sea
Discount	10%	4%	5%	3%
Depreciation	N/A	N/A	N/A	4%
Interest	6%	N/A	0%	2.50%
Salary Increase	1.90%	1.94%	1.94%	N/A
Energy Increase	N/A	0.08%	0.08%	N/A
Maintenance	N/A	0.50%	0.50%	N/A
Loan Interest	N/A	4.00%	15%	N/A

4.2 Financial Net Present Value

In the previous deliverables on the single-use application's business cases, no income or revenues were defined and included in the FNPV calculations. This means that only costs/investments were calculated considering the investment and operating costs as outflows. The cost of financing is not included in the calculation of the investment performance of the $FNPV_C$, which is calculated as follows:

$$FNPV_C = \sum_{t=0}^{n} a_t S_t = \frac{S_0}{(1+i)^0} + \frac{S_1}{(1+i)^1} + \cdots + \frac{S_n}{(1+i)^n}$$

*w*here:

S_t is the balance of cash outflow at time t,

a_t is the financial discount factor chosen for discounting at time t

i is the financial rate

It is assumed that an investment with a positive $FNPV_C$ will be profitable, and an investment with a negative $FNPV_C$ will result in a net loss. In the merged business cases, and mostly all working packages, no inflows are considered, hence the $FNPV_C$ will be negative.

One way to obtain a positive $FNPV_c$ is to establish an initial and projected source(s) of inflow or revenues. The FNPVc of both the North Sea and Mediterranean island at T = 1, or the first year after investments, were (€-2,741.64) and (€5,486,452), respectively. As indicated by previous cashflows in the business case deliverables, the parenthesis indicates a negative number which means the costs are greater than the revenues, which is expected.

The FNPVc, which reflects the initial costs and operating costs as outflows, and no inflows, and therefore does not include financial benefits, it was beneficial to use a second financial indicator, the FNPVk. The role of the FNPVk as a metric includes the net financial present value of capital from the perspective of the assisted public as well as possible private entities. The FNPVk takes into consideration:

- Operating costs
- National – Public and Private contributions to the project
- Capital contributions
- Loans – taken at the time of reimbursement
- The interest taken on these loans

These listed items were included in the cost calculations and reflect some of the cash inflows as a reduction in cost through either capital contributions, or private funding and or/loans. The full FNPV results are presented in section 4.2.1.

4.2.1 FNPVc and FNPVk results

As seen in Table 4-8, the North Sea case is less favourable for both the FNPVk and FNPVc compared to the landfilled alternatives. The FNPVc is 31% greater than its competitor, and the values of the FNPVk are also increased by 25%. An interesting observation is that the inverse is true for the case of the Mediterranean island.

Table 4-8 Summary of combined results for all scenarios

	North Sea			Med. Sea BC		
FNPV item	S@S [M. €]	Landfilled [M. €]	Factor w.r.t. Industry standard	S@S [M. €]	Fixed Jacket [M. €]	Factor w.r.t. Industry standard
FNPV$_c$	-3277	-2058	**1,59**	-4194	-5305	**0,79**
FNPV$_k$	-2274	-1550	**1,47**	-3502	-6011	**0,58**
Δ in FNPV	**31%**	**25%**	-	**-13%**	**26%**	-

4.3 Opportunities and non-financial benefits

4.3.1 The Do-Nothing Scenario

The "Do-Nothing" scenario is an example of the non-quantitative benefits that the modular islands would provide. This scenario lists the impacts that would be expected if the modular islands were not created. This scenario assumes that some costs would occur if the modular islands were not feasible, and instead "nothing" was done concerning the Space@Sea project. The port of Antwerp, the second-largest port in Europe for container freights, is seeing a consistently increasing growth. Below, is the statistical approximation taken from the maritime statistics website, the surveying period being from 2009 to 2019 [9].

The port of Antwerp sees a gradual increase in total maritime cargo traffic (Figure 4-4), based on a fixed area, of approximately 7 million additional TEU per year. This increasing demand in throughput could potentially be relieved by the Transport&Logistics@Sea modules and this was computed into the do-nothing scenario.

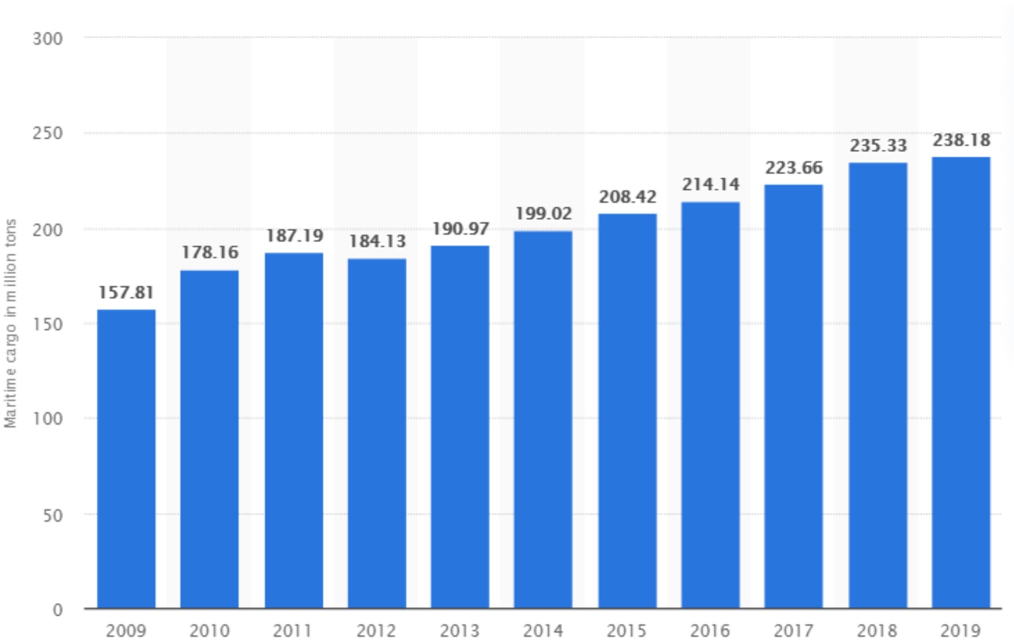


Figure 4-4 Maritime Cargo Traffic of Port of Antwerp 2009-2019

This increasing unmet demand was computed as a “loss” by a “do-nothing scenario” and was quantified as a cost. Another aspect of “doing nothing” would be that no new employment opportunities will be created by the doing-nothing scenario.

