Formulation of requirements

D10.1

Grant Agreement No.	774253
Start date of Project	1 November 2017
Duration of the Project	36 months
Deliverable Number	D10.1
Deliverable Leader	MARIN
Dissemination Level	CO
Status	V1.0
Submission Date	04-04-2018
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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774253.

Modification Control

Version #	Date	Author	Organisation
V0.1	23-01-2018	J.Schay	NEMOS
V0.2	29-01-2018	W.J. Otto	MARIN
V1.0	07-02-2018	W.J. Otto	MARIN
V1.1	16-02-2018	W.J. Otto	MARIN
V1.1	16-02-2018	J. Schay	NEMOS
V1.2	16-02-2018	W. Murtinu	TU Delft
V1.3	28-03-2018	J. Schay	NEMOS
V1.4	04-04-2018	W. Murtinu	TU Delft

Release Approval

Name	Role	Date
J. Schay	WP Leader	16.02.2018
W. Murtinu	Project Office	04-04-2018
M. Flikkema	Project Coordinator	04-04-2018

History of Changes

Section, page number	Change made	Date
Annex 2, p. 19 - 33	Added filled questionnaires from WP 6-9	28-03-2018
Annex 1	Delete Annex 1	04-04-2018

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Table of abbreviations

GSI	Ground Space Index
WP	Work Package
MSL	Mean Sea Level
TEU	Twenty-foot Equivalent Unit

Executive Summary

The purpose of this document is to summarize and document the results of Task 10.2, which has the objective to formulate the requirements for the design of a modular floating island. The requirements are defined by the four applications Energyhub@Sea (WP6), Living@Sea(WP7), Farming@Sea (WP8) and Transport&Logistics@Sea (WP9). This document contains all necessary requirements of the applications, which will be forwarded to the generic work packages (WP1-5) as boundary conditions for their developments.

1. Introduction

1.1 Approach

After initial discussions with work package leaders, a list with possible fields of requirements was created. This list was further refined into a detailed table. This table was the base for a questionnaire that was distributed among the work package leaders of WP6-9. The format of the questionnaire was more of the generic type in order to not restrict the answers and to allow receiving requirements that have not been thought of.

1.2 Relation to the overall project

The overall aim of the Space@Sea project is to demonstrate the concept of a sustainable, low cost modular floater for multiple applications and functions. It is assumed that the most economical and viable solution can be found by standardizing the floater in such a way that it can be used for multiple applications without the need of large modifications. In order to design such a generic floater, it is important to have a clear overview of which applications have which needs. The present document makes an inventory of the specifications of each application; Energyhub@Sea (WP6), Living@Sea (WP7), Farming@Sea (WP8) and Transport&Logistics@Sea (WP9).

2. Requirement descriptions

In this chapter, the requirements of the different applications are explained.

2.1 Deck space, shape and dimensions

The starting point for the development are equilateral triangles with an edge length of 50m and a resulting deck space of 1,082m² per module. However, as the platform has to serve the requirements of the applications, all dimensions as well as the shape of the modules were open for input from WP 6-9 without any restrictions.

WP6 Energy Hub@Sea

WP6 requires a minimum deck space of 1,400m² per module and a minimum edge length of 40m. However with these dimensions it is only possible to have one wind turbine per four modules. This is assuming to have the energy production in on the module itself.

The requirements for an offshore wind energy maintenance hub are the same. A preliminary proposal for a maintenance hub is drafted in Figure 4 (right). For such a maintenance hub an edge length of 50m is required.

WP7 Living@Sea

WP7 requires a minimum edge length of 100m if the modules are triangular, resulting in a deck space of about 4330m². WP7 recommends to rethink the triangular shape as its ground space index (GSI) is only 30-35% compared to rectangular shapes with GSI of 35-50%. GSI describes the proportion of space covered by buildings in relation to the overall space. A detailed discussion on triangular shapes can be found annexed. In case of square module shapes, WP7 requires a minimum edge length of 50m. Possible module formations and resulting GSI are shown in figure Figure 1 to Figure 3.

In case of triangles with less than 100m edge length, WP7 requires rigid connections between several modules to build larger triangular submodules that can be combined to a supermodule in the shape of a hexagon or decagon, as described in 2.2.

WP8 Farming@Sea

WP8 does not have specific requirements regarding the deck space and edge lengths. However 50m is regarded as an appropriate edge length for equilateral triangles.

WP9 Transport&Logistics@Sea

Assuming 20,000 TEU container ships, WP 9 requires a quay length in the order of 400m which corresponds to a ship length. For the quay sides, single modules are advised as it is expected that mooring ships to multiple smaller islands would lead to too large deflections. The very different heights of ships should also be taken into account regarding the design of the quays.

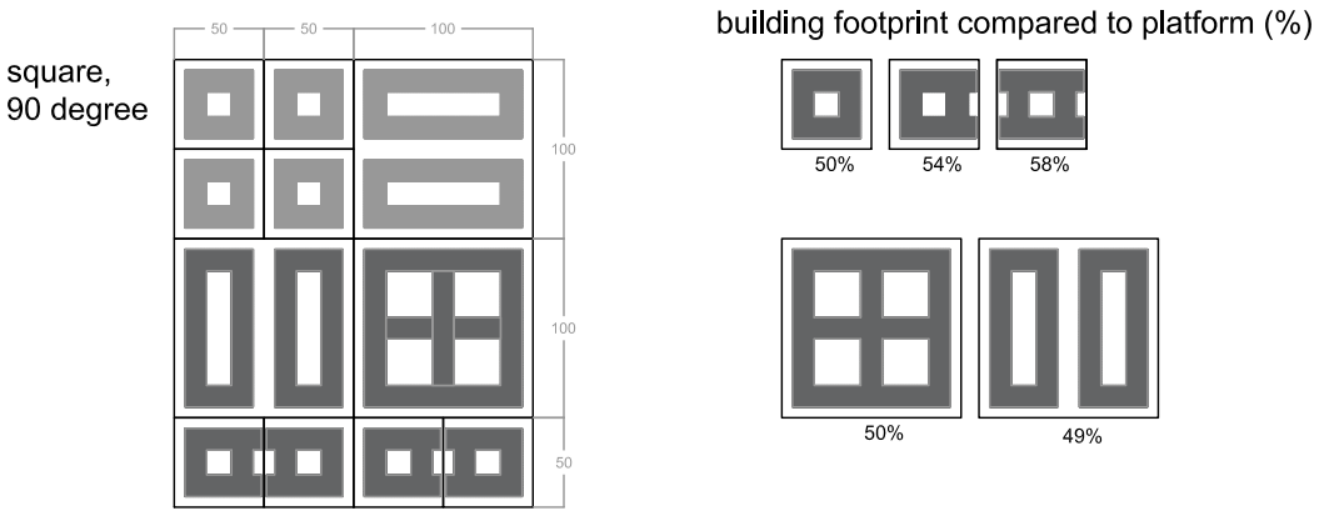


Figure 1: possible layout of buildings on square modules with 50m and 100m edge length and resulting building footprint (GSI), from WP7

