Turn the Tide

A dive into the possibilities of sustainable water sports

CIE4061-09, Multidisciplinary Project

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by

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TUDelft

Abstract

This report will give an in depth view on the technical feasibility of placing an offshore platform from which watersports can be practiced in the waters surrounding the island of Bonaire. The feasibility research is done by appointment of two entrepreneurs on the island of Bonaire. The report will give an answer to the research question:

Can an offshore floating platform, aimed at fast watersports, be built ***as sustainable as possible*** *within the* ***context of Bonaire****?*

This research question can be divided into multiple sub-questions, being:

1. What is the context of Bonaire?
2. What is, for this report, the definition of sustainability?
3. What facilities are needed on the platform?
4. How can 100% renewable energy be generated for the platform?
5. What would such a (conceptual) platform look like?

To answer these questions, the method as described in Kossiakoff (2011) is used. This method gives structure to the design of a system that has not been used before, but tries to combine older systems in new innovative ways. From this method, three important stages in the design process have been identified: The needs analyses, the concept exploration and the concept definition.

This report follows that structure, starting with the chapter: Needs analyses. In this chapter, the report answers the first two sub-questions. The context of Bonaire can be described as: an island with opportunities for every-one, but the local environment suffers from the exponential growth of people and tourists that visit the island.

For the second sub-question the definition of sustainability has been placed within this context of Bonaire, leading to a specialized definition of sustainability. This definition combined with the requirements of the clients has lead to a valid need for the platform.

The concept exploration, gives options to answer those needs. It does so by researching a broad range of possible facilities for the platform. This broad research eventually leads to a morphological map from which 3 realistic and 1 futuristic concepts are designed.

In the concept definition these 3 realistic concepts have been tested by an MCA resulting in one concept that has been worked out for various components, thus answering sub question 5. From this worked out concept, a conclusion is written in where the main conclusion is that an offshore platform aimed at fast water sports van be build sustainable within the context of Bonaire if the clients are able to make some consensus in there plans and the way they will use the platform.

Finally, considering the sustainability of the proposed platform, it can be concluded with current technologies it is hard to build a platform without emissions, negative effects or any hidden impact. However, if the schedule and plans of the clients where to change towards a more 'nature dependent' schedule (so taking peak energy generation into account). The platform could set an example and can even be a global 'first' when it comes to making the practice of watersports more sustainable.

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Nomenclature

ρ_A	Density of the air	1.225 kg m^{-3}
ρ_w	density of salt water	1025 kg m^{-3}
A_V	Frontal area	m^2
A_{disk}	Total surface area that the spinning blades manage to cover	m^2
A_{rans}	ransom area (B X T)	m^2
BM	Distance between centre of buoyancy and metacentric height	m
C_E	Carbon emission	kg
d	Distance	m
E	Energy	J
E_f	Emission factor	kg m^{-1}
F	Force	N
Fr	Froude number	–
g	Gravitational constant	9.81 m s^{-2}
GM	Metacentric height	m
$H_{1/3}$	Significant wave height	m
I	Area moment of inertia	m^4
KB	Centre of buoyancy	m
KG	Distance between keel and center of gravity	m
KM	Distance between keel and metacentric height	m
L	Length of an object	m
m_{ship}	Mass ship	kg
P	Power	J s^{-1}
$P_{available}$	Available power	J s^{-1}
$P_{generated}$	Generated power	J s^{-1}
R	Resistance of an object	N
S	Wetted surface area of the ship	m^2
t	Time	s
U	Speed of an object	m s^{-1}
u_0	Wind speed	m s^{-1}
V_s	Speed of the ship	m s^{-1}
v_w	speed of the water	m s^{-1}
V_{air}	Speed of the air	m s^{-1}
$V_{underwater}$	Underwater volume	m^3
W	Work	J

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1
Introduction

According to Grilli et al. (2021): 'Tourism development is crucial for economic growth in Small Island Developing States, but its management involves trade-offs between ecosystem services and social and cultural identities.' Bonaire is a classic example of this problem. As the inhabitants of the island have to import nearly every product (CBS (2022)) and is unable to export any products, Bonaire is becoming more and more reliant on other streams of income, of which tourism is one of the main contributors.

One of the growing sports for these tourists (and locals) are fast watersports, Especially those supported by a foil to gain even more speed. These foil-assisted watersports are not allowed within the perimeter of the protected marine park due to possible environmental issues such as turtle strikes and marine life disturbances. Athletes are therefore obliged to practice these watersports in deeper seas (outside the marine park) on Bonaire. However, the monitoring of this zoning is impractical for the small NGO's that are, among other things, tasked with supervising, as they have other tasks to maintain the marine park.

This report is commissioned by two entrepreneurs that live and work on the island of Bonaire. They saw the problems above not as problems, but as an opportunity to both start a business and set an example of sustainability. They want to pull the foiling watersports (with the main focus in this report being e- and wingfoiling) out of the marine park and into what is called the 'deep blue'. To accommodate these sports, the idea is to build a sustainable platform from which the activities can take place and also be supervised. The platform will be an example of the current possibilities when it comes to sustainability, in such a way that it will be designed as the most sustainable watersports platform in the world.

Therefore this report will look into the feasibility of the design of a platform where these watersports will take place. Or in other words:

Can an offshore floating platform, aimed at fast watersports, be built ***as sustainable as possible*** *within the* ***context of Bonaire****?*

This research question directly forms two subquestions:

1. What is the context of Bonaire?
2. What is, for this report, the definition of sustainability?
3. What facilities are needed on the platform?
4. How can 100% renewable energy be generated for the platform?
5. What would such a (conceptual) platform look like?

To answer these questions, the report is structured in a way as proposed in the methodology (chapter 2). In chapter 3, a background analysis, stakeholder analysis and SWOT analysis are given. Next, in chapter 4, different options for the facilities (ranging from the toilet to ways of storing energy) on the platform are explored and discussed. In chapter 5, two concepts are chosen and worked out, of which one realistic and one futuristic. In chapter 6 the results of the research are once more concluded, after which in chapter 7 these are discussed, giving recommendations for future work.

2 Methodology

The method proposed in Kossiakoff (2011) was used to answer the research questions defined in chapter 1. This method is fitting for this process as it proposes a structured way for researching and validating the need for building new complex systems. But it also gives a hand into how the research into different solutions should be structured, and how this research can lead to an eventual design.

The book of Kossiakoff (2011) describes a multiple of stages and questions, but only three are considered for this design. This because this report will focus mostly on the conceptual phase, as the engineering part of this project will come at a later stage. The chosen stages consists of the following (see also Figure 2.1 for a graphical representation):

1. Needs analysis. This phase answers, according to Kossiakoff (2011), the questions: “Is there a valid need for a new system?”, “Is there a practical approach to satisfy such a need?”. In addition, this report will also try to give an answer to the question ”What is sustainability within the context of Bonaire”?
2. Concept exploration. answers the question: “Is there at least one feasible approach to achieve such performance within the requirements of the project?”
3. Concept Definition. answers the question: “What are the key characteristics of a system concept that would achieve the most beneficial balance between capability, operational life, and cost?”

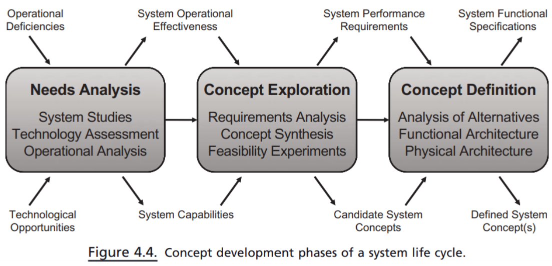


Figure 2.1: Systems engineering concept design phases (Kossiakoff (2011))

For the process to be manageable and understandable, a clear definition of the system has to be given. For this research, the system is considered as the platform itself, including Bonaire as a constraint on which for example electricity, water and food must be produced, transported and for example reused (see Figure 2.2). The reason Bonaire is included is because it will be the main way of supply for the platform and therefore needs to be researched. Everything that is done outside of this system is considered ”external” of the system.

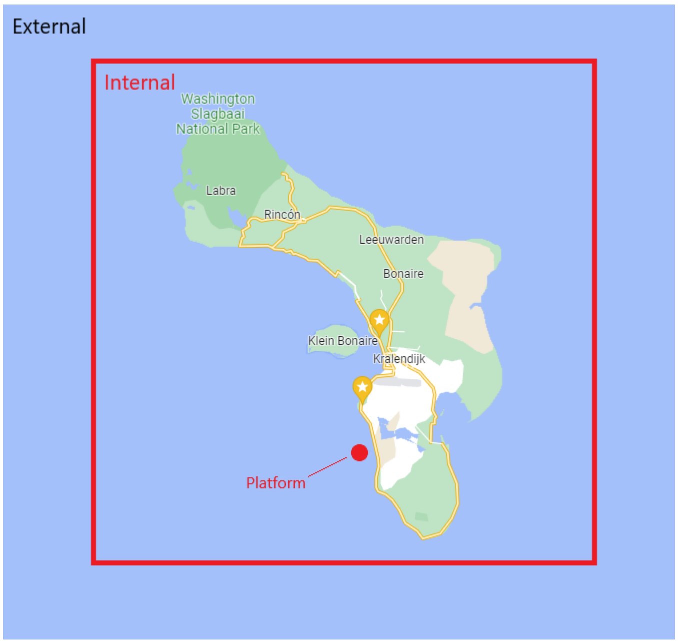


Figure 2.2: The "system" considered for this research

As the above stages only raise questions instead of answering them, the choice has been made to solve the questions in the following ways:

Needs analysis

The needs analysis is, as described above, a way of validating a need and is intended to provide a practical approach to fulfill this need. In the context of this research, this means a background study, stakeholder analysis and a Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis (a frequently used business tool) is done to validate the need, while the "practical approach" will be the research on how to come to the new system (a floating sustainable platform). The practical approach is molded in the compiling and comparisons of different functional solutions.

Background study

The background study is a way of defining context. In this report, research has been done in the following aspects of the system of Bonaire:

- Governmental structure
- Ecology
- Tourism
- Supply chain
- Energy infrastructure
- (Waste)Water management

Information has been gathered using conversations with the relevant persons on Bonaire, while also doing online research. The information gathered is then validated by means of meetings with stakeholders and the client, as well as the information online.

Stakeholder analysis

A stakeholder analysis has been performed to map and contact the relevant parties for the project, as their needs and concerns are important for the needs to be validated and complete. The mapping was done using Figure 2.3

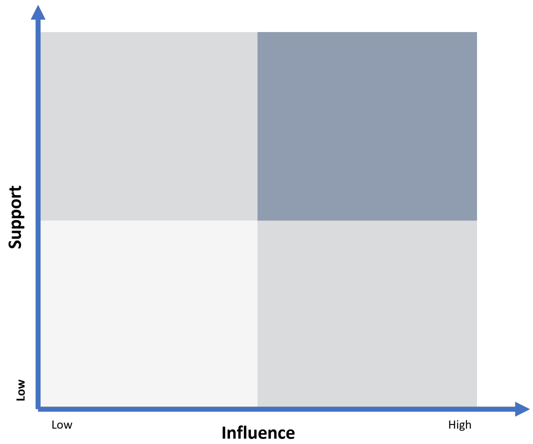


Figure 2.3: Stakeholder mapping template used in the analysis

The meetings that followed were both in collaboration with the client or only the research group. The conversations from these meetings were used not only to gain or validate information, but also to help in the framing of the project and adjust goals or requirements where needed.

SWOT Analysis

A SWOT analysis has been performed in collaboration with the clients to map the current system and project in a structured way. It is a way to assess the strengths, weaknesses, opportunities and threats of the project.

The analysis maps internal strengths and weaknesses and external threats and opportunities. The analysis is performed using a square (see Figure 2.4), divided into four segments representing the four different factors. A strength of the SWOT analysis is that it gives a fact based, realistic overview of the project, while also exposing weaknesses and opportunities. The downside is that it may oversimplify the project.

Figure 2.4: SWOT square. (*SWOT Analysis* (2022))

This SWOT analysis has been performed using a ”Political, Economic, Sociocultural, Technological, Environmental, Legal”, or PESTEL, framework (de Bruin (2022)). The PESTEL framework is an easy-to-use way to perform the SWOT analysis. It helps understanding the business environment in which the project is situated.

The PESTEL framework gives the opportunity to do the SWOT analysis in a more structured way making sure no aspects are forgotten. It also helps in the assessment of entering new markets, helps exploiting new opportunities and gives clear insight in possible threats or risks. For this report it is used in combination with the SWOT analysis to structure the different aspects of the project and to make sure as much of the SWOT analysis is covered.

A disadvantage of the framework is the risk of oversimplification. Also multiple perspectives are needed to be effective. This is why the SWOT analysis is done in cooperation with the client to gain their view on strengths, weaknesses, opportunities and threats in the project.

After the SWOT, the weaknesses and risks identified are mitigated by using the projects’ strengths and opportunities. From here, certain extra or existing needs are defined in combination with the background and stakeholder analysis. These needs have ended up in the definition of the goals of the platform, which were used in the concept exploration phase.

Concept exploration

From the needs the operational requirements are defined. From this, necessary facilities have been defined. The exploration into the different facilities has been kept broad to ensure that there is a possibility to define different candidates for the same goal, according to different system performance requirements. This broad study has been summarized into a morphological mapping.

From this morphological map, six different concepts (three realistic and three futuristic) have been defined through a brainstorm (with the clients) using a later in this section defined Excel tool. From these seven concepts, the three realistic concepts and one combination of the futuristic and ”wild crazy” idea have been worked out in more detail for the evaluation.

Excel tool

The goal of the excel tool was to accomplish two different tasks, one internal and one external. It will form a means to:

- communicate with the clients. Different things such as necessary power and thus necessary facilities are hard to communicate with numbers. Therefore the client will be able to place different objects on a virtual ’platform’ which will directly translate into necessary power and area for the facilities that will generate that power.
- estimate the costs, necessary power and water, the left over space and the total weight of a more detailed concept after the MCA phase. This is the internal strength of the tool.

For both means there are certain assumptions that have to be made.

Concept Definition

In the concept definition phase, two concepts have been worked out: one realistic from the three realistic concepts as defined in the concept exploration phase and one futuristic, which is also defined in the concept exploration phase.

For the choice of one realistic concept, a Multi-Criteria Analysis (MCA) was used. The three concepts have been scored per criterium defined and ranked in a brainstorm with the client. The MCA was used as a tool for the decision making of the final concept in a more objective way than just choosing a concept, by scoring each partial solution per concept relative to each other. Of course, scoring the concepts relative to each other could still be considered not subjective enough, as there is no real quantification. However, within the scope of the work of the project this was feasible. More about this can be read in the discussion 7.

Before the score of the MCA could be finalized, a weight is given to each of the requirements. This is done by giving a 100 points to each of the clients (and to the writers of the report) and giving them a chance to distribute these 100 points over the possible requirements. This leaves space for two things: the ability to rank requirements from important to less important, but also scoring each of the requirements relative to one another.
A note here is that the more important a requirement, the higher the amount of points given to that requirement. From this ranking, the concepts can be scored by making estimations based on the research in this report and the knowledge of the writers. This means that each concept is scored relative to the other instead of based on time consuming calculations (mostly due to time constraints). The scores have been divided in the following way:

- 1 point will be given to a solution of a concept when it is considered to be irrelevant to the criterium analysed.
- 2 to 4 points will be given in relativity if the solution of the concept is considered relevant to the criterium.

Finally, from the MCA one concept will be chosen to be evaluated and worked out in more detail, next to the futuristic concept, meaning:

- An overview of the general arrangement of the platform
- Propulsion
- Stationkeeping
- Carbon emissions
- (Waste) water management
- Energy consumption
- Local environmental impact
- Hidden impact
- Safety
- Modularity and scalability
- An ideal location
- Management System (EMS), meaning: when can one charge the storage (if there is any) and when do we have to draw energy from the storage.
- An estimation of the total costs and sustainability

3
Needs Analysis

This chapter contains the needs analysis, explained previously in chapter 2. This analysis will answer three different questions:

- ”Is there a valid need for this new system?”
- ”Is there a practical approach to satisfy such a need?”
- ”What is sustainability within the context of Bonaire?”

To answer these questions, first the context of Bonaire is mapped, looking into the governmental structure, ecology, tourism, its supply chain, energy infrastructure and (waste)water management. After this, a stakeholder analysis is performed, involving a mapping of the relevant parties, including conclusions with meetings.

After this, an environmental analysis as part of the context study. Finally, results of the SWOT analysis are given, after which conclusions of the needs analysis are given.

3.1. Context of Bonaire

As stated above, this section will contain the information needed to form an image of the island of Bonaire.

3.1.1. Governmental Structure

In this section, the governmental structure of the island of Bonaire will be discussed to shed some light on the context of the island where the project is being held.

Bonaire is an island discovered in 1499 by Spanish discoverers. The island was part of a Spanish colony for about a century and later became a Dutch colony after the Eighty Year War. The island of Bonaire was primarily used by the Dutch for salt production, which was an important resource for preservation of meats.

In some more recent times, the island of Bonaire joined the Netherlands Antilles in 1954. The Netherlands Antilles was a constituent country of the Kingdom of the Netherlands and consisted of the islands of Aruba, Bonaire, Curacao, Saba, Sint Eustasius and Sint Maarten. But in 2010 the Netherlands Antilles was dissolved, and the islands of Bonaire, Sint Eustasius and Saba (BES-islands) form a public body (literally translated from Dutch; openbaar lichaam). This means that the island is organized in a way like a municipality in the Netherlands, but laws and regulations are different than those in the European Netherlands.

The Public Entity of Bonaire (OLB) is structured the same way as a municipality with the highest body being the Island Council. This is a council of nine members who are elected every four years by the people of Bonaire. Their term coincides with the provincial elections in the Netherlands so that it is possible to vote for the Senate (eerste kamer) in the Netherlands. After the elections the parties assemble an Executive Council which consists of 3 commissioners and a Lieutenant Governor. The Lieutenant Governor is responsible for security and public order and chairs both the Executive Council and the Island Council. Additionally, the island has an Island Secretary who heads the Civil Service and provides the Executive Council with advice.

The Civil Service is divided into several directorates; Spatial Planning and Development Directorate, Supervision and Enforcement Directorate, Society and Care Directorate and lastly, Operations and Support Directorate.

The ministries of Finance, Health Welfare and Sport and, Social Affairs and Employment have an executive presence on the island and have certain duties and powers relating to the island. Other ministries have a posted liaison on the island to implement the ministries’ policies. The organogram of the OLB can be seen in figure 3.1. The specific people involved in the ministries that are potential stakeholders can be found in the stakeholder analysis in chapter 3.2.