With the creation of the North Sea island, with its total of **109 modules**, a total of **221,000 m^{2}**, extra “land” space would be created. This includes a total of 1353 facility staff and crew members working in non-existing operations, therefore resulting in an economic loss. Similarly, the Mediterranean island is made of a total of 51 modules, and the Living@Sea module alone can house 1722 people. The total square meter area provided by Living@Sea is also considered a loss in capital.

If the totality of the people accounted for on the modular islands were also working on operations and maintenance, this would also result in a loss of capital. If we take that the totality of these workers are now based on land and must commute to and from work. This would be an additional cost that will be used in the “Do-Nothing” scenario.

4.3.2 Electricity and non-financial benefits

A relevant measurable parameter which is a non-financial benefit is the greenhouse emission rate savings, by building both modular islands. According to the International Renewable Energy Agency (IRENA), findings in recent years show that the emission of Carbon Dioxide (CO_2), contributes to global warming. Today’s climate crisis has encouraged a spur in the attractiveness of renewable energy sources such as wind, solar, hydrothermal, and others. The project of incorporating WEC converters in the Mediterranean is an ongoing project during the S@S project and therefore puts Space@Sea in a competitive and efficient project.

4.3.3 Throughput Alleviation

Another opportunity offered by the conception of the North Sea modular island would be to alleviate the throughput of the Port of Antwerp. Most of the port maritime traffic occurs along the Scandinavian Baltic Sea, the Mediterranean and Black Seas as well as upwards to the United Kingdom (Figure 4-5). The North Sea modular island's location provides a potential to alleviate ~30-35% throughput of that area, rather than having to pass through the Port of Antwerp.

As indicated by the Transport&Logistics@Sea business case, measures of timeliness can also have an economic impact on the business. Port productivity measures are best assessed by examining stevedoring performance, for which the vessel turnaround times are the major parameter. Ports often compete over lowering turnaround times, and this indicator is a major decision criterion for shipping companies when selecting the ports to visit [3].

If the traffic in-between "the triangle" can be alleviated by the North Sea modular island, the ship commuting time from the modular island to the Antwerp port can be reduced and the North sea modular island could provide assistance to the busy port while reducing transport time and therefore reducing the costs of the activities.

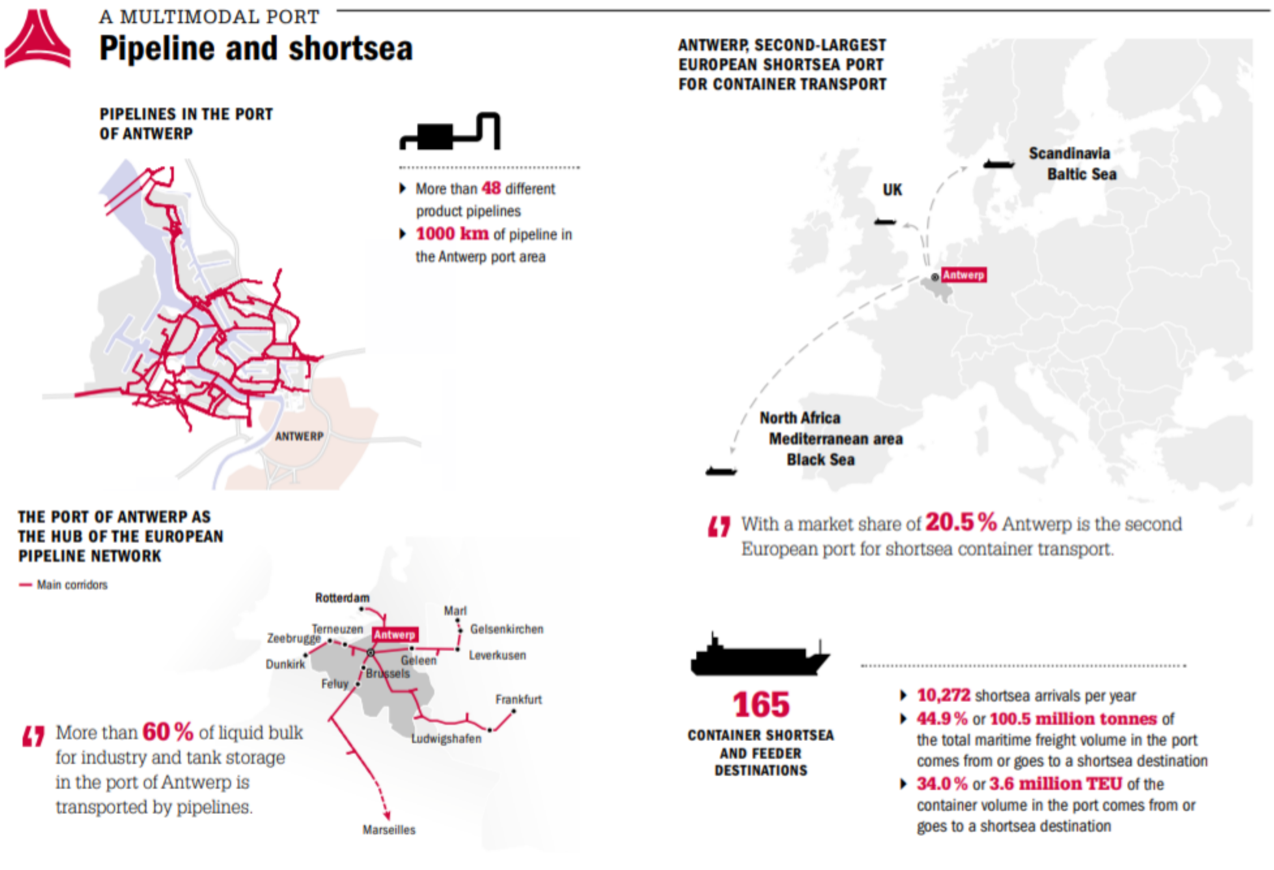


Figure 4-5 Example from the yearly Port of Antwerp facts and numbers 2018

The presence of Transport&Logistic@Sea hub on the vessel turn-around times between Antwerp and the proposed modular island can alleviate the turnaround times because the vessels would not have to negotiate the river Scheldt. This reduces the variation in sailing time, waiting times for sea and river pilots, tugboats, mooring, and loading/unloading times.