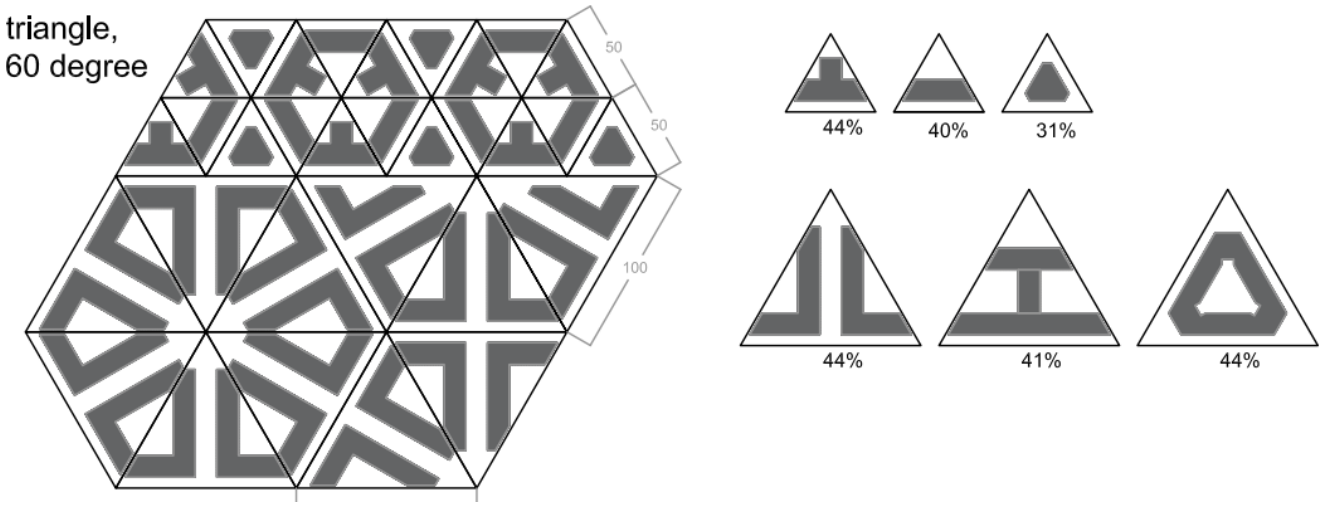


Figure 2: possible layout of buildings on equilateral triangular modules with 50m and 100m edge length and resulting building footprint (GSI), from WP7

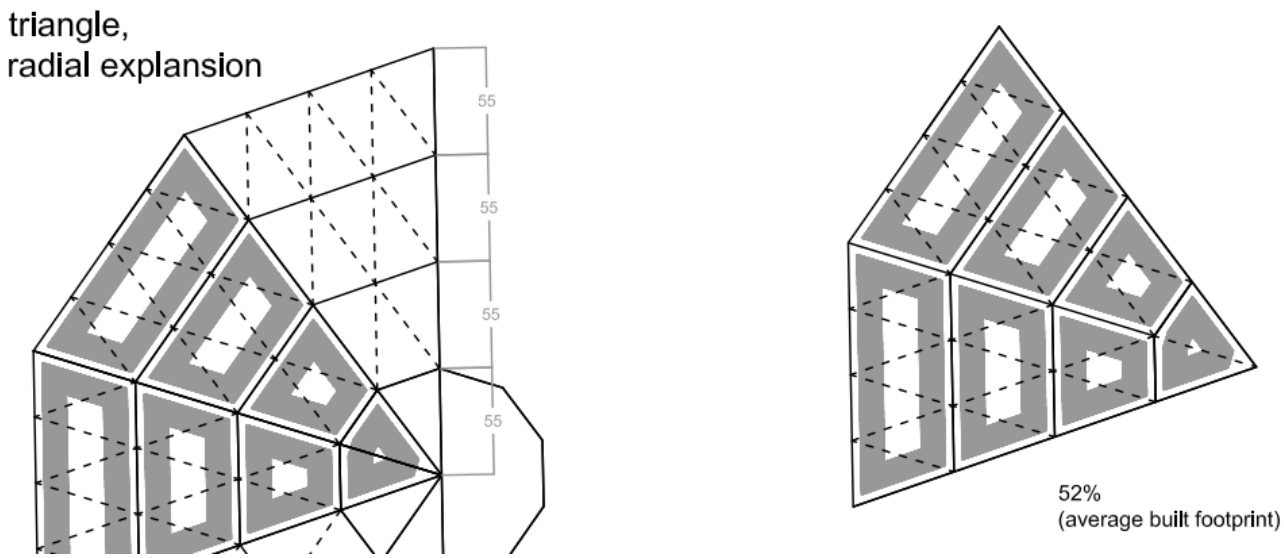


Figure 3: possible layout of buildings on isosceles triangular modules with 55m edge length, 36° opening angle and resulting building footpring (GSI), from WP7

2.2 Formation

WP6 Energy Hub@Sea

WP6 proposed formations of four triangular modules as shown in Figure 4.

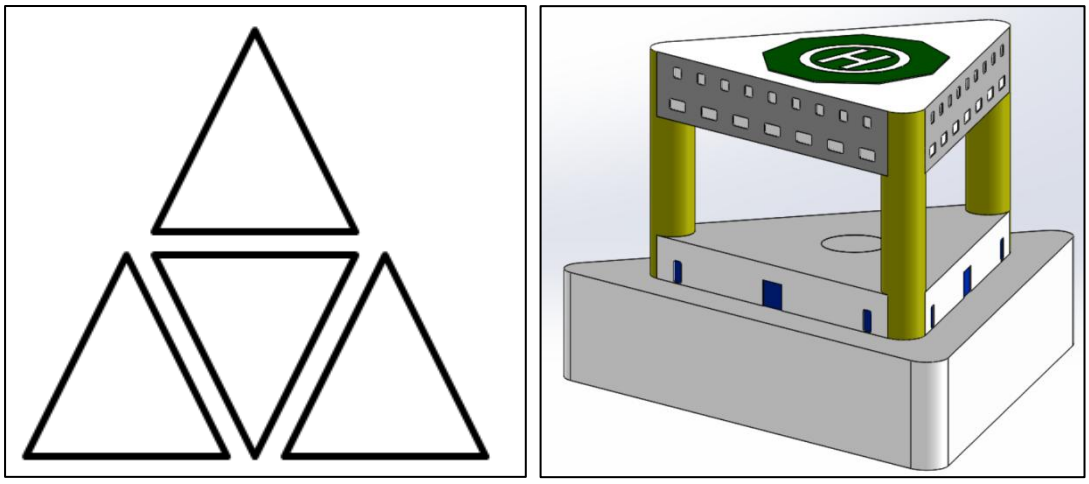


Figure 4: (left) desired module formation of WP6; (right) Windenergy O&M hub on one module of WP6

WP7 Living@Sea

WP7 proposed to create bigger triangular substructures by rigidly connecting base modules as illustrated in Figure 5. By this method the GSI on these substructures can be raised to 52%. These substructures can be combined to superstructures of different shapes. A favourable shape could be a decagon where as shown in Figure 6. This configuration is efficient by means of GSI and is alike the layout of the city of Amsterdam. Smaller substructures or single modules can be added at the outside of this configuration by hinges that allow certain degrees of freedom. These smaller elements can serve for other applications such as wave energy conversion, aquaculture or logistics. The approach to combine several modules to substructures can also be realized with equilateral triangular modules as shown in Figure 5 (left). Here the equilateral triangular modules form a hexagon substructure that can be further extended by adding modules (light grey). Figure 5 also shows the possibilities of combining square shaped modules with triangular shaped modules.