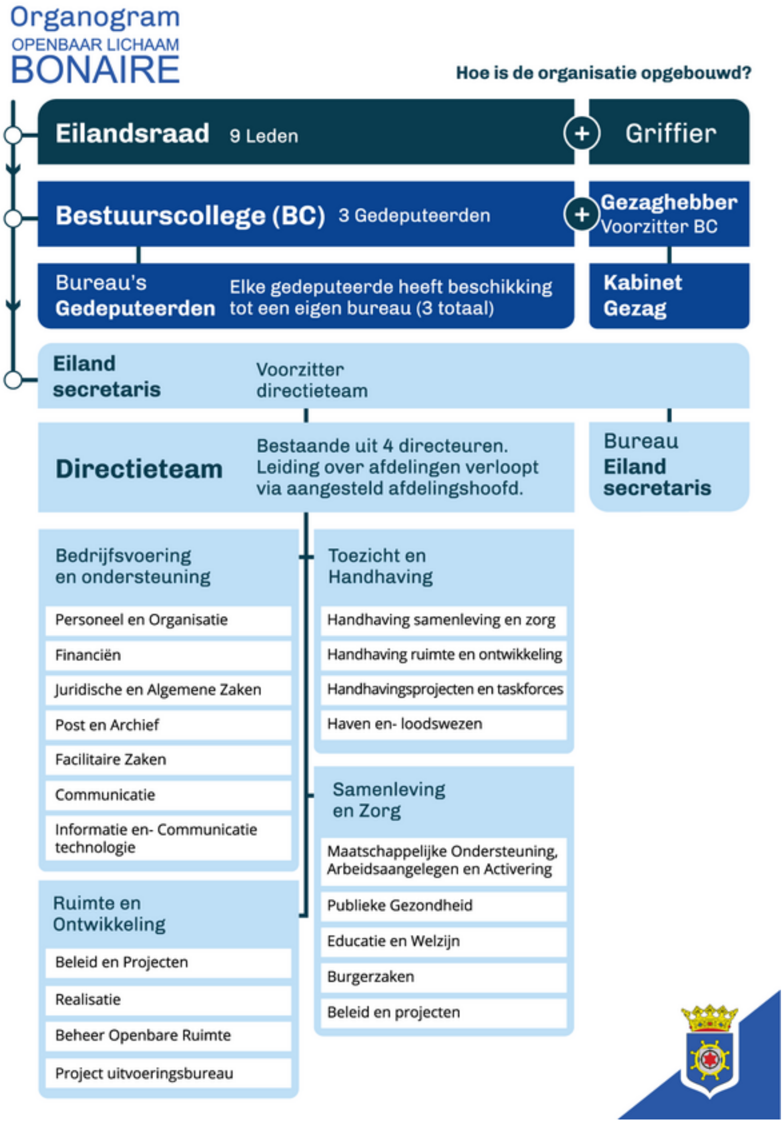


Figure 3.1: Organogram OLB. (*Openbaar Lichaam Bonaire* (n.d.-a))

3.1.2. Ecology

Bonaire is known best for its coral reef. From 1969 on, the marine area surrounding Bonaire was recognized as a protected national park. The park stretches offshore to a depth of 60 meters, covering a total area of around 27 square kilometers (*STINAPA*). It hosts a variety of coral reefs, mangroves and sea grass beds. In Figure 3.2, the marine park is marcated as light blue. From 1999 onwards Klein Bonaire, the small island next to Bonaire, is also part of the marine park. Klein Bonaire is the main nesting place for sea turtles and a very important place for the existence of these mammals.

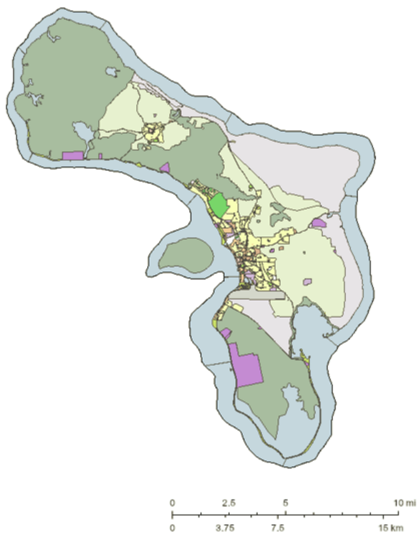


Figure 3.2: The marine park of Bonaire (Source: *ArcGIS Web Application*)

The Washington Slagbaai National Park, located in the most northern part of Bonaire, is also a protected area of Bonaire. Also founded in 1969, it covers 17% of the islands surface. It is a home of many species such as flamingos, lizards and iguanas. There is also a large variety of vegetation, such as cacti and scrub. In Figure 3.2, the national park is marked green in the most northern part of the island.

Finally, there is the Ramsar agreement which is a worldwide agreement in which it has been decided to protect (and try to maintain) wet land area's. All of the wetlands (see Figure 3.3) on Bonaire are protected, inlcuding the island Kleini Bonaire.

Figure 3.3: Ramsar area's of Bonaire. (Source: *Dutch Caribbean Biodiversity Database*)

Both the marinepark as the Slagbaai national park are managed by STINAPA, a nongovernmental organisation founded in 1969. STINAPA is legally supported by the 'Eilandbesluit Bonaire' (Bonaire (2010)) More details on STINAPA can be found in chapter 3.2.

3.1.3. Tourism

Tourism is a vital part of life on Bonaire. Around 40% of the economy is reliant on it (*Kvk Economie* (2021)). In 2017, Bonaire received around 130 thousand tourists by air, and around 400 thousand cruise tourists. On a population of around 20 thousand citizens, the amount of tourists visiting Bonaire is quite large. (Netherlands (2018)

Bonaire is especially popular among divers, snorkelers, as its coral reefs are amongst the best preserved in the world. It has over 60 dive spots for both scuba-divers as free divers, as can be seen in Figure 3.4. Next to this, watersports such as windsurfing, kitesurfing and kayaking are also popular.

Figure 3.4: Dive locations on Bonaire. (Sunwise Bonaire (2021))

From the Tourism Recovery Plan of Bonaire of the Openbaar Lichaam Bonaire (*Openbaar Lichaam Bonaire*), set up since COVID-19 hit Bonaire, some goals of the island are particularly interesting. Bonaire wants to aim its tourism at diversification, meaning that it wants to diversify on-land and water activities.
Next to this, Bonaire wants to be the center for "off the beaten path" and sustainable activities.

In terms of sustainable initiatives, the Tourism Corporation Bonaire in collaboration with the Kamer van Koophandel (KvK) has launched the Blue Destination certification. It is a certification system to help local businesses to be more sustainable and socially responsible (*Blue Destination*). The certification follows the standards and criteria of the Good Travel Program (*Good Travel Seal Assessment Reporting*).

3.1.4. Supply chain

The supplies on Bonaire are something worth writing about, because there are no locally sourced supplies (except for some eggs and a lot of salt). The island of Bonaire is a barren landscape with loads of sun, wind and nearly no rain. This harsh environment and the consequences shows in Table 3.1, where it becomes clear that nearly everything is imported and the island does not export a lot.

Table 3.1: Total value of the in- and export of Bonaire, source: (CBS (2022))

Categories of goods (SITC)	Periods	Import value (1000 USD)	Export value (1000 USD)	Balance of trade (1000 USD)
Total goods	*2022 1st quarter*	*77,251*	*3,456*	*-73,795*
Total goods	*2022 2nd quarter**	*84,773*	*2,053*	*-82,720*
0 Food and live animals	2022 1st quarter	14,679	7	-14,672
0 Food and live animals	2022 2nd quarter*	16,149	0	-16,149
1 Beverages and tobacco	2022 1st quarter	4,790	6	-4,784
1 Beverages and tobacco	2022 2nd quarter*	8,001	10	-7,991
2 Crude materials, inedible	2022 1st quarter	2,354	97	-2,257
2 Crude materials, inedible	2022 2nd quarter*	2,140	47	-2,093
3 Mineral fuels, lubricants	2022 1st quarter	462	0	-462
3 Mineral fuels, lubricants	2022 2nd quarter*	706	0	-706
4 Animal and vegetable oils, fats	2022 1st quarter	210	29	-181
4 Animal and vegetable oils, fats	2022 2nd quarter*	357	0	-357
5 Chemicals and related products, n.e.s.	2022 1st quarter	7,242	11	-7,231
5 Chemicals and related products, n.e.s.	2022 2nd quarter*	7,284	14	-7,270
6 Manufactured goods	2022 1st quarter	12,941	802	-12,139
6 Manufactured goods	2022 2nd quarter*	15,241	672	-14,569
7 Machinery and transport equipment	2022 1st quarter	21,382	829	-20,553
7 Machinery and transport equipment	2022 2nd quarter*	22,475	749	-21,726
8 Miscellaneous manufactured articles	2022 1st quarter	12,890	1,580	-11,310
8 Miscellaneous manufactured articles	2022 2nd quarter*	12,198	437	-11,761
9 Commodities and transactions	2022 1st quarter	301	96	-205
9 Commodities and transactions	2022 2nd quarter*	221	123	-98

Next to the large import values, most products are also imported from the Netherlands. Which in its turn means that nearly all supplies are more expensive than they would have been 'at home' and of a lesser quality than one is used to. Finally, people build homes and resorts and such all round the island, which only aggravates the previous statement. This means that for building something, one is better off by partly building something in Europe and let it ship to Bonaire to have it finished on the Island.

These shipped supplies come either by boat or plane. The latter does not form a problem for the platform, the first however does. As the platform must be placed in the water, for safety reasons it is only logical if it is placed out of the mayor sailing routes of ships that are visiting the island of Bonaire. These are mapped in Figure 3.5

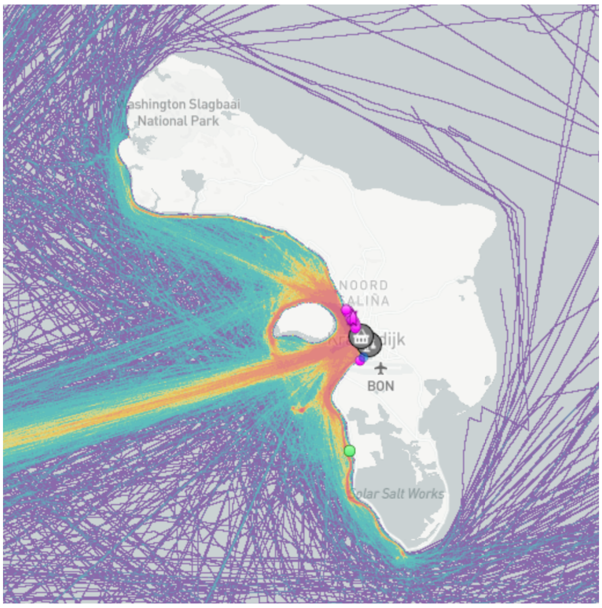


Figure 3.5: Major sailing routes around Bonaire, as taken from Marinetraffic.com

This brings us to re-using materials, as most products come here at the end of their life cycle (subsection 3.2.2, meeting with Otto Bartels), one would expect a large recycling chain. However, this end of the supply chain is also the reason why there is no real recycling chain. A good example of this problem is the following: Bonaire knows no deposit for glass bottles. This is because it is too expensive to re-use these bottles as they either have to be shipped to another island / country where a brewery is stationed. As this would not be a profitable undertaking. Thus, for now, glass is just treated as any other waste. This does not mean however, that there are no plans of reusing waste on Bonaire. A couple of important businessess that are investing more and more time and resources into recycling programs are:

- Selibon. Selibon is the company responsible for waste treatment on the Island. They have just invested in different spots on the island where bulk waste can be seperated. This means that people are able to re-use old electronics, batteries and that toxic waste is seperated from general waste.
- Recycling Bonaire: Recycling bonaire is an initiative from Otto Bartels. He had plans to build multiple recycling streams for waste differing from glass to old cars.
- NOBO bonaire: they try to give new life to old plastics, to be specific: type 2 (HDPE) plastics. They do this by making coasters, bottle openers etc. This company might be interesting for for example making recycled drinking glasses.

Sadly, the initiative from Otto Bartels has been stopped about 5 years ago due to multiple circumstances, so there is no real option of working together with that initiative anymore. Selibon however does offer options of re-using especially car batteries and other old tools such as refrigerators (that still offers a large form of insulation), pumps from airconditioning units etc. The rest of the waste will go directly to a landfill, which is a disaster waiting to happen.

3.1.5. Energy Infrastructure

Outline of Bonaire's Electricity Grid

Since 2013, Bonaire has had its electricity produced not only from diesel generators, but also renewables like wind and solar energy. This major change was due to the breakdown of the only diesel power plant on the island in 2004. During 2004 and 2013, Bonaire relied on temporary diesel plants.
Bonaire's electricity is distributed by the state-owned company WEB (Water- en Energiebedrijf Bonaire). It handles the electricity grid and distribution of power to households and businesses. The generation of electricity is being handled by ContourGlobal, a British Independent Power Producer (IPP).
The power generation consists of five 2.85MW diesel plants. These diesel plants currently run on petroleum-based fuels, but are also suitable to run on biodiesel.

Figure 3.6: Diesel plant on Bonaire (Source: *Contourglobal* (2017))

Next to this, 12 wind turbines of 900kW and one of 330kW power another 11MW for the island, making up for a total of 24MW of power.

To smoothen the transition between diesel and wind power, three batteries of 3MW have been installed.

Figure 3.7: 11MW Wind park in Bonaire (Source: *Contourglobal* (2017))

Furthermore, a pilot solar plant of 0.2MW was commissioned in 2015 to determine the feasibility of future solar parks on Bonaire.

In 2019, the power plant was expanded with five new diesel generators, replacing a temporal supply of diesel generators. Next to this, an advanced energy storage system was installed, paving the way for more renewables in the energy mix. Furthermore, it is allowed in Bonaire to have decentralized solar panels, which are installed on rooftops buildings of companies and individuals.

Bonaire's energy mix

In 2020, Bonaire's electricity supply was for 77% dependent on fossil fuels, the rest of its energy (23%) coming from renewables.

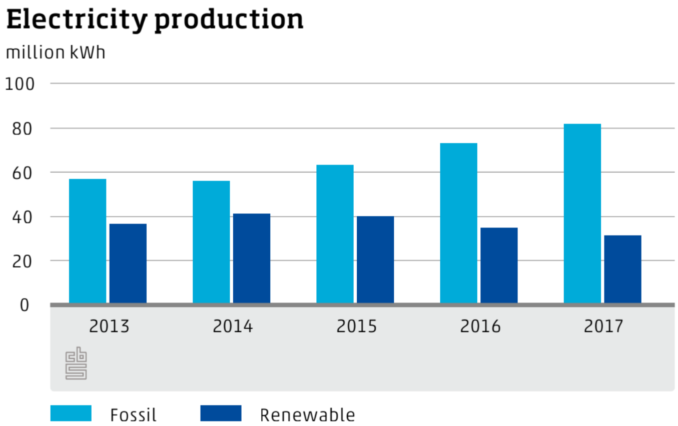


Figure 3.8: Renewable share in electricity production over the years in Bonaire. (Source: Netherlands (2018))

The demand in electricity on Bonaire has been rising over the last years. However, as there haven't been recent plans for the construction of new renewable plants, more fossil fuels are being used for the demand. The share of renewables in the energy mix have as a consequence been in decline.

Bonaire's potential and future developments

Following the official report of the Ministry of Economic affairs (*Duurzame en betaalbare energie in Caribisch Nederland* (2017)), Bonaire has the potential to be 100% sustainable in terms of electricity generation. The consultancy report used by the Ministry (Schellemans & van Weijsten (2016)) conclude that wind energy on Bonaire is a proven technology and thus could be expanded with another wind park, as there is already a windpark on the island there is also local knowledge about these systems. Furthermore, solar power also has potential, although it is concluded that it should be generated in a decentralized manner. This should be managed in such a way that the electricity-grid can handle the return in electricity from homes/buildings to the net.

However, for Bonaire to be 100% sustainable, use has to be made of other sources than wind and solar energy. Too many technical and financial challenges are present to make Bonaire dependent on wind and solar energy alone. For example, the fact that on windless or cloudy days, there would be not enough capacity to meet the demand, especially in the hot months of Bonaire and energy storage would be too expensive to solve this problem.

Thus, other options are proposed, such as the option of Ocean Thermal Energy Conversion (OTEC). The location of the island near deep seas could provide a large energy potential. (See subsection 4.8.5). However, because there are no commercial solutions for this technology, this will be an option for the far future.
Next to this, based on a report on sustainable energy from Wageningen (van der Geest & Teles (2019)), biodiesel produced from algae could also be an option. Currently, a pilot is being developed on Bonaire from the university of Wageningen (*AlgaePARC*). However, as this technology is also still in its development phase, this will be a plan for the long-term.

3.1.6. (Waste)Water Management

Water Generation

Drinking-water is produced fully by WEB by reverse osmosis, next to being responsible for the sewage treatment. The water that is processed by the sewage plant is not reused for drinking purposes. Instead, it is used for irrigation (M Bongenaar (2019)). The price of drinking water on Bonaire is relatively high because of the high production costs and the relative small number of connections. Reverse osmosis is a relatively energy intensive production method. One cubic meter of water costed $3,80 in 2017, about 3,5 times higher than in the Netherlands.

Wastewater Management

In 2017, about 95% of Bonaire was connected to the drinking water network of WEB, next to the 1631 businesses. The 5% that is not connected relies on a watertank, which accumulates rainwater. When insufficient rain has fallen, more water can be ordered, which is transported by truck to the household.

Since 2014, Bonaire has its own sewerage system. It is limited to being connected to households and hotels in Kralendijk (only 8% is connected), but is still in development to connect new households to its system.

The sewers make use of an advanced vacuum system. Households are connected to wastewater collectors in the neighbourhood using free decay of the water. At the collectors, it is being put under vacuum, from which it is transported to the wastewater treatment plant.

The households and businesses which are not connected to the sewerage system mostly have septic tanks or cesspools available to discharge their wastewater. The waste water is then picked up and transported to the water treatment plant, just like the sewerage system. There, the wastewater is filtered.

The purification method used is called Sequence Batch Reactor (SBR). This method makes use of the natural process of bacteria eating the waste in the water. SBR controls this process by means of mixing, deposit and air supply. A schematic overview can be found in Figure 3.9

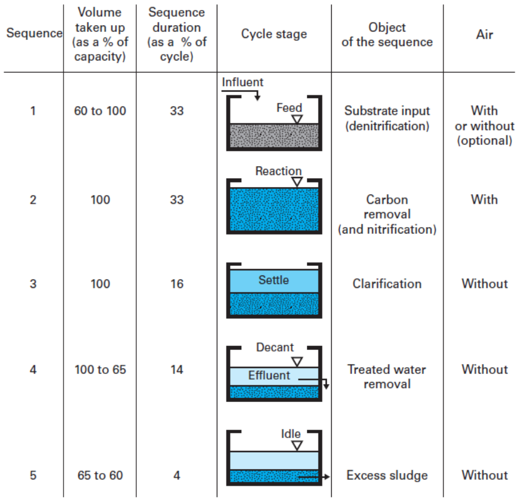


Figure 3.9: Schematic overview of the SBR process. (BeClood.com)

Before the water is used for irrigation, it is treated with UV-radiation to kill bacteria. Next to this, the water still contains fertilizers, making it unpotable. This water is used for irrigation of soil. The sludge which is left over after treatment is dried and used as a fertilizer for the soil. (*Afvalwater*)

Wastewater from sea

Next to inland wastewater, wastewater from boats and ships is also collected at ”Harbour village”, one of the harbours of Bonaire, via a vacuum pump. From a conversation with WEB (see Figure A), a law is in development which requires every ship in the vicinity of Bonaire to discharge its wastewater at the harbour to prevent environmental hazards.
Next to this, there are preliminary ideas of a wastewater collection boat from WEB, which will collect wastewater from ships to prevent traffic at the harbour.