4.3.4 Private vs Government-owned enterprises

As a recommendation from the EnergyHub@Sea deliverable [5], the following excerpt, written by M. Flikkema, presents ways in which these modular islands can contribute to solutions:

In the Space@Sea project, single-use and multi-use business cases have been made from an economic point of view. This may, however, not always be the right way to look at the viability of floating islands, societal and environmental impacts may be sufficient reason for governments to (also) take a role in floating islands.

For a single application such as an offshore energy support hub, a business case evaluation is a viable approach as there is one main application that can be compared to current approaches. It would then be a joint business case for the Transmission System Operator (TSO) and the Wind Power Park (WPP) owner.

For governments, other drivers such as societal and environmental impact are more important than the economic case. Societal impacts such as the creation of jobs or (space for) housing are worth investing in for a government, like fiscal expenditure in the creation of artificial lands by *soldering* or infilling.

In the Netherlands, many local governments purchased agricultural ground surrounding their cities for rapid rural expansion due to the scarcity of affordable housing. Local governments were tasked with creating space for housing and provided the ground to estate developers to create houses. This is what is called an active ground policy.

At the time of writing this roadmap, The Netherlands again is faced with a scarcity of housing, this time however combined with an increasing scarcity of land. Not only has much of the country been built on, but the remaining natural areas should also be preserved. This greatly increases the stress on the existing rural areas. Local governments should also be looking at the water for a solution. To solve the housing scarcity, authorities can consider an active policy for floating ground.

5. Sensitivity Analysis

5.1 Financial assumptions on rates

A sensitivity analysis was carried out on the financial rates applied to the total costs for the North Sea and Mediterranean islands as shown in Table 5-1. Applied to the FNPV, the weight of each rate is estimated for the combined costs. Each year of the lifetime project has a discount, depreciation, interest, energy increase, maintenance, loan, and salary rate adapted to the use of each modular island. The sensitivity analysis starts at year 1, the financial rates are varied to obtain the sensitivity of the FNPVc.

Table 5-1 Financial Rates applied for both modular S@S islands

Financial Assumptions of the combined BCs for Space@Sea				
Working Case	Living@Sea	EnergyHub@Sea	Transport&LogisticSpace@Sea	Farming@Sea
Discount rate	10%	4%	5%	3%
Interest rate	6%	4%	4%	2.50%
Salary Increase	1.90%	1.94%	1.94%	1.94%
Energy Increase Rate	0.08	0.08%	0.08%	0.08%
Maintenance rate	0.50%	0.50%	0.50%	0.50%
Financial distribution per business				
Public Contribution	20%	20%	20%	20%
Private Loan	15%	15%	15%	15%
Private Equity	15%	15%	15%	15%
EU contribution	50%	50%	50%	50%

The rates distributed to the North Sea and Mediterranean modular island during the financial net present value included discount rates of 20%, 8%, 10%, and 6% for T&L@Sea, EH@Sea, L@S, and F@S respectively. These rates were either distributed over the 25-year projection to both CAPEX and OPEX.

Each application applied a specific rate combination, seen in Table 5-1. For the combined multi-use modular islands, fixing all rates but one and giving a range of values, gives the sensitivity of the FNPVc to that rate. The projected values of the FNPVc are shown to each rate as seen below.

5.1.1 Discount Rate

The curves shown in Figure 5-1 and Figure 5-2 show the rate of change of the $FNPV_k$ for the discount rate. The curve of the Space@Sea multi-use modular island's $FNPV_k$ initial discount rate is discussed in Figure 5-1. By varying this value and distributing it over the $FNPV_k$ of both the Space@Sea modular island and its industry-standard competitor, the impact on the risk of the discount rate can be seen. An increase to a 2% rate, results in an increase of approximately 15% for the $FNPV_c$. This concludes that the discount rate does have an impact on the $FNPV_c$ calculation.

North Sea Business Case

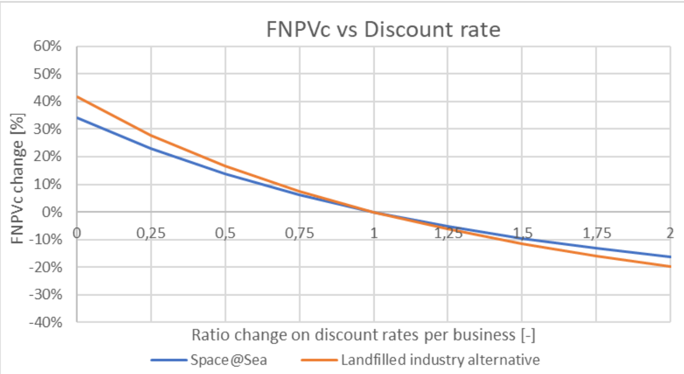


Figure 5-1 FNPVc vs Discount Rate for the North Sea Business Case and alternative scenario

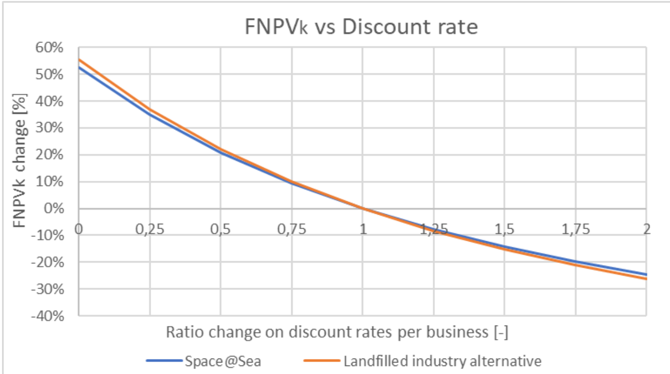


Figure 5-2 FNPVk vs Discount Rate for the North Sea Business Case and alternative scenario

The same approach was used for the sensitivity analysis on the discount rate of the Mediterranean modular island in Figure 5-3 and Figure 5-4. In the case of the alternative scenario and the Space@Sea island that a higher interest, doubled, for example, would result in a much higher decrease in both the FNPVs. In the case of FNPVk vs discount rate, a decrease of approximately 30% is seen in the FNPVc and FNPVk, would be beneficial.