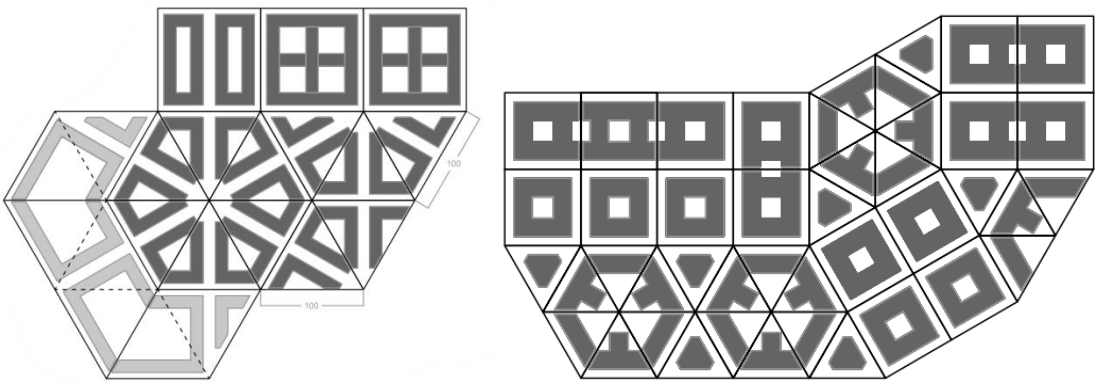


Figure 5: possible combinations of large squares and triangles (left) and small squares and triangles (right) by WP7

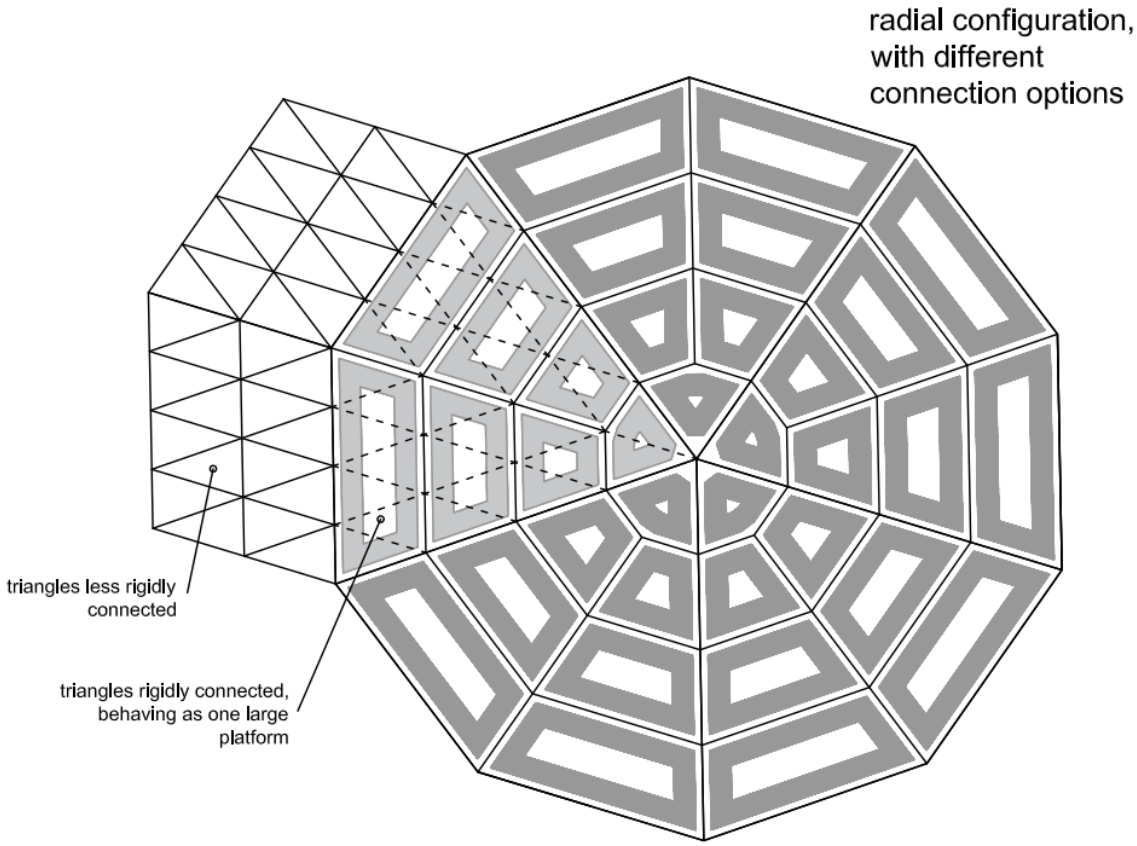


Figure 6: Radial configuration of substructure modules by WP7

WP8 Farming@Sea

WP8 proposed several different formations depending on the actual aquaculture application:

Depending on the location where the floating island is installed, fish/microalgae/seaweed may not be held in cages (due to environmental conditions) and therefore culturing in tank systems on deck may be an option as indicated in Figure 7. This setup might require rigidly connected modules however economic considerations will determine what dimensions are required.

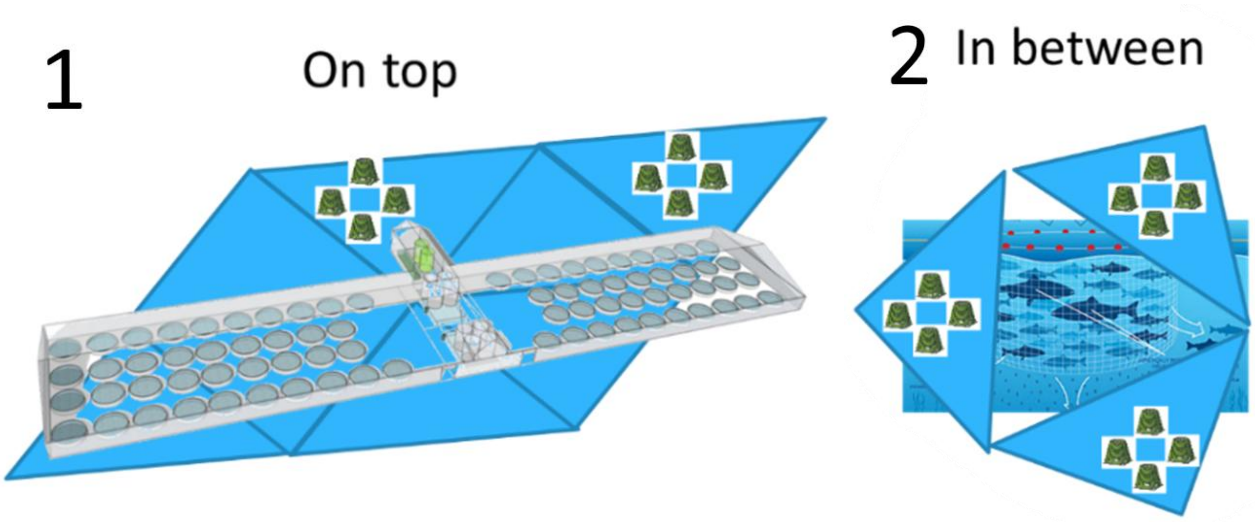


Figure 7: Aquaculture farming in tanks systems on deck (1, left). Aquaculture in between the modules (2, left) by WP8

Another option is to arrange the modules in a way to have a kind of harbour in between the modules. This might be suitable for culturing fish and shellfish (mussels). For seaweed and microalgae, shadowing by the floating modules

might create less favourable conditions, as the available light in the water column in between the modules is insufficient. The described setup is sketched in Figure 8. The sketched setup is just an example – the idea is to use the spaces in between module formations.

For a more rigid setup, the spaces in between module formations could be filled with special modules. These modules would serve as rigid frames for the created pools. Therefor the special modules have to comply with the standard modules in terms of dimensions, interfaces, hinges and so on.