3.2. Stakeholder Analysis

In the process of designing a floating, sustainable platform, multiple stakeholders should be taken into account. In this section, summaries of these stakeholders and their support and influence are shown in a stakeholder map. In Appendix A a full overview of all stakeholders is given including more information: first the general goal of each stakeholder is described. Following, the role of the stakeholder in this project is mentioned.
Next, the influence in the project and the support are being discussed. Some stakeholders will support the project and can be cooperated with, other stakeholders can have a neutral opinion in the project, while some can also object against the project.
Lastly, the regularity of contact with the stakeholder is estimated. Some close stakeholders have been updated regularly and have big influence in the project, others can just be used as source of information and have been contacted when needed.
During this project, meetings with different stakeholders have been arranged. A general summary can be found in this chapter, the individual summaries and goals can be found in Figure A.

3.2.1. Stakeholders

The most important stakeholder in this project was the client. The client is the founder of the idea and wants the project to be executed. Therefore meetings have been scheduled on a regular basis to discuss demands and possible ideas for the platform. Other parties, like environmental organizations or the ”Dienst Ruimtelijke Ordening” (DRO) initially do not have a clear ”support” for the project, and have therefore also been consulted in meetings.

At the beginning of the project an estimation of the level of support and influence per stakeholder was made. However, during the project, it was clear that some changes had to be made. The stakeholder analysis has therefore been an iterative process during the project.

To visualize the influence and support of the stakeholders, a stakeholder mapping is shown in Figure 3.10. Note that this is not a definitive mapping and could be changing in time due to changing opinions and future meetings with the parties involved. The initial mapping made before the start of the project can be found in Appendix A.

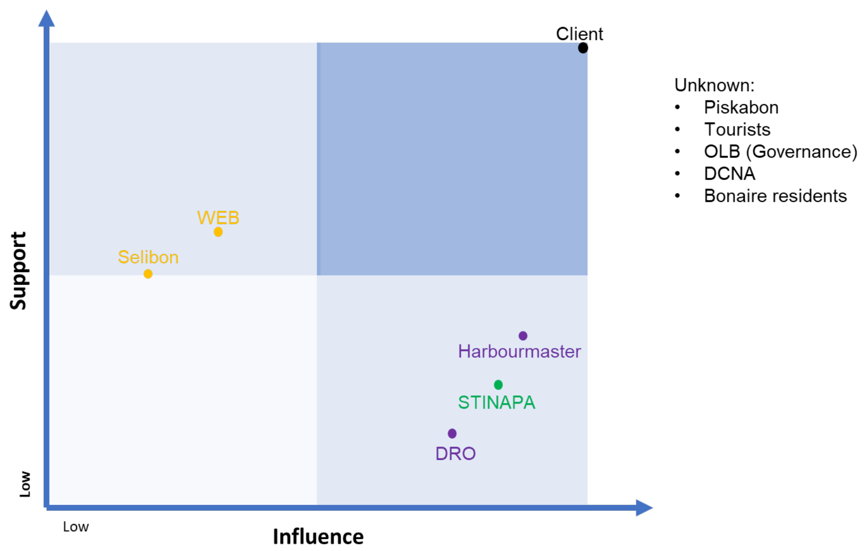


Figure 3.10: Stakeholder map

3.2.2. Stakeholder meetings

During the stay in Bonaire different meetings with stakeholders are arranged. Some meetings are needed to gain information about for example mooring techniques, waste treatment on Bonaire or impacts of watersports on marine life. Other meetings are about the real political feasibility of the project. In Figure A the goals and summaries of every individual meeting can be found.

3.2.3. Conclusions from meeting

STINAPA

The environmental organization STINAPA is one of the most important stakeholders because this organization is in charge of the marine park surrounding Bonaire. Because of their high influence and their prudence around this area, STINAPA was expected to be an objecting party of the project. A meeting with them showed however that the project could also provide a solution to their problems. Cases like dead turtles, killed by foils show that the fast watersports in the marine park are harmful for the marine life. Moving these watersports outside the marine park could provide benefits for STINAPA.
Next to a general meeting for the introduction of the project, more information was gathered in other meetings about the impact of watersports on the marine park and the mooring solutions STINAPA uses, as they are in charge of mooring locations in the waters around Bonaire.

Openbaar Lichaam Bonaire (OLB)

Concluded from the meeting with OLB and the harbourmaster, placing a new platform like this creates a lot of work for the OLB. New policies should be written, a way should be figured out to prevent precedence, the ownership should be determined and an enforcement plan is needed. In the meeting with the harbourmaster and the policy advisor of DRO, all these issues have been discussed.

Other meetings

To gain information about the context of Bonaire, meetings with stakeholders like Selibon (waste processor on Bonaire), WEB (waste water processor on Bonaire) and Recycling Bonaire have been arranged. The information provided was used to have a complete background analysis of Bonaire and its facilities.

Lastly a meeting with Reef Renewal was arranged to gain information on their purpose and see if the project could be of added value for them. Concluded was that placing a platform like this in deep waters makes it difficult to use one of their techniques of coral growing, as they are mainly executed in shallow waters.

3.3. Environmental Analysis

To be able to evaluate the technical requirements and design of the platform, environmental data needs to be analyzed. A focus is given on solar power, wind, wave, current, bathymetry and extremes. Some have extensive evaluation for electricity generation, others more for the evaluation of the design of the hull. Below, an overview is given of the environmental conditions in which the platform is situated.

Bonaire is an island in the Lower Antilles where the average temperature is 29 degrees Celsius. Humidity on Bonaire is 76% which is quite high and the island is surrounded by seawater which has a salinity of 3.5 parts per thousand (ppt).

3.3.1. Solar power

As Bonaire is known for having an average uv-index of 11 (which forms a threat to human health after long exposure) and a near constant stream of sunny days. solar power forms a considerable option for energy generation. However real data about the solar capabalities on Bonaire are missing. Thus to do get an accurate estimation of the possible solar power, real life data of solar panels from the client has been used (as there is a lack of other data). The data is scaled back to square meter solar panel to make an estimation of the necessary amount of solar panels. If we plot the overall data from the solar panels in a histogram, we get an idea of the distribution of the possible power generation. This is done in Figure 3.11. This shows us that about 73% of the time, the solar generating characteristic of a solar

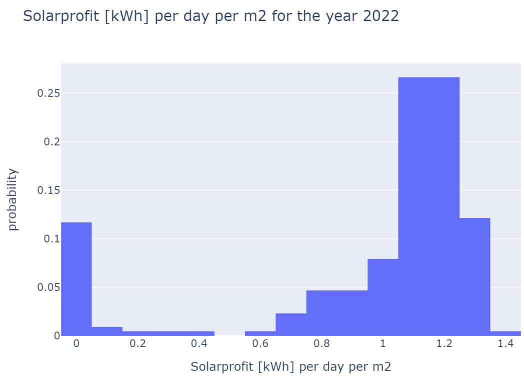
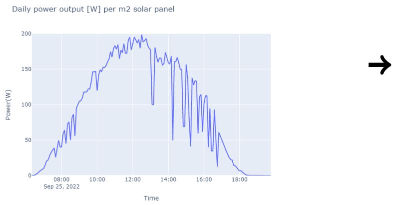
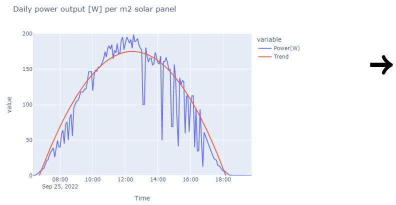


Figure 3.11: Distribution of the solargeneration per m^2 solar panel

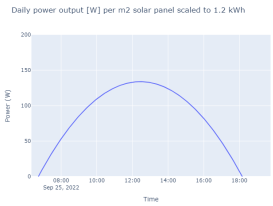
panel is between the 1-1.3 kWh. Which means that for this report, 1.2 kWh per m^2 per day can be taken as the standard for power generation. The generation of this power will not happen instantaneous, but will change over time. Therefore, it is important to get an idea of the power generation curve of the solar power. This is done by taking an arbitrary day, find the trend through the solar generation that day and then finally scale that trend in such a way that the total power generation is equal to 1.2 kWh. This process is visually displayed in Figure 3.12



(a) Original power generation data



(b) Trend through power generation



(c) Final trendline for solar power generation

Figure 3.12: Getting from solar data to a usable trendline

Now that we have usable data for solar power generation, one can start looking at the wind power generation, as this is also an option for the platform

3.3.2. Wind power

For wind power, two things are interesting: The amount of energy that can be deducted from the wind and the general wind force that the platform can encounter. The energy estimation can be made by using the actuator disk theory. This theory gives us a base to estimate what percentage of the kinematic energy (= energy that the wind can deliver) can be used to actually generate usable electric energy. A deep explanation of this calculation is not necessary, but the conclusion drawn by Betz (in the Betz theory) is that there is a theoretical maximal efficiency of a wind turbine of about 60 % of the kinematic energy in the air. Next to that, 'Modern operational wind turbines achieve at peak 75 % to 80% of this Betz limit.' (Ranjbar et al. (2019). Therefore, this report will assume that about 45 % of the available kinetic energy can be turned into actual electric energy.

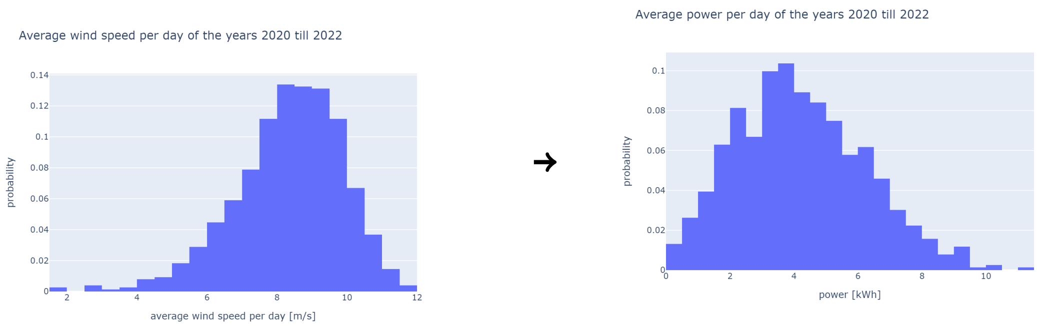
According to Neill & Hashemi (2018) the available power in wind is equal to:

$$P_{available} = \frac{1}{2} * \rho_w * A_{disk} * u_0^3 \tag{3.1}$$

Where

- $P_{available}$ is the available power in watts
- ρ_w is the density of the wind, which is equal to 1.225 $\frac{kg}{m^3}$
- A_{disk} the total surface area that the spinning blades manage to cover.
- u_0 the wind speed.

So, in this formula there are two unkowns: The area spanned by the blades an the wind speed. The latter can be found by using data. This data was obtained from the website of Windguru and gives, for a period of the years 2020-2022 the following probability of windspeeds (average per day) as in Figure 3.13a



(a) Winddata from WindGuru

(b) Available power per day per square meter of 'windmill area'

Figure 3.13: Going from wind data to potential wind power

For the sake of this calculation, the windmill is simplified in such a manner that it is able to operate in wind speeds from 4 to 12 $\frac{m}{s}$. Which means that it can operate in the entire spectrum. By using Equation 3.1, Figure 3.13a can be turned into a histogram containing the possible power per m^2 of 'disk-area'. Here it is important to note that it is a hard assumption to say that the power generation (so not the available power) of a windmill increases linearly with the size of the windmill. This is because the same theory that Betz used to identify the maximum theoretical efficiency also states that the efficiency increases with the rotor size. However, this calculation is not made in this report and thus we get the histogram as displayed in Figure 3.13b. From that figure, it can be concluded that the theoretical average power generated by a square meter of windmill per day is equal to (about):

$$P_{generated} = 4 * A_{disk} \ [kWh] \tag{3.2}$$

For the further impact of the wind on the platform, one can conclude (from Figure 3.13a) that the average wind speed is about 9 m/s and the maximum is about 12 m/s. Therefore, these speeds can be used later to calculate the mean wind force on the platform.

3.3.3. Missing data

Sadly the data about current, tidal, bathymetry, wind and extreme weather conditions is missing or was not accurate enough. From websites such as windfinder, tideschart.com and seatemperature.re however, tidal conditions are assumed to be very mild (smaller then 50 cm of difference).

3.4. SWOT Analysis

For the completion of the needs analysis, a SWOT analysis is performed to minimize the risk of missing certain aspects of the project. The SWOT analysis was performed in the early stages of the project by means of a brainstorm session with the clients. During a 1,5 hour session, both the client as project members wrote down the strengths, weaknesses, opportunities and threats, divided into the subjects by the PESTEL framework. Per subject, a small discussion was started to evaluate the results.

Below, an overview is given of the most important points of the analysis. The full SWOT analysis can be found in Appendix B

3.4.1. Top Strengths

- The platform provides a new watersport zone outside the coastal area, which is needed due to new (potential) restrictions and upcoming new watersport: foiling. The platform provides a solution for the foiling problem on Bonaire. Foiling may cause harm to turtles in the marine park. Moving these activities to outside the park will have a positive impact on the wildlife in the marine park.
- The client has a large network of connections to make use of.
- The client has established successful businesses on Bonaire, providing financial certainty.
- The client is on good terms with the people of Bonaire and government.
- The building and development of the platform will be done in the Netherlands, providing knowledge and facilities.
- The platform will be designed to be modular. Repairability/replaceability will be a focus point in the design.
- A lot of knowledge is available within the project about watersports, which will be the focus point of the platform.

3.4.2. Top Weaknesses

- If Business (from the client or in general) on Bonaire goes bad, this may cause the project to be in jeopardy.
- The clients are non-local investors, which might cause friction with the people of Bonaire and its government.
- Parts and materials will be imported from the Netherlands, which gives restrictions on shipping (size, weight).
- (human) Waste coming from the platform could end up in the water/the reef, causing harm to the environment.
- Foiling is in principle not beneficial for the environment compared to no foiling at all.
- Putting something (such as a platform) in the water disrupts the environment either way.
- The manufacturing and shipping of the platform will produce CO2.
- Patenting a platform will be hard. Risk of competition is there.
- Sustainability is relative, a hard definition should be given to work with

3.4.3. Top Opportunities

- Fast watersports are a problem in the marine park (STINAPA) and is becoming a greater activity on Bonaire. Not offering fast watersports on Bonaire would be detrimental to Bonaire so getting fast watersports out of the Marine Park would be very beneficial.
- The platform is a new opportunity for the economy of Bonaire.
- Acquiring the Blue Destination certificate for ecotourism will provide exposure.

- Promoting the project both locally as within the government might raise support.
- The political relationship of Bonaire with the Netherlands may be helpful in acquiring subsidies or other help.
- There might be subsidies available for sustainable (tourism) projects (on Bonaire).
- Interest has been shown around Bonaire to invest in the project.
- Bonaire's tourism sector has been growing for the last decades, which provides available money from tourists.
- Working together with local businesses for foods/drinks will have a positive impact on Bonaire.
- The project might have opportunities for internships of (local) education.
- Recreation and leisure (on the water) is part of the culture/life on Bonaire, making the project have a likelihood to succeed.
- Both the people of Bonaire as tourists can be targeted for the platform.
- The platform may be an opportunity to bring people together from different ”classes”, reducing the social issues present on Bonaire.
- Bonaire has a lot of solar and wind potential for renewables which can be harvested on the platform.
- The platform has the potential to be a sustainable demonstrator for solar power and storage for the island.
- The platform can be used to raise awareness among tourists for sustainable recreation, by organizing for example lectures/workshops, providing information etc.
- The platform can have room for research facilities for universities, STINAPA or other research institutes.
- The platform can be an example to the rest of the world of how sustainable tourism and watersports can take place.
- Making the platform recyclable is better for the environment by reducing carbon emissions in other projects.
- Patrol of the harbour master could be made possible from the platform, using for example drones.

3.4.4. Top Threats

- The governmental structure of Bonaire tends to cause favoritism and requires lobbying.
- STINAPA's nature policy is strict and doesn't allow a lot of freedom.
- STINAPA controls mooring, and such has quite a lot of power in permissions. Also, this gives restrictions on size, distance to shore of the mooring etc.
- The project probably requires new policy to be designed, which takes a lot of time.
- Risk of too little investors or withdrawing investors may cause the project to be canceled.
- The rise in costs of container shipping might cause financial troubles.
- The current global inflation may cause financial trouble.
- Other investors may copy or have the same idea. If they turn out to be ahead, this may pose a losing scenario.
- If not carefully approached, the platform (in terms of pricing and targeting) may cause the social/economical gap between the people of Bonaire and tourists to become larger.
- Local businesses are not very large; scarcity of foods and drinks might be an issue in the supply chain.
- Materials on the island are scarce, which might give installation issues/delays, or restrictions on material use .

- The island of Bonaire does not have a lot of good facilities when it comes to repair centers, spare parts etc. This may cause trouble in terms of repairability of the platform.
- As Bonaire has quite a harsh environment (heat, dust, sea, uv-radiation), materials must withstand this, or parts should be repaired/replaced more often.
- The shipyard of Bonaire might cause restrictions on size and weight of the platform.
- There is little to no options to recycle materials on Bonaire, which will make it hard to be sustainable.
- Climate change may cause more natural disasters/hurricanes/droughts/heat waves, making the platform unattractive to visit.
- Legislation of the EEZ (Exclusive Economice Zone) of Bonaire can cause trouble in realising the platform.
- Insurance may be difficult to arrange.
- New local legislation is probably required for this new attraction
- The monopoly position (one platform in bonaire) could cause blockades from the government/other companies, or a forcing of a public platform (less/no commercial purpose).

3.4.5. Takeaways SWOT Analysis

A few important conclusions may be taken from the analysis. First of all, the project has a large strength in its way of finding a new watersport zone outside the marine park area, which takes of pressure of the already busy coastal area. STINAPA has already taken precaution in banning e-foiling in the marine park and considers, kite-, wind- and wingfoiling as a problem in the marine park. The floating platform could solve this problem.

Next to this, the project will not focus on just the tourists, but the people of Bonaire will also be targeted as an audience. The fact that the client is on good terms with the locals and government may (is) be a strength.

In the context of the island of Bonaire, a couple of threats need to be considered. Government wise, the running of the country tends to be causing favoritism, where lobbying is required to get things done. This might pose a problem if a conflict arises between parties. The project should thus be handled carefully. A strength of the project is that the client lives for 20+ years on Bonaire and is on reasonably good terms with the government.

Next to this, materials and service is limited on the island. Repairs and spare parts could take a long time to be fixed, as almost everything has to be imported. Luckily, the development and production will be focused mostly in the Netherlands, making a lot more possibilities available. This does however mean that the entire island should be able to fit in a 40-feet container (meaning that the longest part can be about 12 meters).