Mediterranean Sea Business Case

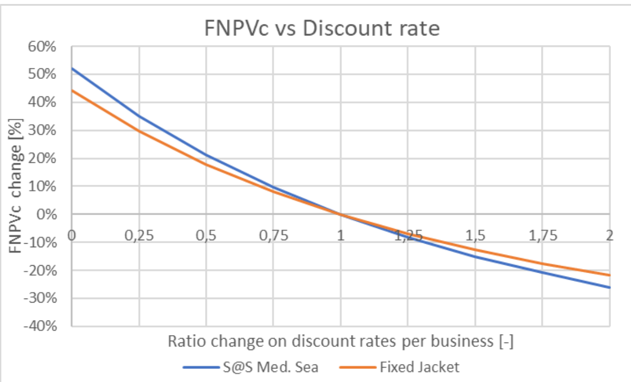


Figure 5-3 FNPVc vs Discount Rate for the Mediterranean Sea Business Case and alternative scenario

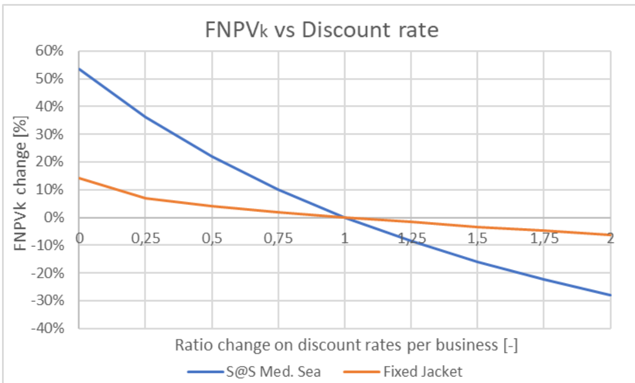


Figure 5-4 FNPVk vs Discount Rate for the Mediterranean Sea Business Case and alternative scenario

5.1.2 Interest

The interest rate varies, depending on each application. These rates have been taken to be 6%, 4%, 4%, 2.5% for Living@Sea, EnergyHub@Sea, T&L@Sea, and Farming@Sea, respectively, as per each deliverable [1] [2] [3] [4]. As recalled from Stakeholders, each application stakeholder committee is responsible for their costs, and the choice of their interest rate. By decreasing the rate to a 0% value, the FNPVc, and FNPVk rate of change, the Space@Sea FNPVk decreases by over 4% and about 4.5% for the landfilled industry alternative.

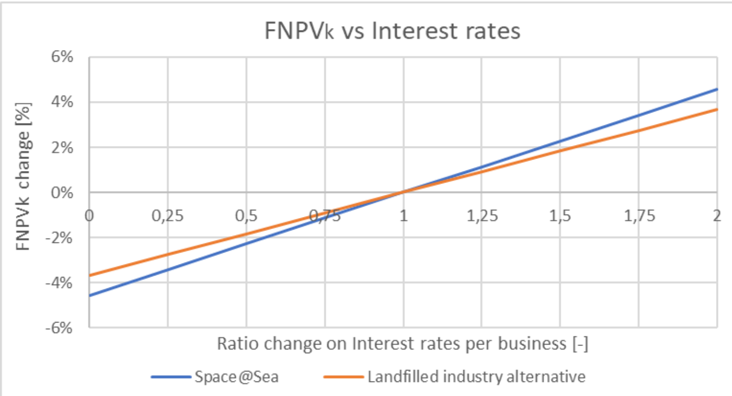


Figure 5-5 North Sea FNPVk vs Interest rate

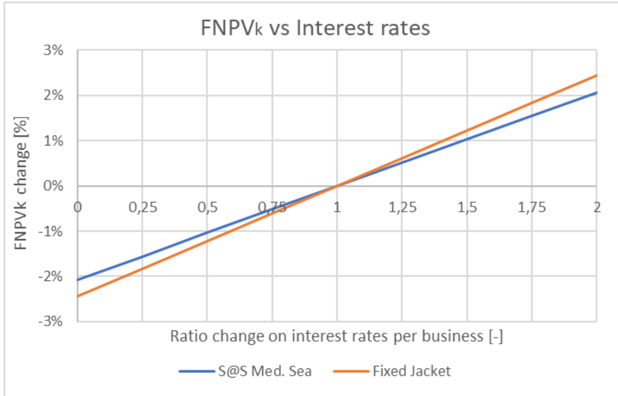


Figure 5-6Mediterranean Sea Business Case FNPVk vs interest rate

5.1.3 Salary Rate

The figures for the North Sea business FNPVc vs salary rate show that, as salary rates fluctuate, so does the FNPV's, as expected. However, over 25 years, the salary rate does not make a significant impact (rate basis of 1.9%) due to the low personnel population. The variations in rate have a minimal impact on the FNPV within the lifetime of the projects. The Mediterranean is relatively more sensitive due to the higher population. Hence, the salary rate for the North Sea is considered as a negligible risk in the combined financials and a medium risk for the Mediterranean. To lower the financial risk in the Mediterranean, searching for more automatization options in the EnergyHub@Sea business could provide solutions. In the case of the salary rate, it is seen that a "medium risk", increasing this rate by 2% results in 14% of the FNPV as shown in Figure 5-7 and Figure 5-8.