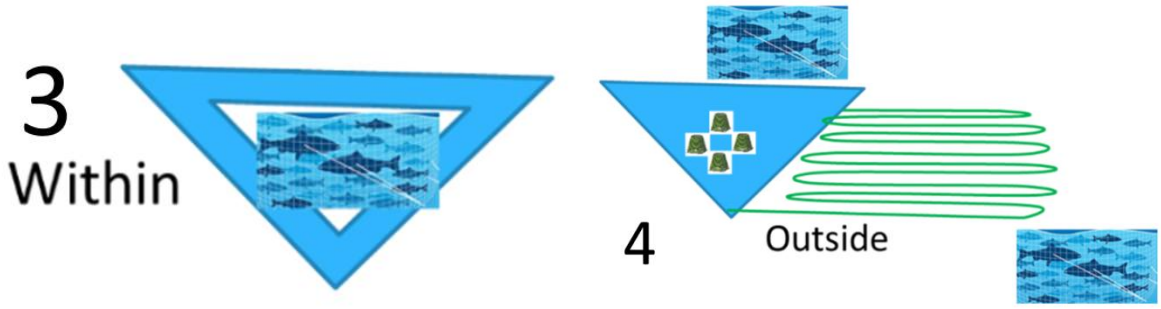


Figure 8: Special modules creating a pool (3, left); Aquaculture connected to a module at the outside (4, left) by WP8

Culture systems could also be secured to a module on the outside border of the floating island, or could be anchored independently. In the latter case, the floating island may serve as working deck, but the culture system itself could be independent from the floating module(s) structure. This option is sketched in Figure 8 (right).

WP9 Transport&Logistics@Sea

WP9 needs to make further investigations to define specific requirements on the formation. It can however be assumed that a sheltered area needs to be created for safe offloading, with for instance a narrow port entrance and a wider open area with quay sides. A quay length of 400m is required to accommodate large container vessels. However the dimensions of the ships are dependent on the location of the island.

1.3 Loads

WP6 Energy Hub@Sea

WP6 made an assumption on the loads of an Operation and Maintenance (O&M) Hub module with an edge length of 50m as shown in Figure 4. The expected overall mass of infrastructure, equipment, stock etc. sums up to 1799t plus 100t for temporary operation. The components included in this estimation are shown in Table 1.

A wind turbine that will be installed on one of the modules has a mass of 40t.

	Mass [t]	**Centre of mass above module surface [m]**
O&M stock hall (concrete)	511	2,5
support columns (steel)	234	10,5
building (steel)	835	18,0
people & equipment	6	18,0
living supply stock	4	18,0
fresh & waste water tanks	135	-1,0
O&M stock	74	1,0
in total	**1799**	**1,4**

Table 1: Estimation of masses for an O&M hub module for WP6

WP7 Living@Sea

WP7 estimated an overall mass of superstructure per inhabitant. This mass includes everything that is built on top of the floating modules in terms of buildings. The rough estimation is that 18t superstructure is required per inhabitant. This is based on the assumption of an overall platform size of 10.000m² with 400 inhabitants and results in a total load of 7200t for a platform of this size. A platform of this size could consist of eight equilateral triangular modules with an edge length of 50m each.

This estimation however does not consider additional infrastructure and equipment that is required as for example fresh water, waste water, supplies, furniture and more.

Living@Sea	Amount	Unit		Manhatten example	Amount	Unit
People:	400,00	pc		**People:**	3900000,00	pc
Weight pp	82,10	kg		Weight pp	82,10	kg
Total	32840,00	kg		*Total*	352950	tons
Pets	12	pc		**Pets**	238500,00	pc
Pets per person	0,03			Pets per person	0,06	
Weight pet average	10,21	kg		Weight pet average	10,21	kg
Total	122,52	kg		*Total*	2683	tons
Food/Drink				**Food/Drink**		
Food/Drink per person	28,64	kg		Food/Drink per person	28,64	kg
Total	11455,93	kg		*Total*	123123	tons
Vehicles (car, train, cab, truck, crane etc.)				**Vehicles (car, train, cab, truck etc.)**		
Average vehicle (here taken the car (toyota cambry)	1496,85	kg		Average car (toyota cambry)	1497	kg
Vehicles weight per person	149,69	kg	10,00%	Vehicles weight per person	557	kg per person
Total	54316925	kg		*Total*	2394111	tons
Roads and Sidewalks				**Roads and Sidewalks**		
weight per person	1000,00	kg		weight per person	971	kg
Total	400000	kg		*Total*	4176000	tons
Buildings				**Buildings**		
Average building	70,00	tons		Average building	70	tons
Amount of (average) buildings	173			Amount of (average) buildings	1687994	
Ratio average buildings vs. person on island	43%			Ratio buildings per person	43%	
Weight per person	30	tons		Weight per person	30	tons
Total	10994115	kg		*Total*	118159600	tons
Sum	65755458	kg		*Sum*	125208467	tons
Other stuff	10%			**Other stuff**	?	
Total	7248	tons		***Total***		
Tons per inhabitant	**18**	**tons**			**32**	**tons**

Figure 9: Assumption on masses by WP7

WP8 Farming@Sea

The loads from WP8 are dependent on the actual application that will be deployed. An assumption can't be made at this stage. However the following infrastructure will be required:

- Equipment (cages, bioreactors) needs to be secured on / to the modules
- Cranes for deploying culturing systems and harvesting
- Air compressors and CO_2 tanks are necessary for microalgae production

WP9 Transport&Logistics@Sea

The loads from WP9 are highly dependent on the cargo type and thus on the location. A preliminary assumption can't be made at this stage. However the following infrastructure will be required:

- Multiple Cranes for transport hub
- Rails for crane operation
- Optionally transport equipment (depending on cargo type)
- Storage area (mass depends on capacity and cargo type)
- Cranes for service cargo
- Housing/infrastructure for workers

2.3 Environment

WP6 Energy Hub@Sea

WP6 requires being close to a wind farm in order to serve as an offshore wind maintenance hub. For security reasons a minimum distance of 1000m to the next wind turbine is required. Concerning the climate, temperatures between 5°C and 45°C are feasible. Temperatures exceeding this range will cause additional technical effort.

For wave energy conversion an area with a constant wave climate would be favorable. This means the extreme wave heights should not deviate too much from the average wave heights.

WP7 Living@Sea

WP7 requires the platform to be located within a few kilometers from shore for the business case where the platform serves as an extension to an existing urban environment. Long distances to the shore can only be accepted if the business case is interesting enough to justify long travel times.

Good water quality is assumed, that is not contaminated or smelly. Moreover, comfort shall also imply that the inhabitants of the Space@Sea platform will not be impaired by too much noise (as by e.g. through the functions of WP6, 8 and 9). This has to be taken into account and evaluated when combining various functions in a platform. Also the noise caused by the water and winds should be taken into account.

WP8 Farming@Sea

WP8 does not have a distance requirement to other infrastructures, however it is pointed out that shipping routes hold the risk of pollution which is harmful to aquaculture. Harbors are potentially required for handling, processing and marketing of the products.

For option 2, 3 and 4 of the module formations as described in 2.2 and sketched in Figure 7 and Figure 8, a minimum water depth of 60m is required.

Generally the salinity has to be between 30g/kg and 35g/kg and should be constant. The water temperature depends on the species and location. No requirements were named yet, however it has to be considered. The turbidity of the water should be preferably low. The current speed should be below 1m/s. The water should be supplied with sufficient oxygen and carbon dioxide which is assured through air-water exchange.