However, once the platform is based on Bonaire, everything will take place from there. Repairs on Bonaire could be a lengthy process. The fact that Bonaire has a harsh environment with lots of direct sunlight, wind and dust makes this threat even larger.

One of the weaknesses of the platform is the risk of (human) waste ending up in the water, which eventually could end up in the reef of Bonaire. This could be reduced by designing solutions to catch waste such as plastics from the platform. Incentives to throw waste into the relevant waste bins could also be introduced. This in term will raise awareness of the visitors' produced waste and will set an example to how sustainable tourism can take place on Bonaire. This can also take away issues with STINAPA, as they are very strict in terms of their marine park management.

Next to this, the production and shipping of the platform to Bonaire will produce CO2, raising the question as to how sustainable the platform will be. To reduce production of CO2, use of recycled materials could be an option to reduce production emissions. Lastly, the materials that will be newly produced could be as sustainable as possible by using materials with the least impact on the environment.

Closing off, putting something unnatural (such as a platform) in the water is "unsustainable" from the beginning, looking from a strict view. The question raised is then, what is sustainable in the scope of this project? A definition of this should be formulated to demarcate sustainability in the context of the island of Bonaire.

The definition of sustainability according to the UN (United Nations) is: "Meeting the needs of the present without compromising the ability of future generations to meet their own needs." Within the scope of this project, sustainability has been defined as a sustainable platform that will:

- Produce the least emissions as possible during its production, its lifetime in use and its decommissioning.
- Mitigate the negative effects of putting it in the water as much as possible, looking at the environment and marine life of Bonaire. Where possible, the platform will have positive impact by providing possibilities for nature restoration and research.
- Make the platform as repairable as possible with the facilities at hand on Bonaire, providing a contribution to the local economy as well.
- Mention the hidden impact of the island in terms of rare earth metals and labour conditions.
- Make the platform in such a way that it will be as circular as possible, meaning materials and facilities could be recycled.

3.5. Results Needs Analysis

In this part of the report, three questions have been researched:

- ”Is there a valid need for this new system?”
- ”Is there a practical approach to satisfying such a need?”
- ”What is sustainability within the context of Bonaire?”

By means of a context study, stakeholder analysis, environmental analysis and finally a SWOT analysis, the background of this project has been mapped to answer these research questions. The conclusions of these questions can be found below. Next to this, further requirements are addressed.

3.5.1. Is there a valid need for this new system?

Watersports play a vital role in tourism and recreation on the island. The problem however is that these watersports mostly take place in the marine park, disturbing life in the great coral reefs.

As a consequence, NGO STINAPA is making efforts to seek alternatives for watersports. Especially (e-)foiling can make an impact on the environment and is already banned from the ”light blue” water (the marine park). However, supervision and enforcement is hard to accomplish for STINAPA. Thus there is a need for a system which regulates where and how watersports will take place out of the marine park.

Next to this, the Openbaar Lichaam Bonaire has their long term tourist goals set up in their Tourism recovery plan. In the report, the need for sustainable tourist activities, diversification of activities is emphasized.
Concluding from the efforts of sustainable energy generation in subsection 3.1.5, new incentive has to be given to Bonaire to make it produce more sustainable energy, as the renewable energy share is only declining in the past few years.
Taking all this into account, the need for the new system, namely a sustainable floating platform from which watersports can take place, is validated.

3.5.2. Is there a practical approach to satisfy such a need?

To satisfy the need of this platform, the approach can be taken in multiple ways. But as subsection 3.1.5 and subsection 3.1.4 make clear, the need for an example in sustainable energy generation and usage of materials is a big one for the Island of Bonaire. Therefore the practical approach to this platform is to make it as sustainable as it possibly can be.

3.5.3. What is sustainability within the context of Bonaire?

According to subsection 3.4.5 the definition of sustainability within the context of this project contains the following requirements:

- Produce the least emissions as possible during its production, its lifetime in use and its decommissioning.
- Mitigate the negative effects of putting it in the water as much as possible, looking at the environment and marine life of Bonaire. Where possible, the platform will have positive impact by providing possibilities for nature restoration and research.
- Make the platform as repairable as possible with the facilities at hand on Bonaire.
- Mention the hidden impact of the island in terms of rare earth metals, labour conditions etc.
- Make the platform in such a way that it will be as circular as possible, meaning materials and facilities could be recycled.

3.5.4. Further requirements of the clients

The platform will have a bar with locally produced food and drinks where possible, possibilities for watersports such as freediving, e-foiling, supping and a strong focus on foil watersports to welcome this upcoming Olympic sport without harming turtles.

Next to this, other activities will take place:

- monthly/more often workshops/lectures
- monthly school swimming trips
- provide a research platform for STINAPA and universities such as TU Delft, Wageningen, Radboud and Twente
- monthly movie nights
- (private) sleepovers in case of special occasions such as weddings
- monthly spa day (massage, wim hof experience, breath workshops, yoga)
- monthly VIP lunch (with professional cook)
- twice a week chill-session: silent disco, sup-boards, snorkling-sets, e-foils, wings, kayakking
- monthly silent disco

The goal is not only to minimize the impact on the marine environment, but the aim is also to look into potential collaboration with initiatives which aim to have a positive impact on the environment. Examples for this are reef renewal initiatives such as Roffareefs and Reefy.

4
Concept Exploration

After performing the SWOT analysis, the goals of the platform were determined. These goals can be found in the previous chapter. By analysing the goals, the following list of facilities can be defined:

- Necessary general facilities such as fridges etc.
- General overview of materials for the platform
- Means of handling waste (both waste water and general waste)
- Means of generating and storing water
- Means of generating electricity
- Means of storing electricity
- Means of propelling the island
- Means to keep the island at a certain position (stationkeeping)

This chapter will give a large overview of the options for these different facilities. These (except for the general facilities) have been summarised in a morphological mapping. This morphological mapping has been used in a brainstorm with the clients to come to six possible concepts, which are to be scored in chapter 5.

4.1. General Facilities

To start, a clear overview of the general facilities in different categories for the platform are written down: Housekeeping, Garbage processing, Sewerage, Sports, Lights, Safety and Other. With this list of facilities, the layout of the platform can be created. Also the total power output and costs can be calculated from this list. The full overview of the general facilities, power output, costs and amounts can be found in Appendix C. This list consists only of power consuming facilities and facilities which are important for the goals and take up a lot of space. For example docking stations for the boat are taken into account, but sunbeds are not.

4.1.1. Facilities

Housekeeping

Taking into account that around 100 people will spend the day on the platform, it is important to have the right facilities on board of the platform. To provide all people with food and beverages a full kitchen is needed. As shown in the previous chapter, one of the goals is providing a VIP lunch with professional cooks which means the right equipment is required. Some of the facilities in this kitchen will be: refrigerators, freezers, an induction cooker, oven, barbecue, dishwasher, kettle etc.

Garbage processing

The waste produced on the island should be collected and separated. The floating jetty around the island, this will be elaborated on in section 4.3, stops the possible waste in the water from floating away. Bins per waste type will have to make sure that the waste will be separated. The waste press presses the waste to bales which are easy to store or transport.

Sewerage

To process the waste water, different equipment is needed. The used water will have to be collected and stored until discharge. In section 4.5 further possibilities possibilities regarding waste water treatment are discussed and elaborated.

Sports

One of the main goals of the floating platform is providing the opportunity to perform watersports from the platform. Some of the watersports like E-foiling needs charging stations. Other sports like wingsurfing just need space to store the wings and the boards. So for all the sports together a large storage is needed to store E-foils, SUP-boards, wings, sails, boards and other equipment like life jackets and snorkelling gear.

Lights

Other indispensable power consumers on the platform is lighting. Some lights are needed for safety restrictions and visibility for other ships like anchor lights, emergency lights and top lights. Besides that, general deck lighting will have to be installed and as one of the goals is organising a silent disco and movie-nights, equipment like ambient lights and disco lights are a good addition to the platform.

Other

Looking at the goals of the platform, different facilities are required for entertainment of the guests. Providing a movie-night requires a beamer, providing a silent disco or ambient music requires a DJ-booth and speakers. Other power consumers are fans and charging points for phones, camera's and laptops.

4.2. Materials

This section will dive deeper into two kinds of materials that are important to consider in the building phase of the concept. Namely the building materials and the materials needed for painting the ship (such as anti-fouling). Both of these are important, especially the anti-fouling as that can have a large environmental impact. The painting materials section however will come to a conclusion about what kind of anti-fouling will be used, as there is not that much choice when it comes to low environmental impact / high effectiveness anti-fouling materials.

4.2.1. Building materials

In this subsection, different materials will be listed and their properties will be combined into an overview. The relevant properties that are compared; fatigue strength, price, CO2 footprint, density, recyclability, a measure of UV-resistance and a measure of sea water resistance.

Different materials have different characteristics and will be used for different functionalities. So an overview of different functionalities must be defined. Functions for different materials are: Hull of vessel, roof and support structure, storage cabinets, floating platform for watersport entry and exit, furniture, kitchen, etc. For this section the materials of the hull will be analyzed as the hull is the largest single material on the vessel. Later in the report when the final concept has been defined more materials and their properties will be analyzed. Most common materials that will be analyzed are; stainless steel, aluminium, polyethylene and hardwood, important properties are stated in Table 4.1

When looking at the hull of the platform, it must be strong enough to withstand the offshore conditions this property is the yield strength of a material. Also important, the material must be able to resist the cyclical loading of the waves and the high salt concentration of the sea. Further properties of importance: price, recyclability, density, embedded CO2, UV-resistance. All these properties are obtained using software CES Edupack (Limited (2022)) and are summarized in the table below.

Table 4.1: Table containing material properties.

	Wrought Al-alloys	**fiberglass**	**Stainless Steel**	**Polyethylene**	**Hardwood**
Yield strength [MPa]	*65.1 - 252*	*207 - 304*	*257 - 1.14e3*	*17.9 - 29*	*43.2 - 52.8*
Fatigue strength [MPa]	*61.7 - 150*	*41.3 - 91.1*	*256 - 542*	*21 - 23*	*42.8 - 52.3*
Density [kg/m^3]	*2.63e3 - 2.7e3*	*1.75e3 - 1.97e3*	*7.61e3 - 7.87e3*	*939 - 960*	*850 - 1.03e3*
Price [USD/kg]	*1.96 - 2.12*	*33.7 - 37.1*	*2.82 - 3.02*	*1.4 - 1.45*	*6.7 - 10.8*
CO2 footprint [kg/kg]	*2.54 - 2.8*	*5.73 - 6.32*	*5.18 - 5.71*	*1.77 - 1.95*	*0.523 - 0.578*
Recyclability [-]	*Yes*	*No*	*Yes*	*Yes*	*No*
Use in salt water [-]	*Acceptable*	*Excellent*	*Excellent*	*Excellent*	*Limited use*
UV radiation [-]	*Excellent*	*Fair*	*Excellent*	*Fair*	*Good*

A more in depth look will be given into the material aluminium. Aluminium is a non magnetic metal that is very lightweight and very good against corrosion. In most use cases aluminium is not kept pure but is combined with other metals to get obtain desired material properties, these are called alloys and aluminium is divided into different series. These series range from the 1xxx to 8xxx series. Where different numbers are filled in for the x's, the different numbers indicate how much of a certain material is added. The lower the numbers in a series, the less alloying materials are added. For this marine application the 5xxx series will be used and is an aluminium-magnesium alloy. Furthermore aluminium alloys have a type of treatment the material underwent during production which is noted behind the series number for example: 5052 H36, where H36 denotes the hardening treatment. This post treatment greatly influences material properties such as yield strength and corrosion resistance. An overview of the 5xxx series is given in Figure 4.1 where different yield strengths for different 5xxx-series alloys and different treatment methods are given. Here can clearly be seen that the more alloying magnesium is added, the less strength the alloys have.

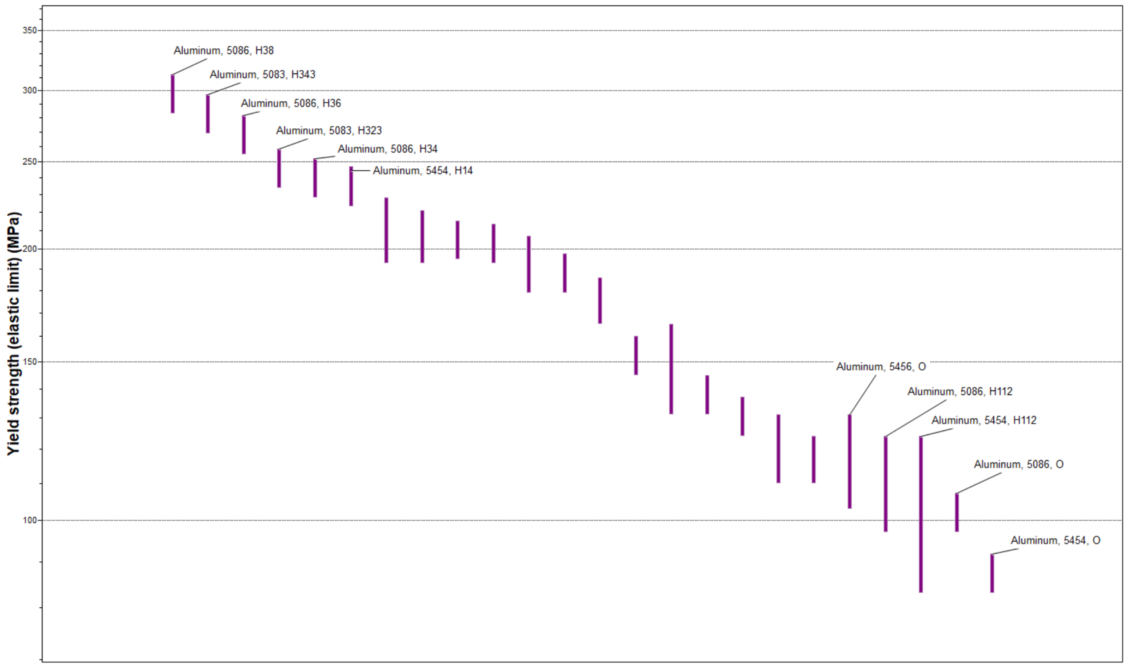


Figure 4.1: Overview of yield strengths of aluminium 5xxx-series.

fiberglass is also quite common when it comes to materials for vessel hulls. The material was primarily only used for sail- and motorboat racing for its lightweight properties, but nowadays is used for many medium to small leisure vessels. Fiberglass is a combination of a fiberglass cloth and a resin to bind the cloth. The fiberglass and resin is built up in layers and must be made in a mold and hardened by curing in an oven, this process is called thermosetting. Once hardened there is no going back which makes it almost impossible to recycle these thermoset materials.

There are some processes in place for recycling these fiberglass materials, but the recycled material won't be used as fiberglass. Instead they are used for construction materials like bridges or filling for concrete. In the future, roughly 10/15 years, the idea is that the amount of CO2 emissions per kg will reduce and more innovations will come along for recycling. This is expected due to the offshore wind industry pushing for renewable fiberglass solutions as windmill blades are mostly made from fiberglass.

4.2.2. Painting materials

This subsection will go deeper into possible anti-fouling materials and maybe even painting. Starting with an explanation of what anti-fouling actually is and what makes it such a problem for the environment. After that different types of anti-fouling and feasible options for this project will be identified.

Anti-fouling is a special category of coating for a marine vessel that slows the growth of marine life on the hull of the vessel. This coating layer usually contains a certain biocide; a material that impedes or slows the growth of organisms. Usually composed of copper or zinc. This layer slowly wears off and the copper and zinc will be distributed, thus enlarging the concentration in the local environment, which leads to negative effects Lin (2021).

Different types of anti-fouling are categorized in hard and soft types. Hard types slowly release toxins embedded in the paint while keeping the paint layer intact. The soft type will naturally shed itself releasing layers of paint where marine growth has grown on the hull. This soft type will also easily shed at high speed applications.

One other method for removing marine growth exists and that would be to regularly remove marine growth by using a high pressure washer for underwater applications. This does cost quite a bit of labour but does not release toxins into the water.

For the application of a floating platform the best type of anti-fouling would be one that lasts longest. This is due to the fact that anti-fouling must be removed and added out of the water. On the island of Bonaire it would not be realistic to get the platform dry completely. So a durable and long lasting anti-fouling would be best, of the hard type.

4.3. Waste Treatment

Using a floating platform providing watersports, activities and food and beverages to tourists entails the generation of waste. As one of the main goals of the platform is minimizing the impact on the environment, a well thought-out plan is required to ensure there will be no impact from this waste on the environment. This section will start with different manners to reduce the general waste to a minimum. However, there will always be generation of waste, therefore the waste handling plan on the platform will be discussed next. Lastly, this waste will always have to be transported to shore for further processing.

4.3.1. Reduce waste

The biggest source of waste generation are the remnants of food and beverages. Cans, glass bottles, carton boxes, plastic packaging and organic waste are all remnants of tourists spending a day on the platform. Assuming all foods and drinks need to be bought at the bar and can not be brought from home, the waste can be reduced mostly at the bar itself, making sure the bar hands off the least waste as possible. This can be done by pouring all drinks in reusable cups and setting a fee on buying a new cup, preventing waste spreading among the platform. Waste like plastic packaging and carton boxes can also be reduced at the moment the foods get served. Dishes and snacks are served after unpacking which makes sure all possible waste stays behind the bar and can be thrown away (or even seperated) by the bar crew.

To increase the positive impact of the platform on the environment of Bonaire, an idea is to produce the personal cups mentioned above by using recycled plastic. As mentioned in Figure 3.10, No Waste Caribbean Vibes is an organisation that collects small plastic waste on and around the island of Bonaire. Currently they melt down the collected plastic and sell it as little souvenirs. A cooperation with this cooperation would mean glasses produced by melting down locally collected plastic waste, which will increase the positive impact on the environment.

4.3.2. Waste handling on the platform

As mentioned, the production of waste on the platform can not be reduced to zero. Therefore a plan of handling the waste is required. At the moment the government of Bonaire and Selibon are working on several plans to improve the facilities in recycling and reusing the produced waste. Investments on advanced waste handling and recycling are scheduled to prevent any waste dumping in 2030. In cases where local waste handling is not possible in 2030, the waste will be transported to be processed somewhere else. To respond to these plans all on-board produced waste will be collected separately. Different bins for plastic, glass, organic and paper will be placed on the platform.

There is always the possibility that some waste will end up in the water which could be extremely dangerous for animals like turtles or fishes. These animals consider this waste as food and try to eat this with death as possible consequence. Also, plastic packages can be dangerous for animals by getting tangled in it or the plastic can cover the coral which is also destroying. This is why all the waste accidentally leaving the platform should be captured immediately.

One possible way to do this is by building a floating boundary around the platform. This can be realised by a floating tube around the whole platform, but this causes problems for the watersports leaving the platform. A better option is to add a floating jetty surrounding the whole platform which can be used to launch the watersports from. Between this jetty and the platform about two meter is clear where the possible waste will fall into. Another benefit of a jetty like this is that the whole deck of the platform can be used for other purposes like bars, furniture and storage instead of a watersports deck. This jetty can then be taken back into the boat when it would need to move, thus not adding any real extra resistance to the platform.