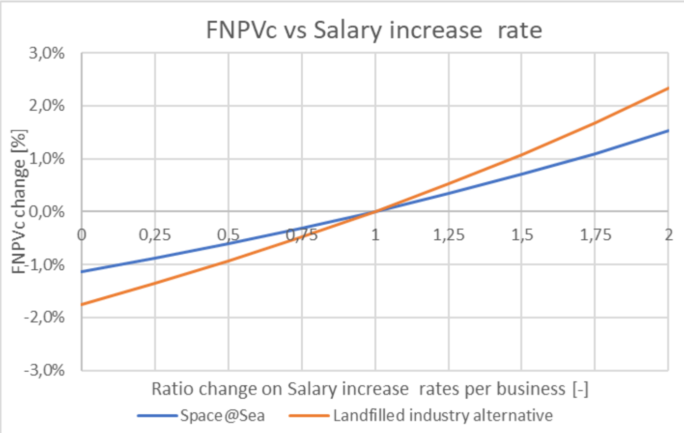


Figure 5-7 FNPVc vs salary increase rate for the North Sea

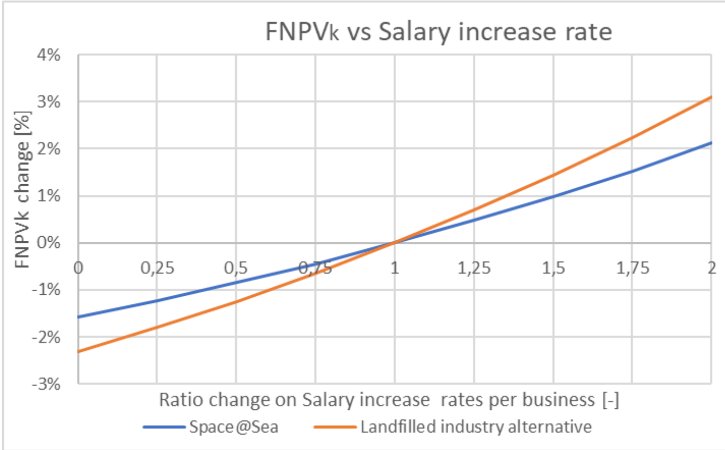


Figure 5-8 FNPVk vs salary increase rate for the Mediterranean island

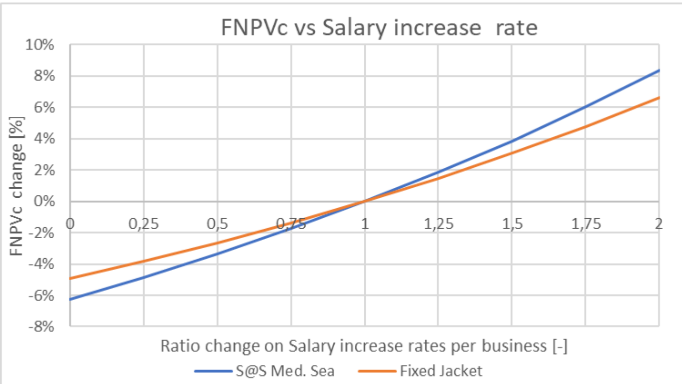


Figure 5-9FNPVc vs salary increase rate for the Mediterranean Sea Business Case

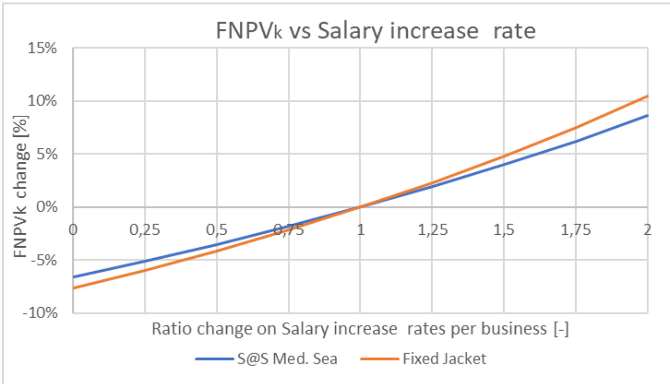


Figure 5-10 FNPVk vs salary increase rate for the Mediterranean Sea Business Case

5.1.4 Energy rate

The FNPV sensitivity for the Energy rate for the Mediterranean Sea business case shows that as energy rates vary so does the change FNPV's, as expected. However, over 25 years, the energy rate does not make a significant impact, due to the low rate basis of 0,08%. The variations do not increase the FNPV within the lifetime of the projects for both business cases. For both, the Mediterranean and North business cases, the Energy rate is considered as a minimal risk in the combined financials.

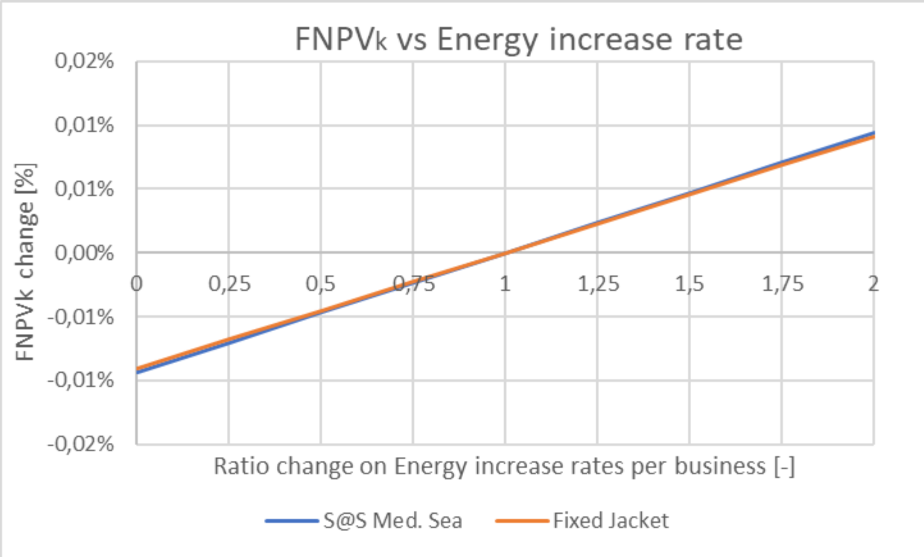


Figure 5-11 Mediterranean Sea Business Case results to imply the sensitivity of the Energy rate fluctuation

5.1.5 Maintenance rate

Increasing the maintenance rate for the North Sea business case, as seen in Figure 5-12, shows the minimum change in both the FNPVc and FNPVk, for Space@Sea as well as the landfill industry-standard alternative. This leads to the conclusion that the maintenance increase rate has a minimal risk on the FNPV calculation.