WP9 Transport&Logistics@Sea

A water depth of at least 25m is required in order to accommodate the largest ship types. Furthermore, the economic viability of the logistics requires the minimisation of cargo handling costs and the prevention of additional changes of the carrier. Cargo that is transhipped from one sea-going vessel to another sea-going ship (e.g. containers from a large intercontinental ship to Feeders) is not the problem. If the destination is in the hinterland and can be reached by short sea ships, sea-river ships or inland vessels, it is required that these vessels can (and are allowed to) operate between the island and the connected inland waterway for at least 300 to 330 days per year. Only few inland vessels are designed to operate in the well-defined zone 1 (H_s<=2.0 m) or zone 2 (H_s<=1.2 m). Dedicated sea-going solutions with small air draught like the lighters from the German BiWi project connecting the Jade-Weser-Port Wilhelmshaven to the Weser are limited to H_s <= 2.5 m. Therefore, the calmest location possible is preferable for WP9.

2.4 Platform response

The platform response describes the accelerations and deviations that the platform experiences due to external forces.

WP6 Energy Hub@Sea

WP6 demands a maximum horizontal acceleration of 2m/s² at 60m above MSL and a maximum inclination of 7 degrees from the vertical plane. As these requirements come from the wind turbine specifications it has to be considered, that the wind turbine tower itself inclines about 1 degree.

WP7 Living@Sea

WP7 has a focus on the comfort of the people inhabiting the Space@Sea platform. Therefor vertical accelerations should be kept below 0,25m/s². As cruise ships have an upper limit of 0,2m/s², this could also be the benchmark that should be achieved.

WP8 Farming@Sea

WP8 points out that wave and wind induced motions on the platform can interfere with operations, but limits are hard to quantify at the moment. It is assumed that for workers on the platform the requirements should not be different to the requirements of WP7.

WP9 Transport&Logistics@Sea

Will specify their requirements for platform response in a later stage.

2.5 Power consumption

WP6 Energy Hub@Sea

Estimates that an energy hub will consume 50 to 500 MWh on a yearly base.

WP7 Living@Sea

When assuming a platform of 10.000m², which is slightly more than 9 equilateral triangles with 50m sides, and 0,4 inhabitants/m² with an average consumption of 5,9MWh/capita/year electrical power consumption (see link below), the yearly power consumption would be 2,360 MWh. This is defined as the production of power plants and combined heat and power plants less transmission, distribution, and transformation losses and own use by heat and power plants. This number already includes all infrastructure and industries / economies.

Depending on the location there will be peak times during the day, when people are at home as well as peak times throughout the year for heating/cooling purposes by instance.

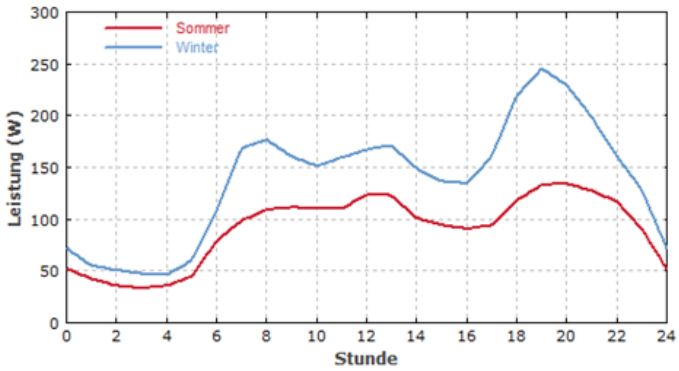


Figure 10: Variation of power demand during 24h

WP8 Farming@Sea

For option 1, a pumping system for continuous water supply will be needed. Power consumption will depend on the dimensions of the culture systems and the distance (height) between the suction point (under water) and the level (above water) of the systems on deck. Also which species is farmed will influence on the water supply needed, and thereby the power consumption. If the system is RAS-based the water supply will be very small compared to a “throughput” system.

For all options, harvesting and unloading (of the harvest) will require cranes that need power supply during these (irregular) activities.

Storage (deep freezing) requires continuous power supply.

For example, the microalgae cultivation option with maximum load on triangle for inoculation and actual production next to platform requires at least the following, depending on the actual size and application (regular/peak load):

- 6 kW/12 kW for pumping inoculation system (or less, depending on amount of inoculation units)
- Up to 10 kW/15 kW for harvesting (centrifuge) - temporary
- 1 kW/2 kW for pumping production unit per module – temporary

WP9 Transport&Logistics@Sea

The power consumption can’t be quantified at this stage. But power consumption will see peak times during cargo unloading and handling. Furthermore power consumption can arise from ‘shore based power’ (cold ironing) while ships are moored / docked.

2.6 Personnel

WP6 Energy Hub@Sea

24 – 40 permanent persons on the platform and 5-10 temporary. The staff will stay on the hub for max. 2-3 weeks. Then a new crew will take over.

WP7 Living@Sea

Living@Sea intends to enable living comparable to land. Consequently, no specific jobs need to be created that exclusively serve the city besides upcoming administrational tasks. Due to that reason, it is estimated that personnel will play a very little role in the Living@Sea concept and therefore can be left unattended. The distance to the shore however, does play an important role in the job typologies. Whereas if very close to shore, law enforcement, doctors etc. could be close to the floating island but not literally present, being further from shore this would be another case.

WP8 Farming@Sea

WP8 made the following assessment, which should be considered as a preliminary guess:

1. The working platform will be used like a ship, i.e. it will serve as a working space that enables operations needed for stocking and harvesting
2. Some processing will take place on the platform. This could include the preparations for
    a. installing equipment (nets, ropes, cages, PBR-collectors ...),
    b. stocking of systems (with small fish, seaweed, microalgae etc.) and
    c. processing of harvest (e.g. cleaning, drying, extraction, etc.) to (semi)finished products
3. Aquaculture systems (including also microalgae cultivation systems) will be used that require full time control by trained personnel.

Table 2 lists the required personnel for these three options.

Option	Number of personnel	Duration of stay
1	5	1 week
2	10	permanent
3	20	permanent

Table 2: Required personnel by WP8

WP9 Transport&Logistics@Sea

Dependent on the size and the equipment on the hub, the following personnel are a minimum requirement:

- 1 operator per crane/shift ~ 4 shifts a day (assuming 24/7 operation)
- 1 operational planner ~ 4 shifts a day
- 1 terminal/hub control ~ 4 shifts a day

Supportive personnel:

- Maintenance
- Facility management

3. Conclusions

In order to design a sustainable, low cost modular floater for multiple applications and functions, an inventory has been made of the specifications of each application; Energyhub@Sea (WP6), Living@Sea (WP7), Farming@Sea (WP8) and Transport&Logistics@Sea (WP9). There requirements will serve as starting point for the basic design.

The requirements stated in this document are based on basic assumptions. It has been communicated by all work packages, that at this stage of the project, the development of the applications is in a very early stage. Further, many requirements are highly dependent on the location of the island and can therefor only be defined after possible locations have been named. This leads to the conclusion, that this document should be revised and updated from time to time in order to bring the requirements to a more detailed and well-founded level.

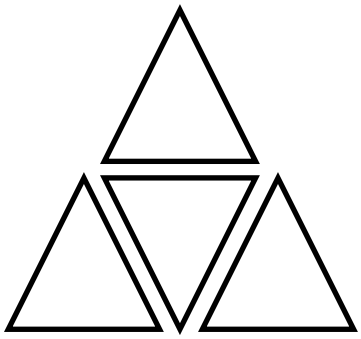
However, the following conclusions can be derived from the document so far:

Triangular shaped modules are an option if the edge length is sufficient. From WP7 the requirement is 100m edge length. From WP9 a quay length of 400m is required. This requirement is hard to fulfil, as manufacturing of such a large structure would be quite difficult if possible. However if smaller modules of around 50m can be rigidly connected, there are many possibilities to create larger substructures that fulfil all of the applications' demands. Therefore one requirement is to develop two kinds of connecting joints:

- **Rigid connection joints** allowing the creation of different layouts that suit the applications' requirements. This enables to create deck space and quay lengths independent from the single module size.
- **Hinge joints** to reduce forces in the overall structure and to enable applications such as wave energy conversion.