In a day a lot of waste can be produced by the guests which all should be stored on the platform during the day. Installing a waste press on the platform could be an outcome for this problem. The press compresses the collected waste to dense blocks of waste which could be transported more easily and stored without taking a lot of space.

4.3.3. Waste processing

All collected waste stored on the platform should be transported to the shore. A pendle boat can be used for this. Every day this boat pendles between shore and the floating platform to bring and pick up people. Also boats needs to deliver the supplies like food, beverages and other required products to the platform. To provide fresh food to the guests, these supply vessels should pendle on a daily basis which means every day the collected pressed waste can be transported to shore.

After arriving at the island of Bonaire the waste should be processed. As stated in subsection 3.2.2 Bonaire (at this moment) can't recycle most its waste and thus dumps this on a landfill. Waste produced by households is picked up once every week. The waste from the households is separated when arrived at the landfill of Selibon.

Selibon is a local company that comes to collect the trash and sorts the trash at their new facility. At their facility waste is separated and processed. Bergwijn (2020) Selibon is working hard on improvements in the processing of waste by investing and making plans for more sustainable and environmental-friendly waste handling. At the moment Selibon yearly dumps 27.000 tonnes of waste on their landfill. 70 to 80 % of this dumped waste is residual waste and therefore difficult to recycle. To tackle this problem Selibon is investigating where all this waste is coming from and supports and provides facilities to the residents to separate their waste. Selibon is in contact with different companies who are interested in the different kinds of waste. They can sell their waste to companies interested in plastic, green waste, compost, construction waste or glass. The earned money will be used for further investigation or investments like a glass crusher for further handling of the waste.

Also organizations like 'Recycling Bonaire' and 'NOBO' are committed to the recycling of waste like glass, compost, car wrecks, paper, wood, rubble and plastic. (*NOBO Bonaire*, *Recycling Bonaire*)

4.4. Water Supply & Storage

Fresh water is an important resource for the platform. The production methods, location and storage of fresh water will be discussed in the following section. The method that are considered will be reverse osmosis, fresh water spring collection and thermal desalination.

Reverse Osmosis (RO) is a membrane based technology which splits ions from salt water to produce fresh water. The RO system has as input a feed stream and 2 outputs, one with a high salinity and one with a low salinity. The high salinity stream is called concentrate, brine or reject while the low salinity is called permeate or product water. This application would be ideal given the location of the platform, on an island surrounded by sea water. The island of Bonaire already produces all of its drinking water with an RO system installed by GE in 2019 which is operated by WEB Bonaire. There are two options when it comes to fresh water from reverse osmosis, onshore or offshore production.
Fresh water spring collection is the easiest method of obtaining fresh water. However this is not an option for the arid island of Bonaire where only one known spring can be found [Borst (2005)]

Thermal desalination is a method of desalinating water by heating the input water and catching the vapors as output. The energy required for thermal desalination is quite a bit higher than for RO, 15-18 kWh/m3 for thermal and 5 kWh/m3 for RO. An advantage of thermal desalination over RO is the fact that there are no membranes used in the process which are susceptible to fouling. The stability of thermal desalination indicates an almost guaranteed water supply [Touati (2017)]

There are multiple options when it comes to fresh water production. Traditionally large installations for desalination are onshore, such as the RO system on Bonaire. But to cut transportation costs and effort, the water could also be produced offshore on the platform itself. An abundant water supply is readily available, one would just need electricity, these are just some of the pro's and con's which are further elaborated below.

Onshore production would be easier with installation of RO systems as there would not be a space and weight restraint though tendering water to the platform could be seen as a minus. Offshore production gives fresh water right at the source and thus no tendering of fresh water is needed. More electricity is needed however on the platform which could end up taking up a lot of space. For thermal desalination there are only large applications in use today, for a small scale platform there are currently no solutions.

The storage of fresh water will have to be onboard the platform whether the production is on- or offshore. The size of the storage tanks will be dependent on the water demand due to visitors. There are some different materials that can be chosen for the storage tank. Most common is a plastic water tank, usually polyethylene.

4.5. Wastewater Management

According to the International Maritime Organisation (IMO): The discharge of raw sewage into the sea can create a health hazard. Sewage can also lead to oxygen depletion and can be an obvious visual pollution in coastal areas - a major problem for countries with tourist industries. Therefore, the wrong use of wastewater treatment systems can have an impact on the environment. To treat the wastewater there are two options. Storing the wastewater in a tank and pumping its contents to an external processing plant whichever way possible or treating the waste locally. Both have their (dis-)advantages that will be discussed in this section. For now, from those two options 3 different systems can be designed:

- A system that stores all 'dirty' water
- A system that tries to re-use some water
- A system that re-uses all of the water

Only the last system will allow 'off the grid' local processing. The process however is often costly either in time or in money and therefore not very viable. Next to that, WEB has the knowledge, money and centralized system that will allow for cheaper treatment but also for possibilities to allow for better usage of space and energy and re-usage of the waste.

Therefore this elaboration starts with the latter. Here one tries to re-use some water namely: Grey water. Grey water can be used to flush the toilets. Grey water is all waste water of the island excluding the toilets and the reuse of grey water for flushing the toilets can reduce the fresh water usage with about 30 % (Vuppaladadiyam et al. (2018)). The levels of contamination that the grey water can contain when it is being used to flush the actual toilets can be found in Vuppaladadiyam et al. (2018).

This means that the grey water has to be treated. This can be done in one or multiple steps (Vuppaladadiyam et al. (2018)). For this treatment system different solutions exist. The wavebrite system from halyard is an interesting possible option for water filtering. This system is able to filter up to 265 liters of grey water per minute (if necessary).

Then, for both options (and for the first this is all that is necessary) the platform would need a black water tank or a septic tank as the ports in Bonaire have the option to dispose of waste water. The black water tank needs to be at least the size of the freshwater tank, if not larger, based on the water usage per person per day and the amount of times that the waste water can be disposed of. Important to note here is that WEB is writing plans to organize a 'waste water ship' that will sail by all of the ships that are anchored outside the harbour to pick up their waste water.

One factor that influences how much waste water will have to be stored a lot is the toilet. The average dual flush toilet uses between 3-5 liters, per flush. Vacuum toilets use between 1-1.5 liters of water per flush, saving over 2 liters every single time they are used. However, according to O'Reilly (2021) The energy consumption of a vacuum toilet however is higher than that of a conventional toilet as the entire system needs to be under pressure. A conventional toilet just needs water pressure, a vacuum toilet needs about 4 kWh per person per year (*Jets vacuum toilets*).

Another toilet option is to use salt water to flush the toilets. This would mean that a pump has to be installed to put pressure on the system and that the waste water will be mostly salt. However, as the research question is mostly about feasibility, the report will try and look if regular 'fresh water' toilets are feasible.

Finally, one could also decide to watch the showers closely. In that case, one could forbid the usage of any detergents. In that case all of the water could flow of the sides of the platform. In that case, the black/grey water tank combination would be considerable smaller.

As it seems, using a black and grey water collection system is the most feasible option. As the grey water is already being reused, it leaves the question whether the black water tank can be used for other means than purely storing wastewater. One of the options here is using the black water tanks as a means to generate methane, which can then be used for other purposes. According to (Gao et al. (2018)). This is feasible, but when reading through the research it becomes clear that to have any form of efficiency, one is talking about a scale of weeks. As the tank must be extremely big to store this amount of black water, this option is not feasible.

4.6. Propulsion

As the ship will not be moored at all times, one has to look at possible ways to transport the ship. This can be done by an alternative ship, or by making the ship self-propelled. But before one can say something about the possible ways of transporting the ship, one should have an idea of the resistance of the ship when it sails through water. This section will dive deeper into the resistance calculation for the floating island and after that into the different options for moving the platform.

4.6.1. Resistance calculations

The resistance on the platform will consist of two different factors: resistance due to the surface area of the ship above the water and resistance due to the underwater area of the ship. Then there are two different types of resistance: resistance whilst lying still and resistance whilst sailing. Both are considered in this chapter, as the resistance of lying still is nearly equal to the resistance of actually sailing, as the maximum speed difference between those two is about 3-4 knots.

To understand how the resistance will be calculated, one has to first take note of the Froude number. This number will help us to estimate which factor of the possible resistances are important:

$$Fr = \frac{u}{g * L} \tag{4.1}$$

As the ship that is considered in this rapport is quite small (18 meters of floater in the water), but also cruises at a very low speed (0-10 km/h, which is the maximum allowed speed in the marine park), the the Froude number is small, probably within the range of: 0-0.23). This means that, if we look at figure Figure 4.2a, the wave making resistance is of lesser importance (has only a little influence) in this calculation. Therefore only the 'viscous' part will be taken into account.
To support the platform, four types of floaters can be used:

- Catamaran
- Trimaran
- Pontoon
- Pontoon with a moonhole.

The resistance can be calculated for all four of these. However, the options giving the best relation between stability and resistance are the trimaran and the catamaran. As the calculation of the viscous resistance is the same for a catamaran as for a trimaran and more information can be found about the resistance of catamarans. The theory will dive deeper into the resistance of a catamaran. This does not mean that the theory is not applicable for a pontoon with or without moonhole, as viscous resistance is mostly a function of wetted and frontal area.
Haase et al. (2013) offers 4 different methods for resistance prediction of catamarans. These consist of:

1. Empirical methods: these methods do exist, but mostly for high speed catamarans, not for smaller slower catamarans.
2. Potential flow methods. Potential flow neglects viscous effects, but show good agreement for Froude numbers exceeding 0.5, therefore this method is not interesting for this ship.
3. Model tests: model tests are expensive and therefore not interesting for this platform.
4. Ranse methods: are capable of describing all the effects of the water on the ship, it is however a very expensive method for resistance prediction.

As shown above, each of these methods have there downsides. A computer-aided analyses would also be too big of a calculation for this research. Therefore a method where estimations are made has to be used. To develop this method, one first needs to know where the resistance of a catamaran consists of, according to (Müller-Graf et al. (2002))

$$R_{cat} = 2 * R_{BH} + R_{Icat} + R_L + R_{AP} + R_{AA} + R_{AW} \tag{4.2}$$

Of these components, only three, so the bare hull resistance (R_{BH}), the hull interference (R_{Icat}) and finaly the wind resistance (R_{AA}) are interesting, the other components are not relevant for this estimation because of the low speeds we are calculating at.

Wind resistance

According to Geurts (2009) the wind resistance can be calculated as:

$$R_{AA} = 0.5 * \rho_A * V_{air}^2 * A_V * C_{AA} \tag{4.3}$$

Where the only unknown factor is the air drag coefficient C_{AA}. For this factor many different options exist, but as there is a big change that the frontal surface of the island will be mostly covered and anti-aero dynamic, this factor can be estimated to be equal to 1.

Bare hull resistance

Then the Bare hull resistance. This can be split up into two factors, the residual resistance and the flat plate resistance (Geurts (2009)):

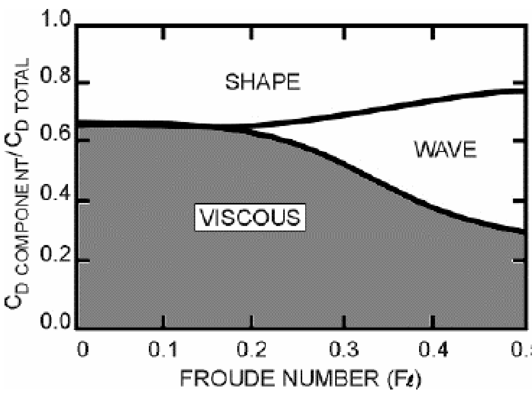
$$R_{BH} = R_w + R_s + R_v + R_{sr} + R_{TR} \tag{4.4}$$

Where we know that the R_w, R_s, R_{sr}, R_{TR} are resistances that start to take effect at higher Froude numbers. (See also Figure 4.2a) therefore, only the viscous resistance is of interest. This resistance is mostly generated by the friction between the hulls and the water and the fact that water meets a wall when it flows 'around' the ship. Therefore the formula for the bare hull resistance can be rewritten to the following formula:

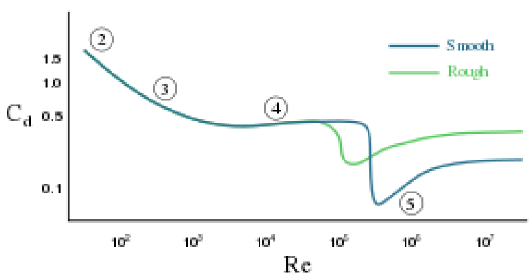
$$R_{BH} = R_v = 1/2 * \rho_w * V_w^2 * S * C_T + 1/2 * \rho_w * V_w^2 * A_{rans} * C_D \tag{4.5}$$

where:

1. C_T can be estimated using the ITTC'57 equation: $C_T = \frac{0.0075}{(log\ (Re)-2)^2}$
2. C_d is the drag coefficient, can be estimated using Figure 4.2b



(a) Distribution of the resistance components according to (Thill et al. (2022))



(b) estimation for C_d according to *Drag of a sphere - glenn research center* (2022)

As the Reynolds number (Re) can be estimated, C_T can also be estimated and therefore an estimation of this viscous resistance can also be made. This brings us to the final resistance, the interference resistance. This interference is hard to calculate, but it can be minimized by placing the floaters of the island at a distance far enough that the waves that they generate are not influencing (reaching) the other floater. The actual resistance calculation will be done at a later stage, as this is only interesting after the shape of the ship is known.

4.6.2. Underwater radiated noise

As the focus of this project is to minimize the impact on the environment, a big factor that should be taken into consideration is the underwater radiated noise of a ship. As stated in Walker et al. (2019) the biggest impact for underwater radiated noise comes from the propeller, especially when cavitation occurs. However, according to Arveson & Vendittis (2000) the engine (and generator) in and itself contribute to the noise as well. Therefore, both the matching of the propeller and engine is important, but also the way the engine is placed and with that the possible structure borne radiated noise. This should be taken into account when one looks at the possibilities where power is generated using an combustion engine.

4.6.3. Matching of propeller and engine

If one were to choose the option of matching a propeller and engine (electric or combustion) one should keep in mind that it is not as easy as just taking a propeller and putting it on the axis of the engine. Changes are then, that the efficiency of the propeller will be so low, that it will mostly be spinning whilst it will not produce any propelling force.

4.6.4. Self propelled with a combustion engine

In the self propelled options, using a combustion engine is one of the possibilities. These engines are readily available, have a high efficiency and are easy to maintain (a lot is known about these engines). They do however have two big disadvantages: the produce CO2 and they generate noise (under and above water). The first problem can potentially be undermined by using bio-fuels. These fuels are not without carbon emissions, but they have the potential (they are not there unfortunately) of becoming carbon neutral and therefore will not enlarge the impact of carbon fuels on the 'world'. The second problem, that of the underwater radiated noise, and possible solutions are discussed above.
Combustion engines come in all shapes and sizes and the possibilities of using for example a car engine for this structure (instead of an outboard motor) do exist. However, a car engine does require a gearbox due to the high rotational speeds of most car engines. As the option of using an outboard engine is still open, when one looks at a self-propelled platform using a combustion engine, this might be the best option, as most of the calculations are done by the engineer of the engine themselves and the facilities for maintenance are available on the Island of Bonaire. A good thing that combustion engines have going for them, is that there is more and more research done into the generation of bio-fuels. For example, (Kumar H (2022)) looks at the possibilities of using seaweed to generate bio-fuels. This would solve two problems. One for the platform, one for the island of Bonaire. As the latter has to deal with yearly returns of 'sargassum', it might (in the future) be able to use research such as the one of Kumar H to generate C02 neutral fuels, which in their turn make the platform a more sustainable entity.

4.6.5. Self propelled using an electric engine

Another option one could consider is using an electric engine. With some small research it was found that the average installed power of a catamaran in the 30-40 ft range is about 90-120 hp. This would result in a necessary engine of about 66-88 KW. Expecting 100 % efficiency (lower efficiency means even more stored energy), this is a lot of energy that has to be stored and generated purely for propulsion purposes. Next to that, electric engines do contain more rare earth materials than combustion engines. The one thing that the electric engine does have going for itself is the fact that they are more robust, more silent and have a larger operational area (so speed at which they can deliver a certain amount of torque which the propeller translates to a force to push the boat forward).

Enviromentally the obvious choice at first glance would be to use an electric engine on board of the platform. However, as stated above, an electric engine uses energy. This energy has to be stored but also generated. If one takes subsection 3.1.2 into account, one would already need about 55 m^2 of solar panels purely for energy generation for propulsion. Another option is to start looking at hydrogen cells. The last option is to use the energy generated in the central grid as described in subsection 3.1.5. The thing here however is that most of the energy is generated by a diesel generator, meaning that it would be more 'C02 efficient' to use that same amount of diesel for propelling the ship.

4.6.6. Towed

The other option is to tow the platform itself. When a ship is towing, one has to consider one thing: the towing ship has to be designed is such a way that it can deliver a lot of power without any speed. Just as with cars, you can design a ship to either sail very fast, or to be able to tow with a large force. Most of the times the combination of both is not a viable option. This brings its own problems in the sense that most outboard engines are designed to make a ship sail as quick as possible, not for towing operations. So if this option is considered, one has to dive deeper into possible propulsion options, especially because the platform is quite a large object to tow with a 'standard' boat.

4.7. Stationkeeping

As the platform needs to be safe for both the surrounding environment and the attendees of the platform, it needs a form of stationkeeping. To assess which option is most suitable, a broad perspective in stationkeeping is taken. This section elaborates on the options available, giving both the technical as the practical aspects.

4.7.1. Mooring

Mooring is one of the simplest and cost effective ways of stationkeeping. However, there are numerous ways of mooring a vessel or platform.

Catenary line mooring
This system derives its 'stationkeeping force' from the weight of its mooring lines. The mooring lines are partially resting on the seabed, and will gradually be lifted up and down once the platform moves from its equilibrium position. A downside of this system is that its footprint is relatively large. Also from an environmental perspective, the mooring line could harm the seabed's marine life.

Taut line mooring
A taut line system derives its restoring force from the rope being under constant tension. This means that the rope's path is a straight line from the bottom. An advantage is that it does not hit the bottom, which could spare marine life. A downside is that the tensions in the mooring lines are higher, which could limit its lifetime.

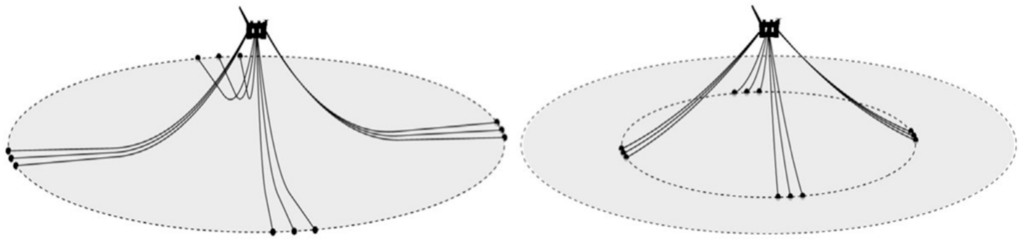


Figure 4.3: Example of a catenary and taut leg system. Source: (Luo (2019))

Next to the type of mooring line, the way this is attached to the platform can also differ. Here, there are two distinct types; Single point mooring (SPM) and spread mooring. Single point mooring has the advantage that it allows for weathervaning and simple (dis)connecting using for example a buoy. Spread mooring makes use of multiple lines, making it more redundant. Also, it is more cost effective for less wave load sensitive designs. However, it restricts the structure in one position, it adds more lines which could stand in the way of watersports, and (dis)connection might be an issue. (Luo (2019))

Line materials

The most used materials in lines are chains, steel wire and polyester rope. Each offer their own characteristics, up and downsides. Chain ropes are heavy, strong and provide relatively well resistance against wear. Steel wire provides more elasticity and is lighter, but gives in on resistance against wear. Polyester is light, provides more resistance against fatigue and is strong. It does however not stand up well against uv-lighting.