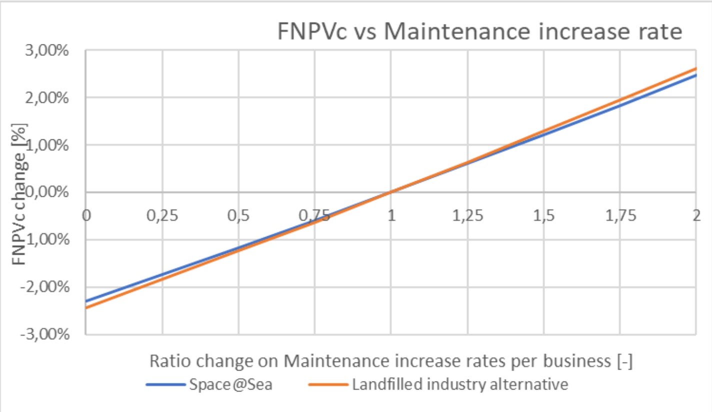


Figure 5-12 FNPVc vs maintenance increase rate for S@S North Sea modular island and landfilled industry alternative

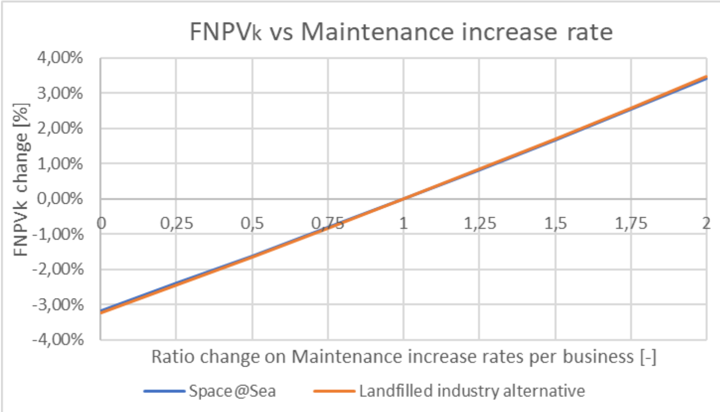
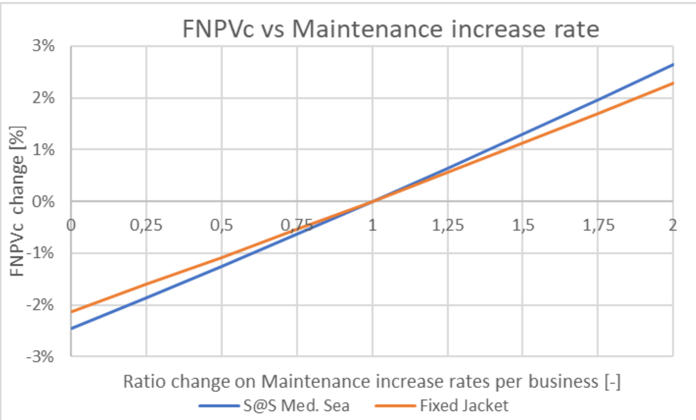
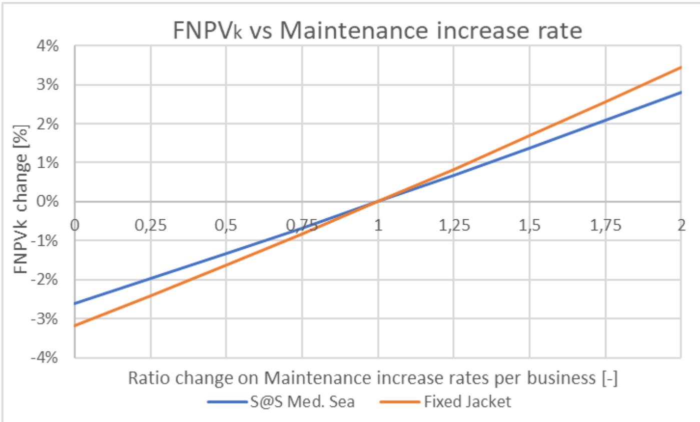


Figure 5-13 FNPVk vs maintenance increase rate for S@S modular island and landfilled industry alternative





The maintenance increase rate is distributed along the FNPVc and FNPVk for both the Mediterranean island and its fixed jacket competitor and varied. The increase of the rate by a factor of 2, results in a decrease in FNPVc and FNPVk would increase overall between 3-4% for the Space@Sea FNPVc, and inversely for the FNPVk.

5.2 Cost of land reclamation

The North Sea business case considers land reclamation as a competitor to Space@Sea and concludes that land reclamation is a better alternative from an economic point of view. However, the land reclamation cost estimates for the North Sea do not provide a global representative. As the Palm Island in Abu Dhabi was created on an average price of €/m³ 125 for similar water depth, an interesting variable alone.

To reflect the impact on the FNPV, an analysis adjusting the cost variables aims at determining the intersecting plane indicating necessary current or future prices or water depth needed to break-even was done. Figure 5-14 and Figure 5-15 show the sensitivity to the $FNPV_C$ and $FNPV_k$ versus the cost of the land reclamation. For the current water depth in the North Sea, the breakeven point for Space@Sea versus land reclamation is approximately 175 €/m^3. The required land reclamation cost decreases rapidly for increasing water depth. However, the price will increase for land reclamation, depending on complexity, or longer vessel transit time. This emphasized the favourability of Space@Sea in deeper sea locations.