WP7 recommends rethinking the initial approach with equilateral triangles. The proposed shapes and formations should be investigated from the hydrodynamic point of view.

Annex 1: Requirement questionnaires

WP: 6	**WP leader: Frank Adam**
Deckspace: Describe how much deckspace is approximately required by your application (per module, in total). If applicable add minimum/maximum values for single floater module length and width.	
At the moment we assume with a triangle of 50 site length (ca. 1400m²). Less would be possible, but not less 40m! More would be good, but please consider fabrication issues. If we need significant more space, we have to combine more than one triangle. At the moment we are assuming a minimum of 4 triangles with a site length of 50m (ca. 5600m²).	
Module formation: Describe/draw/sketch how a favourable module formation could look like for your application.	
	
Environment: Describe all requirements that your application has to the environment. Where applicable provide numerical values or ranges. Environmental requirements can include but are not limited to: Distance to shore, shipping routes, harbours, wind energy farms …, water depth, soil type, turbidity, salinity, temperature (air/water), current velocity, …	
There should be no special requirements to environment. Distance to Wind farms as near as possible (max 1000m distance). Perhaps direct in the centre of a farm with a distance of 5*D D=200m to the next turbines.	

Safety and Comfort: Describe limitations and requirements in respect to the safety and comfort. This can be for example maximum accelerations, maximum inclination …
Maximal acceleration at the tower top of the wind turbine (40m TP – TP level assumed +20m MSL) = 2m/s² Maximal inclination at the tower top of the wind turbine (40m TP – TP level assumed +20m MSL) = 7° Maximal movements and accelerations for the service staff will be defined by WP7. A solid temperature range is between 5 to 45 °C. Conditions differing from these causes additional technical expense. It will be a solid waterproof container (for the energy storage system). The access will be limited to qualified electricians.
Infrastructure and technologies: Which infrastructure is required for your application? Workshop, storage, roads etc. What kind of technologies will be required for your application – e.g. cranes, wind turbines … ? If possible provide an approximate mass.
Small workshop, storage for wind farm O&M, storage for staff, housing, service ways to and from the applications, HSE application (e.g. safety boats etc.) Cranes, Wind turbine (ca. 40t), PV, Energy Storage system, Housing incl. the needed comfort (single rooms, kitchen, gym, etc.) for service staff
Power consumption: What is the approximate power consumption of your application? How is it distributed? Are there peak times with high demands?
50.000 – 500.000kWh per year, no peak times available at the moment – only average values. The values have to be confirmed and proven in collaboration also with WP7 and based on our own design
Personnel: How much personnel are required for your application? How many permanent / temporary?
We assume at the moment 24 – 40 permanent persons on the platform and 5-10 temporary. The staff will stay on the hub for max. 2-3 weeks. Than a new crew will take over.

WP: 7	WP leader: Karina Czapiewska

Deck space:
Describe how much deck space is approximately required by your application (per module, in total). If applicable add minimum/maximum values for single floater module length and width.

Definition WP7 application: existing city expansion, city development, “living island”, independent living island

Deck space approximately required by application per module:

In question 2 we describe that we would prefer a different shape to the proposed triangles as we fear that it will be difficult to use the platform efficiently with triangular shapes.

If the shape will stick to triangular shapes, we would advices to make the shapes relatively big in size to prevent the shape restricting efficient floor plans. In that case we estimate that we would be able to reach a GSI of 30-35%. Meaning that 30-35% of the module would be covered with building blocks. However, we think that with another shape than triangles we would be able to reach a ground space index (GSI) of 35-50% per module.

From our point of view, convenient dimensions are:
Square modules: min about 50 m x 50 m
Triangular elements: min 100 m per side

Module formation:
Describe/draw/sketch how a favourable module formation could look like for your application.

We would like to suggest to rethink the triangular shape of the modules as we fear challenges arising from the triangular shape. The root of this concern will be explained in the following:

Triangular grids, more often referred to as ‘hexagonal urban plans’, have fascinated urban planners for centuries. Yet, only two hexagonal plans have ever been executed.

One of the first hexagonal city plans was proposed in 1807, aimed at rebuilding Detroit after the 'Great Fire'. The plan was designed by Augustus Woodward and used triangles of 2500 ft (760m). The triangles were split up into two superblocks that were further subdivided into 8 city blocks. While the design covered over 4 sq km (and potentially more), only 0.5 sq km was realized. The plan was abandoned after about a decade, and none of the triangles was fully completed. While local stakeholder dynamics and politics likely share in the blame, it can be argued that Woodward's urban plan, ultimately, did not offer the flexibility that a booming city required.[1]

Nearly a century later, around 1900, several urban planners and architects embraced hexagonal urban plans again.[2] Their efforts finally saw one plan executed: Lutyen's design for the capital of imperial India: New Delhi. This urban plan, designed in 1912, was based on triangles of 350 m that were to be lined with grand monumental buildings and spaciously planned villas (Luyen's Bungalows). The plan was almost entirely built and Lutyen's work was received with critical acclaim for the efforts to fuse western and local styles.

In the last century however, the period in which 80% of today’s cities were built, not one additional hexagonal

[1] http://detroiturbanism.blogspot.nl/2016/06/woodward-plan-part-iii-interruptions.html
[2] Ben-Joseph, E., & Gordon, D. (2000). Hexagonal planning in theory and practice. *Journal of Urban Design*, *5*(3), 237-265.

plan has been attempted. The 'gridiron' plan (a regular orthogonal grid), originating as far back as the Ancient world, continues to be the most dominant urban plan. Yet hexagonal plans, while attempted by architects today, remain only on paper.

Feasibility for floating urbanization
Of the two existing hexagonal cities, only Detroit was designed for a density that could be applicable to an (extensive) floating city on the sea, but it would still have its issues. Not only did this plan somehow fail to be completed, it also featured triangles of 760 m. Such a size would be impossible to construct as a single floating structure. The triangles of Detroit could of course be scaled down (and broken up into two parts), but this would still require triangles with a side of about 300 m and is likely to result in lower densities than the initial plan.

Urban development is not the only system that would be challenged by a hexagonal plan of limited proportions. High-yield agricultural systems are also organized in a linear (orthogonal) fashion, as are manufacturing plants and many other industrial sites. Triangles will present a difficulty in finding a use for the extremities (the three pointy parts).

Alternatives
While a hexagonal plan may not be ideal for cities, an orthogonal grid may not be ideal for marine applications. This discourse is not a testament for square platforms. What is claimed is that the most optimal marine solution will not automatically be an appropriate solution for urban development. In order to develop an optimal concept, the objective is to find a system that is optimal for both dealing with the marine environment and providing an efficient space for its functions. To illustrate how this could work, we are currently working on sketches which we will send in a separate e-mail by the end of this month.

Environment:
Describe all requirements that your application has to the environment. Where applicable provide numerical values or ranges. Environmental requirements can include but are not limited to:
Distance to shore, shipping routes, harbours, wind energy farms …, water depth, soil type, turbidity, salinity, temperature (air/water), current velocity, …

- **Location:** Concept must be placed in a location where economic opportunity/ an interesting business case will be provided (this aspect was one of the main selection criteria for our location selection paper that we are working on for WP1)

- **Distance to shore:** Restrictions arise from the fact that a long distance to the shore can only be accepted if the business case is interesting enough that people would accept the travel time until the platform → until now it is assumed that with a living island/ urban expansion platform the distance to the shore should be kept within a few km from the coast

- **Water quality:** A location with good water quality is assumed (no smell/ contaminations etc.)