Anchoring

There are different types of anchors available for mooring systems:

- Suction piles
- Drag embedded anchor
- Gravity anchor
- Driven pile
- Vertically loaded anchor

Within the context of Bonaire, mooring is the most used system to keep vessels in their place. From meetings with STINAPA (see subsection 3.2.1, it has become clear that mooring is, for now, the most used and feasible solution for stationkeeping on Bonaire. Only STINAPA is allowed to place these moorings on Bonaire, consisting of screw-like moorings (driven pile) or just simple concrete blocks (gravity anchor) of 2.4 tonnes, placed on the seabed. The lines used are polyester ropes of about 30 mm, providing a single point semi-catenary mooring on a (selfmade by STINAPA) buoy.

(a) Selfmade buoy

(b) Line used for mooring

Figure 4.4: Mooring setup used by STINAPA

4.7.2. Dynamic Positioning systems (DP Systems)

The platform can be equipped with a Dynamic Positioning system, which is able to automatically keep the platform in its position. These systems consist of a controller which calculates the position with respect to its intended position (using GPS) and directs power to the thrusters to correct any positional errors. This is done using a PID-controller (Proportional, Integral, Derivative) with assigned gain controls.

Without getting too theoretical, the PID-controller balances the output of the system, meaning the rise time of power to its thrusters, its overshoot of its position, its settling time, steady-state error and stability. Next to this, a mathematical model of the ship is incorporated, taking care of the degrees of freedom (DOF) necessary to keep station (Surge, Sway and Yaw). A layout of such a system is given below in figure Figure 4.5.

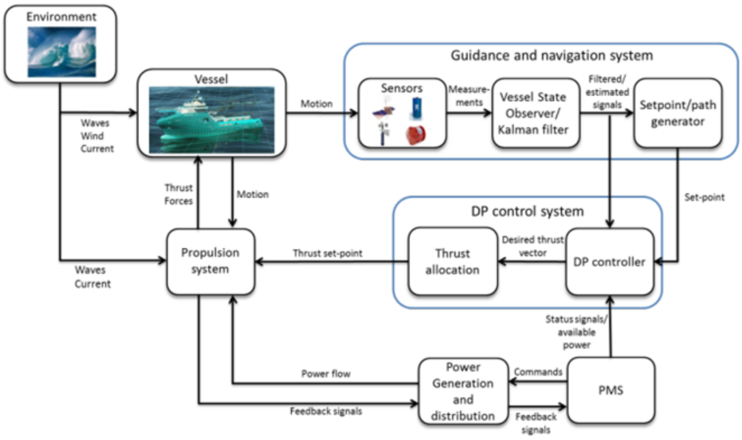


Figure 4.5: System layout of a DP system. (Source: *Assessment of station keeping capability of dynamic positioning vessels* (2018))

The advantage of such a DP-system is that position keeping is automated and its quite accurate. Downsides are that such systems consume lots of fuel, requiring large power generators. Also, the fact that it is constantly active means that the motors are in constant movement. As people will be in the water during the stationkeeping, this provides large safety issues as the thrusters will be constantly active. The risk that a person will be caught up in one of the propellers is significant, causing harm to both the person as the system. If a DP system is chosen, one should design it in such a way that no physical harm can be done. (W.W. Massie (2000))

4.7.3. Thrusters

In case that the platform will be equipped with thrusters, these can be used to keep the platform in its desired position. Use can be made of Fixed Pitch Propellors (FPP) or Controllable Pitch Propellors (CPP). These thrusters can be powered both by diesel generators or electrical drive. In practice, diesel drives are rarely used as they do not provide instant torque. However, thrusters are a very specialized solution and therefore probably not cost-effective. Also, cavitation might be an issue with these thrusters, as this produces a lot noise, raising environmental questions. (W.W. Massie (2000))

Another option is a simpler solution of ”thrusters”, by using the propulsors that are used for propulsion of the platform in case there is independent propulsion onboard. This could be done by positioning the motors up in a specific manner. Both solutions however bring, just like the DP system, extra fuel costs and questions about safety.

4.7.4. Drift anchor (+sail)

A drift anchor is a device to create extra drag on a vessel in water. It makes use of the fact that under the water surface, different or no current is present. This property can be used to counteract the wind and wave forces on the surface. Also a sail can be added to the platform to balance this effect. To this date, the practical uses are mostly in fishing and extreme sea states (storm), however it could be an option if no other solutions are feasible. (*Drift Anchors* (2022))

4.8. Energy Generation

To provide electricity to all facilities on the platform in a sustainable way, different energy sources should be considered. In this chapter the different possible energy sources will be discussed. For every source different types of energy generation systems are descripted and the pro's and cons will be mentioned. The considered energy sources are solar, wind, wave, current, OTEC and fuel cells powered by hydrogen.

4.8.1. Solar

Because the island of Bonaire has a tropical climate with a lot of sunshine, solar energy is thus a logical choice as energy source. Solar panels consist of multiple structured solar cells which convert the energy of the sun into electricity. Different types of solar panels can be used like monocrystalline solar panels, polycrystalline solar panels or thin-film solar panels. This subsection will dive deeper into each of these possibilities. However, for the final design (if solar power is choosen) the data produced in section 3.3 will be used.

Monocrystalline Solar Panels

Monocrystalline solar panels are made of solar cells consisting of one crystal of silicon. Because of this, electrons can flow easier through the cell which results in a higher efficiency. A higher efficiency means less solar panels are needed in the power system, this makes monocrystalline solar panels ideal for cases with limited space, like on the floating platform. Next to the efficiency, the lifetime of monocrystalline solar panels is long; up to 25 years. All these superior properties costs a lot of money, therefore monocrystalline solar panels are one of the most expensive solar panels on the market. The edges of monocrystalline solar cells needs to be cut off which results in a lot of waste, this is one of the reasons why this is so expensive. The efficiency of these solar panels are 15-20%. (*Monocrystalline solar panels* (2020))

Polycrystalline Solar Panels

Polycrystalline solar panels consist of multiple silicon crystals in one photovoltaic cell. The raster of blue squares absorbs energy from the sun and converts this into electricity. Because multiple crystals are placed in one cell, no individual placement or shaping is needed like in monocrystalline solar cells. therefore the production is more eco-friendly, generates less waste and is cheaper. Cons of polycrystalline solar panels is the lower efficiency due to less purity. Also the lifetime is shorter than monocrystalline solar panels and they damage more easily due to high temperatures. The efficiency of these solar panels is 13-16%. (*What are the different types of solar photovoltaic cells?* (2020), Lavaa (2021))

Thin-film solar panels

Thin-film solar panels are made of one or more layers of a thin film that can absorb energy of the sun and convert to electricity. The layers used are about 1 micron thick. Because of the thin materials, these solar panels are great for portable applications like ships or a floating platform. The production costs are relatively low because of the easiness and efficiency they can be produced with. However, the lifetime is not very long. The efficiency of thin-film solar panels varies between 7 and 18%. Because of these efficiencies can be low, they require more space to generate the same amount of energy. (Tilford (2022))

4.8.2. Wind

Next to solar energy is wind an often used energy source to generate power. The west-coast of Bonaire is not the ideal place for wind energy, but there are still different options to generate power from the wind here. The two options discussed are wind turbine generators and airbornes.

Wind Turbine Generator

Both onboard and onshore wind turbines can be used to generate energy from passing wind. At the coast of Bonaire multiple wind turbine generators are placed with a capacity of 900 kW each. Wind energy is a mature way of generating power in a sustainable manner. The downside of making use of wind turbines is the uncertainty of the wind speeds. Periods with no or few wind will make the platform dependant on stored energy.

On shore huge wind turbines are placed to generate a lot of energy. There is also the possibility to make use of smaller wind turbines which can be placed on ships or buildings. These small wind turbines are used in a range of 400 Watts to 20 kiloWatts. A household using for example 300 kWh per month in a location with 6 meters per second wind speed, means a wind turbine of 1.5 kW will meet the demand. Due to inconsistency in wind speed, a well-working storage system is needed. (*Small wind electric systems*, *Installing and maintaining a small wind electric system*)

Airborne

At higher altitudes the wind reaches higher speeds. To make use of these higher wind speeds, a futuristic solution is using airbornes. These are flying kites connected by a rope to the ground. Two different ways of generating energy with these flying kites are making use of the movement of the kite itself or by placing propellers on the kite. In the first way the energy is generated by the kite flying in circles and pulling the tether on the ground. In the second way the propellers on the wings generate the energy. The rated power of an airborne is 6 MW with a capacity factor of 0.4-0.7. Unfortunately this technique is still in the concept phase and is not realistic to use for this project. For this reason there will not be looked into this technique any further. (*Technology* (2020), *00 - Technology pack (25 Feb 2022)* (2022))

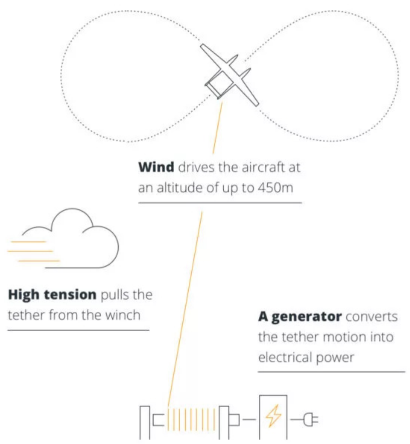


Figure 4.6: Airborne technology (from *Technology* (2020))

4.8.3. Wave

The perfect location for the floating platform is somewhere where zero to low waves occur. This is at the west-side of Bonaire. Waves can create harsh conditions for the platform and for the ones practicing the watersports, therefore the location with the least waves is desirable. This is also the reason why wave-energy converters are not a feasible option for this platform and why there will not be looked into this technique any further.

4.8.4. Current

Energy generation by using currents of the sea is still in its infancy, just a few commercial current-based energy powerplants are operational in the world. These powerplants are very expensive because of this reason. A positive point in using current as energy source is the reliability of current. Two options for generating energy out of the moving water is with horizontal axis turbines or with subsea tidal kites. Both options are working on the same principles as the two mentioned in the wind section. The horizontal axis turbine can be placed on the seabed or placed underneath the platform and works as a wind turbine generator in which moving water replaces the wind. Subsea tidal kites are working on the same principle as the airbornes. Tethered to the ground and moved by the moving water causes the power production. The downside of this option is that the device should be tethered to the ground which could be a problem for the environment. The benefit of both options is that the cut-in current speed low is. A minimum current speed of 0.7m/s is enough for the kites and 1.0 m/s for the horizontal axis turbine to generate power. (*00 - Technology pack (25 Feb 2022)* (2022), *Tidal Energy*)

4.8.5. Ocean Thermal Energy Conversion (OTEC)

Ocean Thermal Energy Conversion uses the differences in temperature of the sea water at different depths to generate energy. The energy of the sun heats the water at the surface, therefore the water at the surface can be much warmer than at deeper layers. The minimum water difference to generate energy in an efficient way is about 20 degrees Celsius. The warm water at the surface is pumped through an evaporator which then drives a generator. The vaporized fluid is then returned to a condenser with cold ocean water from deeper layers of the ocean. Around Bonaire the water surface temperature is about 28 degrees Celsius. In Figure 4.7 the data of a dive by a tech-diver is shown. The temperature at a depth of 90 meters is 22 degrees Celsius which makes a difference of 6 degrees Celsius. To really get a temperature difference of 20 degrees, the sea should be way deeper than this. therefore at this location OTEC is not very realistic.

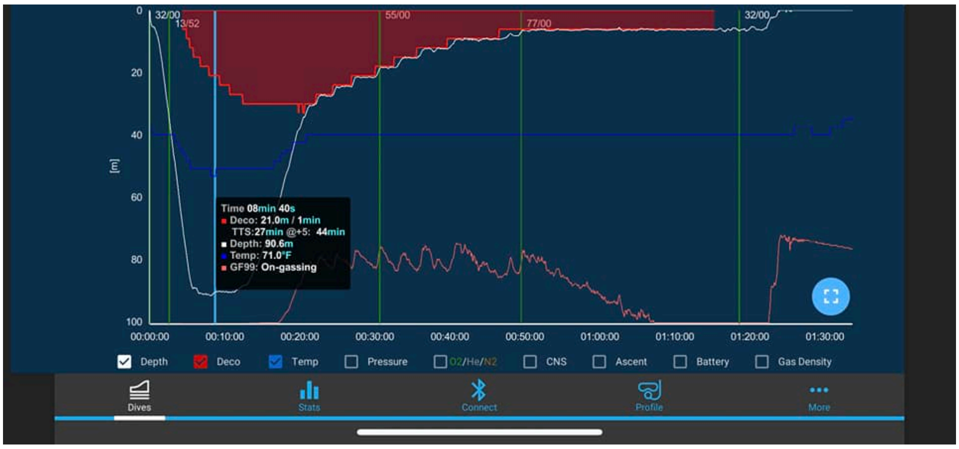


Figure 4.7: Techdive data Sage Hagan

4.8.6. Fuel cell

A fuel cell consists of a positive and a negative electrode around an electrolyte. The fuel hydrogen is fed to the negative electrode, the positive electrode is fed with air. The hydrogen molecules are separated into protons and electrons, the electrons follow a circuit which creates a flow of electricity. The protons migrate to the positive electrode and react with oxygen to water. Hydrogen has a high mass-based energy density which makes it a very promising fuel for producing energy. It contains 33.33 kWh energy per kilogram, where diesel contains 12 kWh per kilogram (Yue et al. (2021)). The downside of hydrogen is the large volume which means large storage tanks are needed. Another option for storage is therefore compress it to compressed gas or to liquid hydrogen. Also hydrogen production is on the rise, but at the moment hydrogen is limited available which makes it an expensive fuel.

4.9. Energy Storage

Storage of energy is vital for any project containing renewable energy generating sources, due to intermittency of a renewable power source. A prime example of intermittency is the fact that the sun does not shine at night and thus no solar power can be generated. But also when a cloud passes and the solar power input dips down, a constant power is still required. An energy storage solution is essential for a constant and reliable energy system on the platform. In this section different technical solutions for energy storage will be discussed, namely: batteries, hydrogen and potential energy storage.

4.9.1. Batteries

The first storage system to be considered is one that is already used in the current market, namely battery packs. Battery packs are usually an arrangement of smaller batteries usually a Lithium-ion battery. These battery packs can come in many different shapes and sizes to suit different applications best. A distinction can be made in cylindrical and prismatic battery cells. Prismatic battery cells are square modules that can easily be stacked into larger shapes, such as a car battery. While cylindrical cells as the name implies are cylindrical and often quite small. An array of these small batteries can be made and are usually used in laptops and cars (Tesla). Because the cylindrical batteries are placed in such cells and have a lot of connections, an array of them can produce a large amount of power in a short amount of time, and thus used in high performance use cases. While prismatic batteries are used for energy efficiency use cases.

One important factor with batteries is the fact that degradation occurs, and its rate of degradation can be explained by 3 main variables; Discharge and charge rate (C-rate), temperature and state-of-charge (SOC). This degradation is unwanted because the performance and lifetime of the battery are decreased if these variables are unfavorable. Firstly, a high C-rate can cause chemical changes in the electrode layers of the battery which are permanent. These changes cause a higher internal resistance and lowered capacity of the battery. Secondly, temperature ageing plays a role in decreasing the performance of the battery. At higher temperatures the reactions of the electrode will decrease cyclic lithium amounts causing a loss in capacity and increased capacity. The working temperature range of a battery is –30 °C to 52 °C but the optimum lays more in the middle and towards the edges of the range, aging will affect the battery more. Lastly, using the battery at high SOC, the electrode can be damaged, leading again to an increased resistance and a loss in capacitance (DeRousseau (2017)). All these variables need to be carefully monitored to increase the lifetime of a battery, especially when considering the high temperatures of Bonaire.

Lithium-ion batteries are very efficient batteries having an efficiency between 80-90%. One issue with these batteries is that they are very costly to produce, not just in terms of money but also in terms of emissions. The process of mining Lithium also has a large impact on the environment. Another issue is the End-Of-Life of these batteries as recycling them is a very costly process and quite often a choice is to dump them on a landfill. That is where the next type of battery comes in, old car batteries.

Old car batteries at the EOL still hold 70-80% of their original charge, making them good for less demanding solutions such as stationary energy storage. With the repurposing of these batteries, the costs of recycling are neglected and the battery gets an extended lifetime. Repurposing old car batteries is a way of extending the lifetime of an old battery. According to a study conducted for the European Federation for Transport and Environment, second life batteries can in theory cut the embedded emissions in half [Melin (2019)]. One important factor however is the irreversible damage that has already occurred. The battery health must be checked up to get an estimation of the remaining lifetime of the battery. This could simply be done by checking the voltage of the battery with a voltmeter.

4.9.2. Hydrogen

The second method of storing excess energy from renewable sources is by converting electricity into hydrogen. This process is currently being researched and is seen by many as the future of renewable energy storage. How could this process be fitted into the context of this project.

The most relevant method of hydrogen production in the application of this project is the electrolysis of water. This is done in the simplest of senses by running a current through pure water so that the Hydrogen and Oxygen in H2O split and then catch off the Hydrogen. The hydrogen must then be stored and there are two methods for storage of hydrogen; compression and liquefaction. Compressing hydrogen must be done to a pressure of 700 bar which requires quite the industrial compressor. Liquefaction requires that the hydrogen gas be turned into a liquid which occurs at the low temperature of 20 K. These methods of hydrogen storage are still under development and will improve in the future making them cheaper and scalable.

Another issue with hydrogen as storage is that currently hydrogen production is done mainly with natural gas. This method of hydrogen production means that when looking at total CO2 emissions, hydrogen emits more CO2 into the atmosphere than Heavy Fuel Oils. This can also bee seen in Figure 4.8.