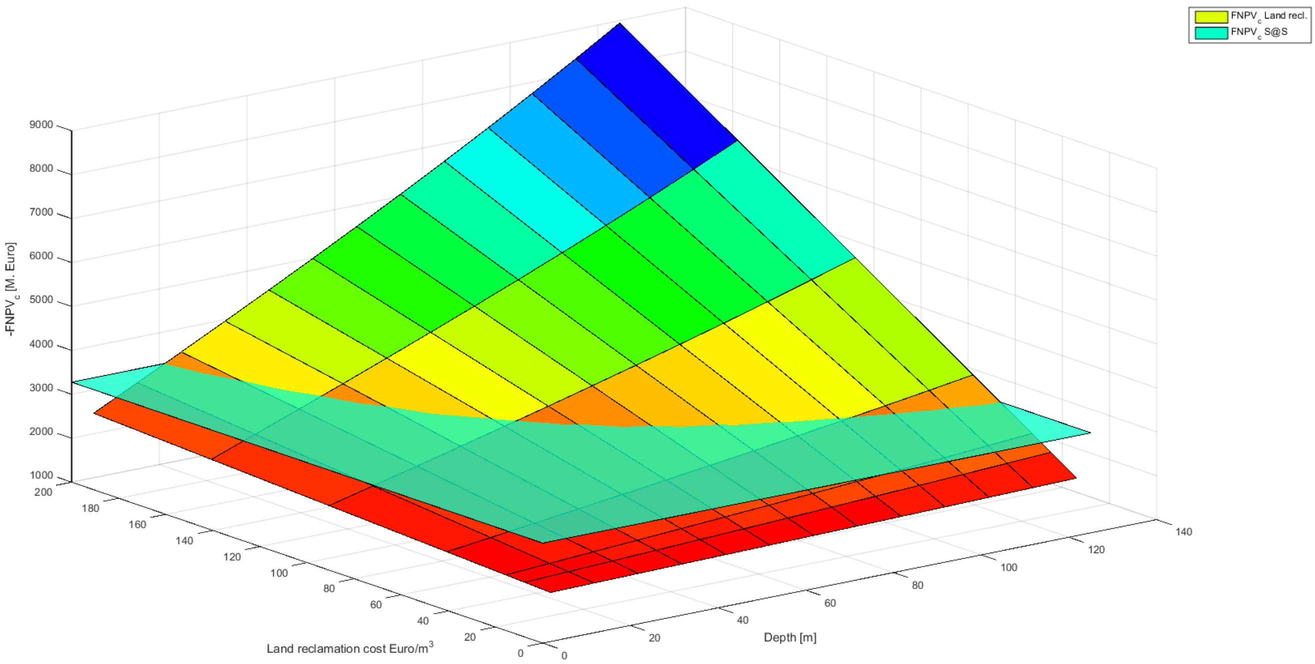


Figure 5-14 Surface plot showing the $FNPV_c$ sensitivity for land reclamation cost and water depth

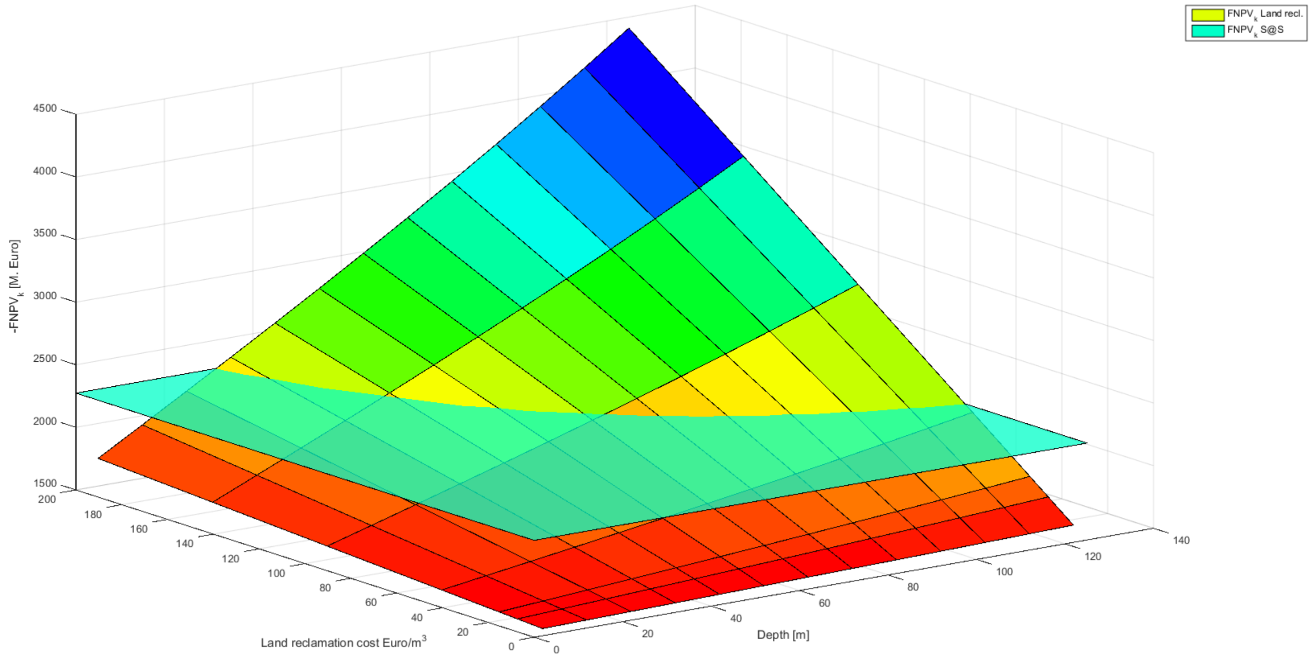


Figure 5-15 Surface plot showing the FNPVk sensitivity for land reclamation cost and water depth

From the $FNPV_k$ point of view, Space@Sea becomes less attractive because of the relatively higher break-even point of approximately 244 €/m^3 of expenditure and accounting for the business case.