- **Character of the water:** current velocity, wave lengths, accelerations etc. must be kept within a limit so that a comfortable living situation is ensured and in critical weather conditions, the safety.

Safety and Comfort:
Describe limitations and requirements in respect to the safety and comfort. This can be for example maximum accelerations, maximum inclination …

Human comfort is of very high importance for Living@Sea. Comfort can be described in many ways, however here comfort is mainly characterised by people being able to go after their everyday task as they would onshore. Therefore, an absence/limitation of people getting motion sick is the absolute minimum requirement for such a project.

Moreover, comfort shall also imply that the inhabitants of the Space@Sea platform will not be impaired by too much noise (as by e.g. through the functions of WP6, 8 and 9). This has to be taken into account and evaluated when combining various functions in a platform. Also the noise caused by the water and winds should be taken into account.

Safety standards for multi-use offshore platforms will integrate both safety standards from on land urban planning, as well as already existing safety living and building standards from the offshore industry. The combination of these standards, as well as filling the gaps of these safety guidelines do not exist yet and will be the task of WP7.3.

There are no norms for multi-use platform requirements yet available, however some orientation points already exist, such as:

- **Motion sickness**
  1. Colwell, J. L. (1989). Human factors in the naval environment: a review of motion sickness and biodynamic problems (No. DREA-TM-89/220). DEFENCE RESEARCH ESTABLISHMENT ATLANTIC DARTMOUTH (NOVA SCOTIA).

  2. ISO 2631-3,1985
     Mechanical vibration and shock - Evaluation of human exposure to whole-body vibration

  3. Table 1: Vertical acceleration limit criteria, Table 5: Severe seasickness level
     https://www.shipjournal.co/index.php/sst/article/view/140/406

- **Noise**
  1. Comfort and Health on-board Offshore Units - ADDITIONAL REQUIREMENTS FOR NOTATION COMF HEALTH-NOISE
     https://www.veristar.com/portal/rest/jcr/repository/collaboration/sites/veristarinfo/web%20contents/bv-content/generalinfo/giRulesRegulations/bvRules/rulenotes/documents/636-NR_2016-12.pdf

- **Safety**
  1. Besides the to be evaluated safety requirements for living and building at the floating multi-use offshore platform a minimum safety distance must be evaluated. This distance will indicate the minimum distance between the platform boarder and the building blocks to ensure safe living conditions. If the water conditions are to rough it might be even necessary to think about the installation of a floating breakwater.

Infrastructure and technologies:
Which infrastructure is required for your application? Workshop, storage, roads etc. What kind of technologies will be required for your application – e.g. cranes, wind turbines …?
If possible provide an approximate mass.

Infrastructure required by our application	**Approximate mass, if possible**
Housing/accommodation (also for personnel)	
Hotel	
Recreation area/ green spaces/sports ground	
Conference centre/ hotel	
Schools/kindergarten	
Transportation infrastructure/ helicopter deck/ helicopter traffic area	
Maintenance unit	
Safety & environmental monitoring unit	
Cafeteria/catering area	
Lifeboats	
Administration centre	
Leisure activities	
Medical centre/Hospital	
Technical rooms/Storage/Work shops	
Workshop area	
Community centre	
Shopping facilities/Bars/Restaurants	
Utilities (energy, water, heating/cooling)	
Storage (utilities, food, water)	
Waste (water) treatment facilities	
…	

Technologies required for your application	**Approximate mass, if possible**
Cranes	
Broadband infrastructure / Telecommunication	
Energy production facilities (collaboration with WP 6?)/Utilities	
Central control room/Monitoring unit	
…	

Power consumption:
What is the approximate power consumption of your application? How is it distributed? Are there peak times with high demands?

Power consumption will highly depend on the final location of the platform, the provided facilities as well as the energy consumption behaviour of local inhabitants.
For European latitudes we estimate:

Assuming a platform of e.g. 10.000 m² (100 m x 100 m²)

- ➔ Inhabitant density: Approx. 0.4 Inhabitants/m² platform
- ➔ 400 inhabitants

400 people using on average 5.900 kwh/p/year (electric power consumption)[3]. Which would equal 2.360.000 kwh/year/module. However, this estimation is very vague and will be iteratively adjusted.

Depending on the location there will be peak times during the day, when people are at home as well as peak times throughout the year for heating/cooling purposes by instance. [4]

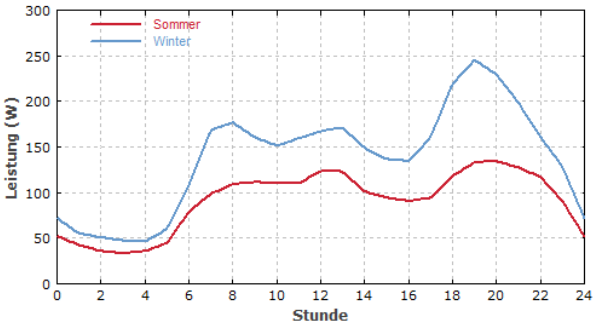


Figure 11 Branch profiles of small consumers (without electric heating) for electrical energy in summer and winter.

Personnel:
How much personnel is required for your application? How many permanent / temporary?

Living@Sea intends to enable living comparable to land. Consequently, no specific jobs need to be created that exclusively serve the city besides upcoming administrational tasks. Due to that reason, we estimate that personnel will play a very little role in the Living@Sea concept and therefore can be left unattended. The distance to the shore however, does play an important role in the job typologies. Whereas if very close to shore, law enforcement, doctors etc. could be close to the floating island but not literally present, being further from shore this would be another case.

[3] https://data.worldbank.org/indicator/EG.USE.ELEC.KH.PC?end=2014&start=1960&view=chart

[4] https://www.energie-lexikon.info/lastprofil.html

WP: 8	WP leader: Robbert Jak

Deckspace:

Describe how much deckspace is approximately required by your application (per module, in total). If applicable add minimum/maximum values for single floater module length and width.

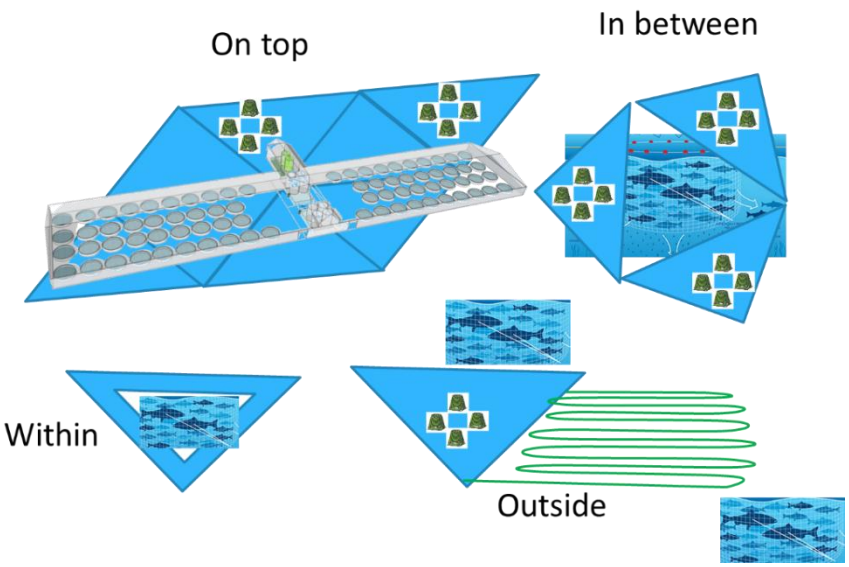
There are several options for deploying aquaculture systems and therefore several configurations are possible. These will also depend on location and species, see below.