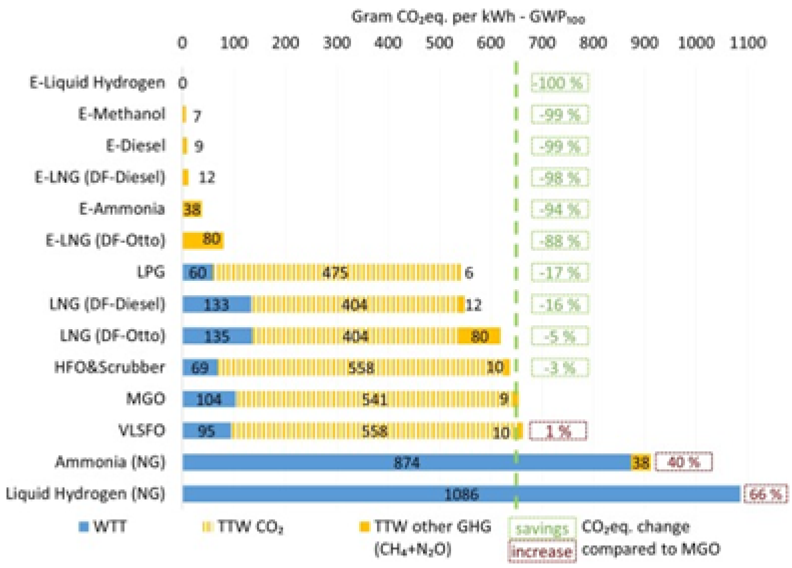


Figure 4.8: GHG emissions of different fuels (Lindstad et al. (2021))

4.9.3. Potential energy storage

A final option for storage of energy is an underwater balloon. This system is not yet widely used in the market but is of interest for it's offshore energy storage capabilities. The principle of the system is that a balloon filled with air is attached to the seabed via a rope and a generator, when there is an excess of energy the generator pulls the balloon down to the seabed. When the system is stationary a brake will be applied to the generator to stop the generator from turning. When energy is required, the brakes on the generator will be released and the balloon will ascend, causing the generator to turn, feeding energy back into the system.

To be able to determine the power output, calculations need to be made. However, these calculations are currently not verifiable with any current products on the market, making this an energy storage source that is hard to predict.

4.10. Results Concept Exploration

4.10.1. Morphological mapping

To have an overview of the options for the facilities of the platform, a morphological map is made. The results can be found below in Figure 4.9. The reason why waste treatment has not been included in the map is because of its lack of variety in options.

	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Energy generation	Solar	Wind	Wave	Current	OTEC	Fuel Cells
Energy storage	Battery pack	Electrolysis (hydrogen)	Potential energy (balloon)	Old car battery pack	Bio-fuels	-
Buoyancy	Monohull	Katamaran	Barge	Moonpool	Trimaran	-
Station keeping	Mooring	DP system	Drag anchor	Thrusters	-	-
Wastewater treatment	Septic tank	Grey + Blackwater tank	Blackwater tank	-		-
Materials	Wood	Aluminum	Polyethylene	Steel	Glassfibre	-
Mobility	Self propelled Electrical engine	Self propelled combustion engine	Towed electric engine	Towed combustion engine	-	-
Water Generation	Reverse Osmosis	Thermal Desalination	Fresh Spring Water Collection	Re-usage of waste water	-	-
Water Storage	Large tank for import of water	Small tank because local production	-	-	-	-

Figure 4.9: Morphological mapping of the necessary solutions

The morphological map was used in a meeting with the client to choose six concepts (three realistic, three futuristic concepts). The filled in morphological mappings can be found in subsection 4.10.2

From these concepts, the realistic concepts will be worked out in the next section, together with one of the futuristic concepts.

4.10.2. Concepts

The concepts from the morphological scheme will be elaborated on below. A general remark is that partially, the concepts match each other in a couple of the partial solutions. This is due to the limitations of the island in environmental, social and technical view. This leads to the fact that some solutions could already be concluded as not feasible on the island. Therefore, first the general idea of the concepts is elaborated on, after which the differences between the concepts is explained.

General concept

The general concept is that the platform will use solar energy to generate its electricity. To accommodate storage and intermittency, batteries will be used.

Stationkeeping will be facilitated using mooring, as this is for now the only feasible solution. The choice for materials (for the hull) will be mainly aluminium due to its excellent properties (see section 4.2). Furthermore, each concept makes use of reverse osmosis to produce water, due to its costs and availability.

Finally, each concept will be about 18 meters in length and 10 meters in breadth. As of now, this is the largest size that STINAPA is known to work with at this moment. This would mean that the hull, which is build in the Netherlands, would have to be be split up into two pieces of 9 meters in length. These can then be welded together on the location where the platform would enter the water.

Concept 1

The distinctive characteristics of concept 1 lie in the fact there will be made use of both new as old battery packs. The choice for this is that it will reuse materials, while also providing the needed redun-

dancy and quality from new battery packs.
Furthermore, the hull choice has fallen on a catamaran due to its stability and material saving properties. For the wastewater treatment, a grey and blackwater tank is chosen to make use of water as much as possible, while also keeping in mind availability. Furthermore, the platform will be tugged by a boat with combustion engine, saving space on the platform and being realistic in the fact that a combustion engine is readily available on Bonaire. For water storage, use will be made of a small tank because of the capability of re-usage of water and space saving.

	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Energy generation	Solar	Wind	Wave	Current	OTEC	Fuel Cells
Energy storage	Battery pack	Electrolysis (hydrogen)	Potential energy (balloon)	Old car battery pack	Bio-fuels	-
Buoyancy	Mono hull	Katamaran	Barge	Moonpool	Trimaran	-
Station keeping	Mooring	DP system	Drag anchor	Thrusters	-	-
Wastewater treatment	Septic tank	Grey + Blackwater tank	Blackwater tank	-		-
Materials	Wood	Aluminum	Polyethylene	Steel	Glassfibre	-
Mobility	Self propelled Electrical engine	Self propelled combustion engine	Towed electric engine	Towed combustion engine	-	-
Water Generation	Reverse Osmosis	Thermal Desalination	Fresh Spring Water Collection	Re-usage of waste water	-	-
Water Storage	Large tank for import of water	Small tank because local production	-	-	-	-

Figure 4.10: Morphological scheme of concept 1

Concept 2

Concept 2 only makes use of old car batteries. The hull will be a trimaran, providing again stability, while also providing more storage space in its floaters. For wastewater, use will be made of the blackwater tank. For mobility, the choice has fallen on the platform to be self propelled by a combustion engine, guaranteeing mobility. For water storage, use is made of a small tank because of local production due to the reverse osmosis process.

Concept 2	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Energy generation	Solar	Wind	Wave	Current	OTEC	Fuel Cells
Energy storage	Battery pack	Electrolysis (hydrogen)	Potential energy (balloon)	Old car battery pack	Bio-fuels	-
Buoyancy	Mono hull	Katamaran	Barge	Moonpool	Trimaran	-
Station keeping	Mooring	DP system	Drag anchor	Thrusters	-	-
Wastewater treatment	Septic tank	Grey + Blackwater tank	Blackwater tank	-		-
Materials	Wood	Aluminum	Polyethylene	Steel	Glassfibre	-
Mobility	Self propelled Electrical engine	Self propelled combustion engine	Towed electric engine	Towed combustion engine	-	-
Water Generation	Reverse Osmosis	Thermal Desalination	Fresh Spring Water Collection	Re-usage of waste water	-	-
Water Storage	Large tank for import of water	Small tank because local production	-	-	-	-

Figure 4.11: Morphological scheme of concept 2

Concept 3

The difference of concept 3 lies in the fact that use will be made of small wind turbines next to solar energy. This will provide redundancy and will decrease intermittency issues.
Use will be made of new battery packs for extra redundancy. The hull will be a katamaran. For wastewater, again a grey+blackwater tank combination is chosen, while water production is done using reverse osmosis onshore. This will require a large water tank on board. Furthermore, for mobility the platform is equipped with a combustion engine.

Concept 3	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Energy generation	Solar	Wind	Wave	Current	OTEC	Fuel Cells
Energy storage	Battery pack	Electrolysis (hydrogen)	Potential energy (balloon)	Old car battery pack	Bio-fuels	-
Buoyancy	Mono hull	Katamaran	Barge	Moonpool	Trimaran	-
Station keeping	Mooring	DP system	Drag anchor	Thrusters	-	-
Wastewater treatment	Septic tank	Grey + Blackwater tank	Blackwater tank	-		-
Materials	Wood	Aluminum	Polyethylene	Steel	Glassfibre	-
Mobility	Self propelled Electrical engine	Self propelled combustion engine	Towed electric engine	Towed combustion engine	-	-
Water Generation	Reverse Osmosis	Thermal Desalination	Fresh Spring Water Collection	Re-usage of waste water	-	-
Water Storage	Large tank for import of water	Small tank because local production	-	-	-	-

Figure 4.12: Morphological scheme of concept 3

Futuristic scenario

For the futuristic scenario, one concept will be worked out. The futuristic scenario is defined as a concept that will be feasible in about 10 years, following the developments on Bonaire, assuming everything is available on the island. It is therefore a morph concept, assuming an ideal situation, while also keeping in mind the developments on Bonaire.

The choice for this is that it shows what will be possible in terms of sustainability worldwide, while also keeping it in the context of Bonaire, which is the main focus point of this report.

The concept will rely on the fact that there are ongoing developments with biofuels on Bonaire (see subsection 3.1.5). Therefore, use will be made of solar panels in combination with a biodiesel-generator, to ensure lower intermittency (so a more constant delivery of energy) Furthermore, this same biodiesel will be used for the propulsion using a combustion engine.
Mooring will be used for stationkeeping, which is still a very reliable solution. The rest of the facilities will be assumed to be optimized and developed through, looking at the developments worldwide.

Futuristic concept	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Energy generation	Solar	Wind	Wave	Current	OTEC	Fuel Cells
Energy storage	Battery pack	Electrolysis (hydrogen)	Potential energy (balloon)	Old car battery pack	Bio-fuels	-
Buoyancy	Monohull	Katamaran	Barge	Moonpool	Trimaran	-
Station keeping	Mooring	DP system	Drag anchor	Thrusters	-	-
Wastewater treatment	Septic tank	Grey + Blackwater tank	Blackwater tank	-		-
Materials	Wood	Aluminum	Polyethylene	Steel	Glassfibre	-
Mobility	Self propelled Electrical engine	Self propelled combustion engine*	Towed electric engine	Towed combustion engine	-	-
Water Generation	Reverse Osmosis	Thermal Desalination	Fresh Spring Water Collection	Re-usage of waste water	-	-
Water Storage	Large tank for import of water	Small tank because local production	-	-	-	-
		*Combustion on bio-fuel				

Figure 4.13: Morphological scheme of the futuristic concept

The concepts chosen by both the client as the project group will be scored and ranked in section 5.1, out of which one concept and the futuristic concept will be worked out and evaluated.

5

Concept definition

In this section, the realistic concepts that followed from subsection 4.10.2 are analysed using an MCA, after which one realistic concept is chosen. Together with the futuristic concept from, these concepts are worked out, taking into account the results from chapter 3 and chapter 4.

5.1. MCA

Using an MCA entails that several concepts are scored on different requirements. These requirements follow directly from the statement of sustainability and other requirements as presented in section 3.5. The following 11 criteria have been defined to score the concepts:

- CO2 emissions: The CO2 emissions during the lifetime, production and decommissioning of the platform.
- Other harmful emissions: the same as the CO2, but for other emissions such as NOX.
- Ecological impact: the impact on the surrounding environment (marine park and sea) during production, lifetime and decommissioning of the platform.
- Repairability (locally): the degree in which the platform can be repaired with the resources, facilities and knowledge on the island.
- Circularity: The degree in which the platform, or parts of the platform, can be reused. For example melting down the material of the aluminium hull to use somewhere else, or sell the solar panels at the end of the lifetime of the platform.
- Costs: The total amount of money that is needed to produce and operate the platform (decommissioning excluded)
- Technical feasibility: The degree in which the execution of the project is feasible in a technical way. For example: Is it possible to build a hull from aluminum? Are the chosen solar panels available for everyone? Is it possible to propel the whole platform with available engines or is the resistance too high?
- Intermittency: The degree in which the regularity of electricity- and water supply is important.
- Leisure area: The degree in which free surface is available for leisure activities for the guest, after equipment, storage and facilities are installed on the platform.
- Safety: The safety on board and around the platform. For example the presence of life jackets, fire extinguishers and stability of the platform.
- Modularity/scalability: Modularity is the degree in which the platform can be disassembled and assembled without too much complications. Scalability is the degree in which the platform can be placed in other locations without changing the concept too much.

These 11 criteria were been given weights by distributing 100 points them. Both members of the projectgroup (4 persons) from the TU Delft as the Clients (2 persons) were given these points. This lead to a total of 600 points to be distributed over the 11 criteria. The results of this can be found in Table 5.1.

Table 5.1: The results of scoring the MCA requirements

	Client 1	Client 2	Robin	Simon	Camiel	Marijn
CO2 emissions	12	9	18	25	25	20
Other harmful emissions	10	2	10	6	9	10
Ecological impact	17	8	20	25	20	20
Repairability (locally)	12	11	9	7	3	9
Circulairity	10	5	6	5	7	11
Costs	0	10	2	13	5	3
Technical feasibility	10	14	14	9	15	6
Intermittency	0	1	3	1	1	5
Leisure area	12	13	3	2	4	10
Safety	0	15	14	4	8	4
Modularity/scalability	17	12	1	3	3	2
Sum	**100**	**100**	**100**	**100**	**100**	**100**

As shown in these result, all participants unanimously agree on the importance of the ecological impact and CO2 emissions, as this is the final goal of the platform, to be as sustainable as possible. Discrepancies are more visible in modularity/scalability and leisure area. This is because for the TU Delft students the importance is mostly on creating a floating platform which is technically feasible, for the clients the importance is also on making money out of it eventually. Hence, their importance is high on modularity/scalability and leisure area to satisfy the guests with enough leisure area and possibly recreate a similar platform on different locations.

These scores were then used to define 4 different MCA-scoresheets. The first is based on the result from the clients. The second one is based on an even distribution between: client 1, client 2, average of authors. The third one is based on an even distribution between all six of the attendees and the last one is based on average clients and average of students. This resulted in the MCA scores as presented in Table 5.2

Table 5.2: Final MCA weights

	50/50 Clients	Client 1/Client2 /TUDelft	All six	50/50 Clients/TUDelft
CO2 emissions	10.5	14.3	18.167	16.2
Other harmful emissions	6	6.9	7.8	7.3
Ecological impact	12.5	15.4	18.3	16.8
Repairability (locally)	11.5	10	8.5	9.2
Circulairity	7.5	7.4	7.3	7.3
Costs	5	5.2	5.5	5.3
Technical feasibility	12	11.6	11.3	11.5
Intermittency	0.5	1.1	1.8	1.5
Leisure area	12.5	9.9	7.3	8.6
Safety	7.5	7.5	7.5	7.5
Modularity/scalability	14.5	10.4	6.3	8.3
Sum	**100**	**100**	**100**	**100**

Notable here is that intermittency and costs where found to be low scoring by each member. Intermittency was deemed less important as guests could be restricted in terms of showering and electricity use. In terms of costs, money was not a decisive factor for one of the clients (Client 1). For the other client (Client 2) it was deemed more important as this was the investing client.

As stated in chapter 2, the concepts have been scored relative to each other, from a range of one to four points:

- 1 point would be assigned to a concept if the solution would be considered to be irrelevant to the criterium. By assigning one point however, a baseload of the importance of the criterium has been assigned
- 2-4 points would be assigned to a concept if there would be a difference to the other concepts. The best scoring concept would get 2 points, the worst scoring 4 points.

These points were then multiplied by the weights assigned by the client and project group, after which the lowest scoring, thus ranking better, concept was chosen to be worked out.

5.1.1. Scoring of the concepts

In this section the concepts will be scored using Table 5.3. Here the *xx* stands for the chosen option in the morphological map as described in subsection 4.10.2. This approach is chosen because it allows for a more objective decision, as one zooms in on the different facilities, one loses the sense of the total concept and therefore is not directly biased to one concept. The thought process that has been followed can be found in Appendix E. Some interesting take-aways of the thought process are:

- The discussed energy generating solutions have no relevant influence on the local Ecology as the impact that they have is more on the environment where they are produced.
- Most aspects of the platform are considered to not have relevant influence on the ”other harmful emissions” criterium. This is mostly because they are either all equal (i.e. each concept has an aluminium hull) and therefore have no decisive factor, or the actual emitted harmful emissions during the lifetime are considered to be negligible.
- Options that are good in terms of circularity and thus CO2 emissions and harmful emissions during their lifetime are not the most technical feasible options. As is expected that an older/recycled

option will degrade faster than an optimised and new option.

Table 5.3: The table to score the concepts on the MCA

	1. Energy generation	2. Energy storage	3. Buoyancy	4. Station keeping	5. Wastewater treatment	6. Materials	7. Mobility	8. Water Generation	9. Water Storage	
	xx	xx	xx	xx	xx	xx	xx	xx	xx	Sum
Ecological impact										0
CO2 emissions										0
Technical feasibility										0
Leisure area										0
Repairability (locally)										0
Safety										0
Modularity/scalability										0
Other harmful emissions										0
Circulairity										0
Costs										0
Intermittency										0

5.1.2. Results MCA

The thought process as mentioned in Appendix E lead to a scoring per 'requirement'. This score is then multiplied with the given weights. This lead to Table 5.4 through Table 5.7

Table 5.4: Scoring the concepts with an equal weight

		C 1	C 2	C 3
Equal weight (1/6)	Weight			
Ecological impact	18.3	311.1	329.4	256.2
CO2 emissions	18.2	455	400.4	491.4
Technical feasibility	11.3	271.2	248.6	271.2
Repairability (locally)	8.5	212.5	195.5	221
Other harmful emissions	7.8	132.6	140.4	132.6
Safety	7.5	142.5	135	142.5
Circulairity	7.3	138.7	146	153.3
Leisure area	7.3	146	146	146
Modularity/scalability	6.3	119.7	132.3	144.9
Costs	5.5	137.5	121	137.5
Intermittency	1.8	34.2	34.2	27
Total		2101	2028.8	2123.6

Table 5.5: scoring the concepts where the students get an equal weight to the clients (so 50/50)

		C 1	C 2	C 3
50% Client 50% TU Delft	Weight			
Ecological impact	16.9	287.3	304.2	236.6
CO2 emissions	16.3	407.5	358.6	440.1
Technical feasibility	11.5	276	253	276
Repairability (locally)	9.3	232.5	213.9	241.8
Leisure area	8.6	172	172	172
Modularity/scalability	8.4	159.6	176.4	193.2
Safety	7.5	142.5	135	142.5
Other harmful emissions	7.4	125.8	133.2	125.8
Circulairity	7.4	140.6	148	155.4
Costs	5.4	135	118.8	135
Intermittency	1.5	28.5	28.5	22.5
Total		2107.3	2041.6	2140.9

Table 5.6: Scoring the concepts using the input of only the clients

		C 1	C 2	C 3
50/50 Clients only	Weight			
Modularity/scalability	14.5	275.5	304.5	333.5
Ecological impact	12.5	212.5	225	175
Leisure area	12.5	250	250	250
Technical feasibility	12	288	264	288
Repairability (locally)	11.5	287.5	264.5	299
CO2 emissions	10.5	262.5	231	283.5
Circulairity	7.5	142.5	150	157.5
Safety	7.5	142.5	135	142.5
Other harmful emissions	6	102	108	102
Costs	5	125	110	125
Intermittency	0.5	9.5	9.5	7.5
Total		2097.5	2051.5	2163.5

Table 5.7: Scoring the concepts with a 1/3 ratio for: client, client and students

		C 1	C 2	C 3
Client 1/Client 2/TUDelft	Weight			
Ecological impact	15.4	261.8	277.2	215.6
CO2 emissions	14.3	357.5	314.6	386.1
Technical feasibility	11.7	280.8	257.4	280.8
Modularity/scalability	10.4	197.6	218.4	239.2
Repairability (locally)	10	250	230	260
Leisure area	9.9	198	198	198
Safety	7.5	142.5	135	142.5
Circulairity	7.4	140.6	148	155.4
Other harmful emissions	6.9	117.3	124.2	117.3
Costs	5.3	132.5	116.6	132.5
Intermittency	1.2	22.8	22.8	18
Total		2101.4	2042.2	2145.4

From this scoring, no matter what weight ratio was applied, concept 2 always wins.
When analyzing the weighted sum of the scored concepts there are some noteworthy differences. First is that the second concept scores quite a bit lower on CO2 emissions than the other concepts. This is due to the use of the old battery pack and using green energy to produce fresh water. The second point is the technical feasibility. Because of the use of a trimaran which generates less loads and moments and blackwater tank which is already widely used in the marine world, concept two has the upper hand.