5.3 Business risk register

A sensitivity analysis provides information regarding which assumptions are important for the business case outlook. The next step is the qualitative analysis of risks which might lead to significant deviations in variables connected to the adopted assumptions. For this purpose, a Business Risk Register is developed. Once a risk is identified, a probability of occurrence of a risk event needs to be estimated. For the high-level business case a low, medium, and high scale is more suitable. The same scale can also be used to assess impact risk. The performed sensitivity analysis provides valuable insight regarding the potential impact of a risk. If applicable, the effect of risk to cash flows is also recorded. A heat map, like the one shown in Figure 5-16, can then be used for assessment of risk level. Risks falling under the red color category exhibit a high-risk level. For these risks, and initiative-taking response plan is needed. Risks with yellow colour have medium risk levels and a response plan for them might or might not be developed. Risks with a green colour exhibit a low-risk level. They are usually only monitored without adopting a specific response plan until their status changes.

Figure 5-16 Risk Register overview

5.3.1 Financial Risks

The summary of the financial risks, obtained from the sensitivity analysis, are presented in Table 5-2. The risk results towards the financial distribution, reflected in Table 5-2 are extracted from D1.5 T&L@Sea [3]. Combined with the sensitivity performed in section 5.1.1, they imply that the financial data relating to discount rates, private loan amounts, EU, and public contributions have a significant impact on the business case, adding the medium probability of occurrence results in a high-risk level. The loan, salary, and maintenance risk are found to low due to the relatively low impact on the $FNPV_c$ and $FNPV_k$.

Table 5-2 Financial risk register

Financial data	Impact	Probability	Risk Level
Discount rate	High	Medium	High
EU assistance on initial costs	High	Medium	High
public contribution	High	Medium	High
Private equity	High	Low	Medium
Private loan	High	Medium	High
Loan interest rate	Low	Medium	Low
Salary rate	Low	Low	Low
Energy rate	Low	Low	Low
Maintenance rate	Low	Low	Low

6. Conclusions and Recommendations

Space@Sea's main statement states: "17 European partners aim to provide sustainable and affordable workspace at sea by developing a standardized and cost-efficient modular island with low ecological impact". This report has listed benefits in which the sustainable approach of both modular multi-use islands would be met. The North Sea and Mediterranean modular islands, through Space@Sea, set an example of innovation, as it has never been done before, of self-sustainable, employment-generating, service-providing example for other countries and continents such as Asia and America, leading towards a more sustainable future.

The major outcomes of the modular islands include inclusive growth, which requires actions intended to modernize and strengthen the employment and social protection systems. This outcome has been fulfilled by the Space@Sea business case as was shown by the creation of available space and employment which are not readily available and at a remote location: the sea.

This Space@Sea business case evaluates the concept's competitiveness for the Space@Sea modular island concept for the North Sea and the Mediterranean Sea. The comparison of Space@Sea to the locally assumed industry-standard alternative, respectively land reclamation and fixed jacket platform, allowed for an evaluation of the future financially competitiveness if decided that this concept has inevitable to be installed.

The financial analyses of North Sea and Mediterranean Sea business cases give an estimate of the initial costs, operational and maintenance costs for each addition to the business cases, and some projections of the Financial Net Present value of these multi-use islands.

Although the initial expenditures were relatively high for Space@Sea, it has been demonstrated that the concept and alternative scenarios also prove to be quite costly. However, the non-quantifiable benefits of the multi-use modular islands veer towards accomplishing several of the set goals that HORIZON 2020 has established.

The North Sea business case evaluated the CAPEX to be 1,83 times higher and the OPEX to be 1,38 times higher than its competitor, the landfill alternative. The main reason for this high CAPEX difference is mainly due to the relatively shallow water depth of the North Sea combined with a relatively low cost for land reclamation replacing an expensive module substructure. The difference in OPEX is consequently due to the higher cost of maintenance for the substructure of the module and its moorings.

The Mediterranean Sea business case evaluated the CAPEX to be 0,49 times lower and the OPEX to be 0,99 times lower than its competitor, the fixed jacket alternative. The high CAPEX difference is mainly due to the deep-water characteristic of the Mediterranean Sea which results in high initial investment for the jacket structure. The low difference in the OPEX is due to similarities of items for the operation and maintenance for both concepts.

The use of the jacket platform alternative is efficient only in the case of shallow water island creation as the cost of jacket platforms for deep waters increases linearly [2]. The Mediterranean Space@Sea modular island is also a more economically beneficial option concerning the industry alternative standard of the fixed jacket water platform.

The $FNPV_c$ and $FNPV_k$ reflect the cashflow for the cost for 25 years and resulted in the North Sea business Space@Sea were found to be 1,6 and 1,5 times respectively more expensive. Whilst the Mediterranean business case concluded a factor of 0,8 for the $FNPV_c$ and 0,6 for the $FNPV_k$.

Based on the sensitivity analysis and D1.5 T&L@Sea [3], the discount rate and financial initial investment distribution per business are found to have a large impact on the $FNPV_c$ and $FNPV_k$. Resulting in a medium to mostly high-risk level for financial risk assessment. The effect of loan interest, salary, energy, maintenance rates on the $FNPV_c$, and $FNPV_k$ were individually found to have a significant impact and resulted in a low-risk level for the financial risk assessment.

A sensitivity analysis was performed on the estimated reclamation cost [€/m³] versus water depth to evaluate the break-even point for both business cases resulting in the following conclusions:

- $FNPV_c$, for the North Sea, was found at 170 €/m³;
- $FNPV_c$, for the Mediterranean Sea, was found at 46 €/m³;
- $FNPV_k$, for the North Sea, was found at 244 €/m³;
- $FNPV_k$, for the Mediterranean Sea, was found at 64 €/m³.