It seems modules of 50 m length are appropriate, and different configurations / combinations of modules might be applied. For some options total deck space of module(s) is needed, for others just the outer margins of the module, for approx. 10-15 m (probably).

In addition to the culture system itself, also deck space may be used for operations, including harvesting (use of cranes) and (pre-)processing), and for storage. 1 module seems big enough for these.

Module formation:

Describe/draw/sketch how a favourable module formation could look like for your application.



Several options are possible, as drawn above.

1. On top, depending on location, fish/microalgae/seaweed may not be held in cages and therefore culturing in system on deck may be an option. Economic considerations will probably determine the scale (dimensions) that are required.
2. In between the modules. Open spaces within the island may serve as culturing locations. These may be suitable for culturing fish and shellfish (mussels). For seaweed and microalgae, shadowing by the floating modules may create less favourable conditions with regard to light availability is deployed in the water

column (in between modules).

3. "Open modules" may be created that may be more "rigid" than option 2 (where modules may act as moving parts).
4. Culture systems could be secured to a module on the outside border of the floating island, or could be anchored independently. In the latter case, the floating island may serve as working deck, but the culture system itself could be independent from the floating module(s) structure.

In options 2, 3 and 4 there are operational and maintenance triangels necessary (producing seeds, inoculum, nutrient supply etc.).

Environment:

Describe all requirements that your application has to the environment. Where applicable provide numerical values or ranges. Environmental requirements can include but are not limited to:

Distance to shore, shipping routes, harbours, wind energy farms …, water depth, soil type, turbidity, salinity, temperature (air/water), current velocity, …

- Distance to shore: not a limiting requirement (but more costly offshore)
- Shipping routes: risk of pollution (of cultured products)
- Harbours: Potentially required for handling, processing and marketing of products.
- Wind energy farms: not required
- Water depth: For options 2 and 3 minimum required water depth approx. 60 m.
- Soil (sediment?) type: no requirements ?
- Turbidity: preferably "low"
- Salinity: 30-35 and constant
- Temperature (air/water): depending on species and location. Relevant to consider!
- Current velocity: Relevant for option 2, 3 and 4. In general, current velocity should be not too high (< 1 m/s).
- Climate: stable climate conditions
- Water quality: oxygen and carbondioxide supply (air-water exchange)

Safety and Comfort: Describe limitations and requirements in respect to the safety and comfort. This can be for example maximum accelerations, maximum inclination …
For installations on top of modules (especially applicable to option 1), motions induced by waves and wind can interfere with operations, but will not be different from regular working and living environment. However, it will hard to quantify at the moment. For workers, it will probably not be different from people living@sea.
Infrastructure and technologies: Which infrastructure is required for your application? Workshop, storage, roads etc. What kind of technologies will be required for your application – e.g. cranes, wind turbines … ? If possible provide an approximate mass.
Equipment (cages, bioreactors) needs to be secured on / to the modules. Cranes are needed for deploying culturing systems and harvesting. Energy supply is needed for operations (e.g. for automated feeding) and harvesting (e.g. cranes, centrifuge). And also for freezing the harvest in case this will be stored on the island. Also, air compressor and CO_2 tanks are necessary for microalgae production.
Power consumption: What is the approximate power consumption of your application? How is it distributed? Are there peak times with high demands?
For option 1, a pumping system for continuous water supply will be needed. Power consumption will depend on the dimensions of the culture systems and the distance (height) between the suction point (under water) and the level (above water) of the systems on deck. For all options , harvesting and unloading (of the harvest) will require cranes that need power supply during these (irregular) activities. Storage (deep freezing) requires continuous power supply. For example, the microalgae cultivation requires the following, depending on the actual size (regular/peak load): - 1 kW/2 kW for pumping inoculation system per module - Up to 10 kW/15 kW for harvesting (centrifuge) - temporary - 1 kW/2 kW for pumping production unit per module - temporary

Personnel:

How much personnel are required for your application? How many permanent / temporary?

For Task 7.2 we have made the following assessment:

1. The working platform will be used like a ship, i.e. it will serve as a working space that enables operations needed for stocking and harvesting
2. Some processing will take place on the platform. This could include the preparations for
    a. installing equipment (nets, ropes, cages, PBR-collectors ...),
    b. stocking of systems (with small fish, seaweed, microalgae etc.), and
    c. processing of harvest (e.g. cleaning, drying, extraction, etc.) to (semi)finished products
3. Aquaculture systems (including also microalgae cultivation systems) will used that require full time control by trained personnel.

Option	Number of personnel	Duration of stay
1	5	1 week
2	10	permanent
3	20	permanent

WP: 9	**WP leader: Dingena Schott – 20180203**

Deckspace:
Describe how much deckspace is approximately required by your application (per module, in total). If applicable add minimum/maximum values for single floater module length and width.

- Very early: will follow from design of transhipment configuration and determination of storage volume and area (a single large container vessel carries up to 20.000 TEU, space requirements are significant)
- Length of module could follow shipsize/shiplength (depending on the location of the island large container vessels with a length of 400 m, maybe further growing within the next years)
- It is likely that single modules should be able to equip transport equipment (to avoid deflection, and high number of fatigue cycles).
- The very different heights of ships should also be taken into account regarding the design of the quays.

Module formation:
Describe/draw/sketch how a favourable module formation could look like for your application.

Input by TUHH

Environment:
Describe all requirements that your application has to the environment. Where applicable provide numerical values or ranges. Environmental requirements can include but are not limited to:
Distance to shore, shipping routes, harbours, wind energy farms …, water depth, soil type, turbidity, salinity, temperature (air/water), current velocity, …

- Depth min 25 m to accommodate largest shiptypes (will be updated when cargo and specific vesseltypes are known)
- Economic viability of the logistics requires the minimisation of cargo handling costs and the prevention of additional changes of the carrier. Cargo that is transhipped from one sea-going vessel to another sea-going ship (e.g. containers from a large intercontinental ship to Feeders) is not the problem. If the destination is in the hinterland and can be reached by short sea ships, sea-river ships or inland vessels, it is required that these vessels can (and are allowed to) operate between the island and the connected inland waterway for at least 300 to 330 days per year. Only few inland vessels are designed to operate in the well-defined zone 1 (H_s<=2.0 m) or zone 2 (H_s<=1.2 m). Dedicated sea-going solutions with small air draught like the lighters from the German BiWi project connecting the Jade-Weser-Port Wilhelmhaven to the Weser are limited to H_s <= 2.5 m. Therefore, the calmest location possible is preferable for WP9.

Safety and Comfort: Describe limitations and requirements in respect to the safety and comfort. This can be for example maximum accelerations, maximum inclination …
-
Infrastructure and technologies: Which infrastructure is required for your application? Workshop, storage, roads etc. What kind of technologies will be required for your application – e.g. cranes, wind turbines … ? If possible provide an approximate mass.
- Multiple Cranes for transport hub - Rails for crane operation - Optionally transport equipment (depending on cargo type) - Storage area (mass depends on capacity and cargo type) - Cranes for service cargo - Housing/infrastructure for workers
Power consumption: What is the approximate power consumption of your application? How is it distributed? Are there peak times with high demands?
- Peak times equipment when operational (unloading/handling) - ‘shore-based’ power (cold ironing) during mooring/docking

Personnel: How much personnel are required for your application? How many permanent / temporary?
Linked to equipment/hub: - 1 operator per crane/shift ~ 4 shifts a day (assuming 24/7 operation) - 1 operational planner ~ 4 shifts a day - 1 terminal/hub control ~ 4 shifts a day Supportive personnel: - Maintenance - Facility management