Thirdly, the repairability is higher due to the local availability of the old car batteries and due to the simplicity of the blackwater tank system for waste water.
These are the biggest contributors to the lower scoring of the second concept, causing concept 2 to come out of the MCA as the winner.

The futuristic concept is (for now) the same in every way, only the energy generation will be done using a bio-diesel fueled generator and the hull will be made of glass fiber. If future developments allow for different systems that are more energy efficient, one should consider those instead of the advised systems in this report. For example a sudden development in wind energy for local energy generation could change the futuristic concept to using these new techniques instead of solar panels. Also, other techniques in mooring or fresh-water generation for example can be developed in the coming years, these developments can change the concept if this overrules the capacities of the current used systems.

This means that the winning concept has the following characteristics:

- Power generation using only solar panels
- Energy storage by using old car batteries
- A trimaran multi-hull
- Waste-water stored in a blackwater tank as explained in section 4.5.
- Propulsion managed by using an outboard combustion engine.
- Fresh water produced by using a reverse osmosis water generation system.
- Fresh water produced on board by reverse osmosis, thus a small fresh-water storage tank is sufficient.
- Waste treatment as discussed in section 4.3.
- Two toilets and two showers on board.
- Multiple fridges on board.
- A dishwasher on board.
- Upstairs area with DJ booth.
- Deep-fryer, induction plate and the possibility of a barbecue on board.

Concluding, the design of both concepts can be found in Figure 5.1. More angles of the same platform can be found in Appendix I. The 'leisure area' for this design is equal to 297 m^2, which equates to 2.97 m^2 per person in the busiest hours (100 persons on board) if nothing else then the necessary facilities (bar, toilets, showers and a DJ booth) were placed on the platform.

Figure 5.1: Render of the final design

5.2. Propulsion

In this section, the resistance of both the realistic and the futuristic model will be calculated using the information in section 4.6 as both of them have the same trimaran hull. These calculations can be found in Appendix F, concluding from that the total resistance can be found. From that total resistance, a worst case scenario will be worked out to give an idea of the necessary power in the conclusion of this section.

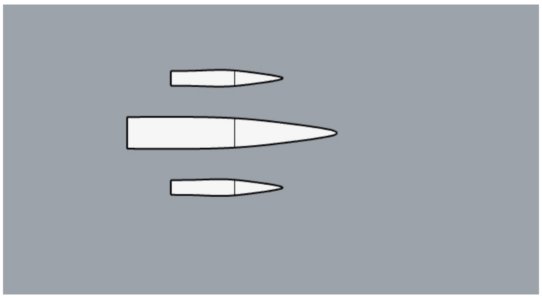
The rough possible layout of the multihull of the design as presented in Figure 5.1 has been used for the calculations of the platform. Note that this layout is not optimised in terms of design. The resistance of this multihull was calculated using the previously stated equations for the bare hull and the wind resistance, which can be found in section 4.6. Both are mentioned again in Appendix F.

5.2.1. Hull layout

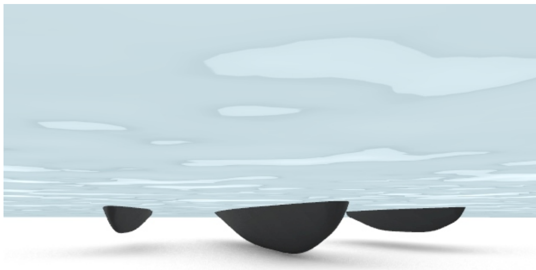
The topview of the layout of the multihull can be found in Figure 5.2a. The assumptions made here are that the 'structure' should be able to support a weight of 35000 kg, or: 100 people of 80 kg (8000 kg) and 27000 kg of structure. The latter is estimated using real trimarans of about the same length and multiplying it's weight by a safety factor of two to account for the extra facilities on board. This results in a necessary underwater volume of:

$$V_{underwater} = \frac{m_{ship}}{\rho_w} = 34.1463m^3 \tag{5.1}$$

Where both the mass of the ship (m_ship) (30.000 kg) and ρ_w are known and thus resulting in a volume of 34 m^3. This volume can then be used for the design to estimate how deep the hulls would have to lie in the water, which is 1.25 meters (found through an iterative process in rhino). The resulting under water ship can be seen in Figure 5.2b.



(a) Multihull design as seen from above



(b) Multihull design from below water line

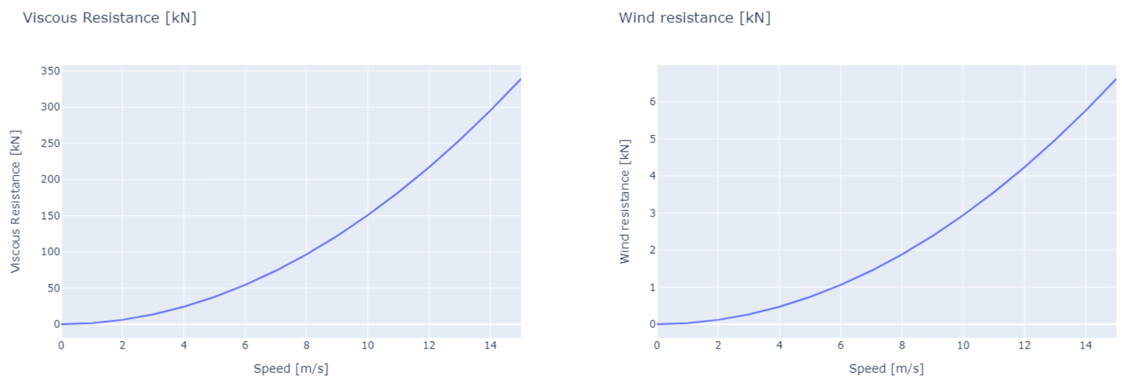
5.2.2. Necessary engine power

The resistance componenents found in Appendix F can be combined into one resistance formula. From that, a worst case scenario is sketched. From this worst case scenario a minimum necessary engine brake horse power will follow. The calculation done below can be done for any speed.

The total resistance of the platform is equal to the sum of the bare hull resistance and the wind resistance, thus:

$$R_{Total} = 0.0294 * V_{air}^2 + 1.507 * V_w^2 \tag{5.2}$$

both the water as the air resistance have been plotted in Figure 5.3



(a) Viscous resistance of the multihull (against water speed) **(b)** Wind resistance of the multihull (against wind speed)

Figure 5.3: Both the viscous as the air resistance plotted against speed

This resistance can be changed into necessary power by using the relation:

$$P = R * V_s \quad (5.3)$$

Where V_S is the speed of the ship. This power however is notated in kW, so to get an idea of the necessary power in brake horse power (BHP) one has to multiply the total number by 1.34 (ratio kW to BHP).

Worst case scenario

In the worst case scenario, the ship has to be able to sail at 2.5 m/s (roughly 10 km/h the maximum speed in the marine park) whilst experiencing headwinds of up to 10 m/s and a head current of about 1.5 m/s. This means that the total power needed to overcome this scenario is equal to:

$$P_{wind} = 0.0294 * 12.5^3 = 57.42\ kW \quad (5.4)$$

and the total resistance due to the water is equal to:

$$P_{water} = 1.507 * 4^3 = 96.48\ kW \quad (5.5)$$

Resulting in a total necessary power of about 154 kW, assuming an efficiency of the propeller and transmission of 60 % we would need an engine that is able to produce about 256 Kw. Which is equal to about 343 Pk. This be can translated into an installed power of 400 pk (so two 200 pk outboard engines). This total power of 400 pk leaves room for about 15 % of bad sailing conditions (such as fouling, extra wind or high waves).

Important to note here is that the matching of an engine with a propeller is not as easy as stated here. There is a chance that even two 200 pk outboard engine might not be able to achieve the wanted speed as these engines are mostly build for high speed propulsion, not for the slow speeds that we are talking about here. Keep this in mind when selecting the outboard engine for the platform (or consider an inboard engine with optimised propeller).

To conclude, this section contains a simplified calculation of the expected resistance of the entire system. This resistance is translated (using a worst case scenario) into a possible propulsive system. This lead to a necessary installed power of 343 BHP, which could be achieved using two 200 BHP outboard engines.

5.3. Stationkeeping

In this section, an initial calculation of the mooring forces is given. A static analysis is worked out, as a simplification of the problem for the manageability of the project. To account for the simplifications and assumptions, a safety factor is applied in the end. As both the realistic and futuristic concept make use of mooring it is assumed that these calculations will be the same, therefore only one calculation is done.

An important remark to this method of calculations is that dynamic loads, stiffness and torsional stiffness of the mooring lines are not taken into account, which are in mooring calculations often a main contributor to loads. However, for the scope of this project, in combination with time management, it was chosen to not do further research into the dynamics of the platform. More extensive research into these dynamics should be done when entering the engineering phase, therefore these calculations cannot be used as a final result for the design of the platform.
For a future dynamic analysis, a so called "uncoupled taut leg mooring analysis" (Luo (2019)) should be performed. This analysis uncouples (or "splits", so to speak) the motions of the platform itself from the mooring system, resulting in only the motion responses from a freely floating platform. These motion responses can then be used for the mooring analysis to calculate the stiffness and loads on the mooring.

5.3.1. Calculations

For the calculations of the static loads, the forces from section 4.6 are used. For the calculation of wave loads (second order wave forces), the following equation is used from Wellens:

$$F = \frac{-\rho_W * g * H_{1/3}^2}{16} \tag{5.6}$$

Where $H_{1/3}$ is the significant wave height, a property of a given sea-state. This significant wave height for the calculations will be set at 1 [m].

It is assumed that the concrete blocks as gravity anchors used by STINAPA for their mooring (See subsection 4.7.1) will be used to place the mooring for the platform. These blocks have a weight of 2400 kg per block. An example of such a block can be found below in Figure 5.4

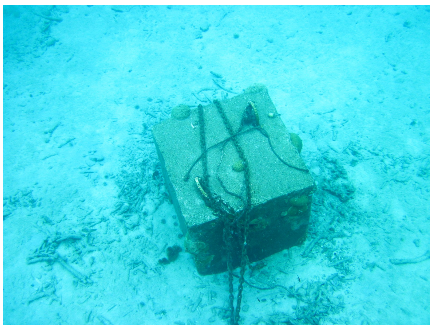


Figure 5.4: Mooring block used by STINAPA

For the calculation, the platform is assumed to be a block placed in water, on which only horizontal forcing is applied from wind, waves and currents. Tidal effects are neglected as they are considered to have minimal contribution to the result. Furthermore, a taut leg mooring is assumed (the mooring line is tensioned). Assuming horizontal and vertical equilibrium of forces, one can calculate the minimum weight of the anchor based on the seabed. A schematic overview of the problem, see Figure 5.5 below

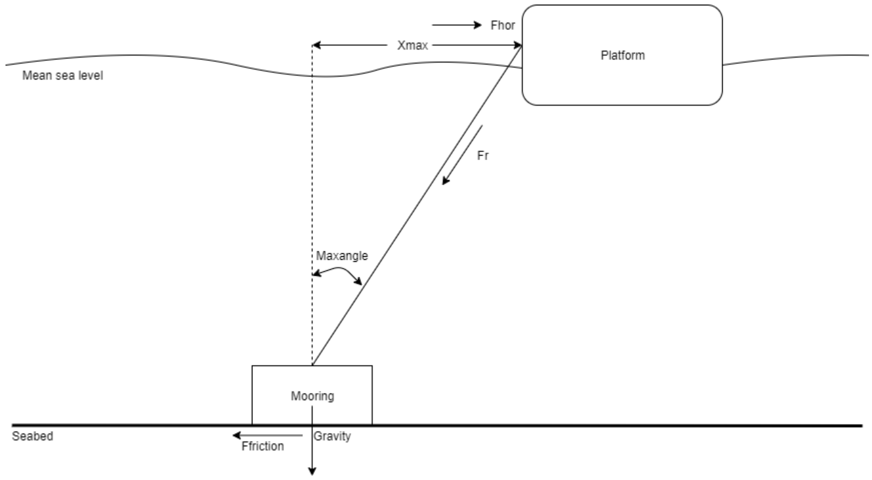


Figure 5.5: Schematic visualization of the simplification

For the calculations, the following assumptions are made:

- A water depth of 60 m
- A soil friction coëfficcient of 0.4 (*Coefficient of friction*)
- A maximum horizontal offset of the platform of 5 meters from the original mooring position, resulting in a maximum angle of 4,76 degrees.
- a maximum extreme current of 1 m/s, resulting in a current load of 1,57 [kN]
- a maximum extreme wind speed of 10 m/s, resulting in a wind load of 3,06 [kN]
- a maximum wave height of 1 m, resulting in a wave load of 628 [N]

Adding the three loads results in a total horizontal load of 5,23 [kN]. Using basic goniometric rules and static equilibrium, one can calculate the maximum loads on the mooring. This results in a minimum vertical resistance of 55,56 [kN] and a minimum horizontal resistance of 11,58 [kN].
In the calculations, the vertical force is the determining force, as this has the higher value. This results in a minimum vertical weight of 5663 kg. Providing a safety factor of 2, this gives a value of 11327 kg. This results in five required concrete blocks as anchoring to keep the mooring in place.

From this study, five concrete blocks seem reasonable to place as mooring, as these blocks can be made locally, and STINAPA places these block more often. Sidenotes that should be given is that these calculations are done using a water depth of 60 meters and a fixed maximum offset of the platform. These values could be different in real life, therefore these calculations are not representative for the final design.
Next to this, STINAPA does not have the experience in diving deeper than 60 meters. For the monitoring and checking of the mooring placement, Tec-divers or an ROV should be hired to do this. This brings extra costs. For maintenance and regular checkups, these facilities should be hired as well, bringing again more costs.

5.4. Carbon Emissions

As mentioned before, a sustainable platform ideally will produce the least (or none) emissions as possible during its production, its lifetime and its decommissioning. Now the final concept is chosen with the help of the MCA, the carbon emissions during these three stages can be estimated. The goal is to mitigate the emissions as much as possible, however, to make this project both technologically as economically feasible it is concluded from chapter 3 and chapter 4 to be inevitable to emit carbon during the different stages, due to restrictions within the context of Bonaire. These emissions are dependent on many different variables and these calculations can be made extremely complex; to still get a final value different assumptions are made and shown.
The carbon emissions of the futuristic concept will differ from the carbon emissions from the chosen concept as different design choices have been made. In the rest of this section will be mentioned in what cases the carbon emissions differ from the original concept.

5.4.1. Production

Looking at the context of Bonaire and the different stakeholder meetings (for example Otto Bartels), Bonaire is the final destination for most of the materials and products which arrive at the island, meaning that little materials are reused or recycled into new products. All products used on the island are imported and the availability of the simplest materials is very low. On top of that, technical knowledge available on the island is insufficient, following from conversations with the clients and stakeholders (see subsection 3.2.3). These circumstances added up make it a feasible and convenient decision to produce the platform somewhere other then on the island of Bonaire, namely in the Netherlands.

Transport

After production in the Netherlands, the whole package of the floating platform should be transported to Bonaire. Considering the options airplane or cargo ship on the criteria of emissions, the cargo ship is the logical choice. According to Dizikes (2010) a long-haul air freight produces 47 times as much emissions per ton-mile as ocean freight. To predict the carbon emission C_E of ship transport of one container (TEU) from the Netherlands to Bonaire, the travelled distance is multiplied with the emission factor in Equation 5.7. The emission factor E_f is assumed to be $50g/(km * TEU)$ (Thibault (2015), Starckx (2019)). The distance d between the port of Rotterdam and the Port of Kralendijk is estimated on 8000 kilometers. To calculate the total emissions in terms of transport, the following equation is used:

$$C_E = E_f * d \tag{5.7}$$

This results in a total carbon emission of 400 kg for the transport of one container.

Materials

For the production of the platform, different materials are used. The materials used first need to be processed before they can be used in the final product. From the MCA the chosen material for the hull is aluminum. As shown in section 4.2 the CO2 emission in production of this material is 13 kg CO2 per kilogram. The total amount of used aluminum is calculated by multiplying an estimation of the volume times the density of the material. To calculate the volume of the used aluminum in the hull, the wetted surface area ($86m^2$) is multiplied by a thickness of two centimeters. The same calculation is applied to the amount of wood, where the surface is $180m^2$ times a thickness of two centimeters. This wood is used as the floor installed at the upper side of the hull. For the futuristic concept, fibre glass will be used instead of aluminum, the volumes will therefore be the same. Densities are also gain from section 4.2. All values are shown in Table 5.8.

Table 5.8: Carbon emissions per material

Material	Volume [m^3]	Density [kg/m^3]	Total weight [kg]	CO2 emission [kg/kg]	Total CO2 emission [kg]
Aluminum	1.72	2770	4764	13.0	62000
Wood	3.60	1030	3700	0.578	2140
Fibre glass	1.72	1970	3390	6.32	21400

5.4.2. Lifetime

From the moment the platform is produced, arrived at the island of Bonaire and fully installed, the lifetime of the platform starts. The lifetime of the platform is assumed to be 15 years looking at well maintained materials in the given circumstances.

Mobility

As shown in Concept 2, the mobility of the platform is regulated by a combustion engine on board of the platform. This means carbon dioxide is emitted into the air by burning diesel to propel the platform from the harbour to its location and back. According to the client, this will happen twice a day, seven days a week for 15 years. To determine the power $P[W]$ which is needed for this propulsion Equation 5.4 and Equation 5.5 are used, but in this case the average wind speed and average current speed relative to the sailing velocity are taken. Filling in these equations and adding them up gives a result of 182 kW, including a propeller efficiency of 60%. This estimated power is used to determine the total used energy (the total work) W $[kWh]$ for the propulsion:

$$W = P * t \tag{5.8}$$

An estimated distance from the harbour to 60 meters of the coast of Pink Beach is about nine kilometers which results in four hours sailing per day at a speed of 2.5 m/s. Using Equation 5.8 results in a total energy usage of about 325 MWh per year.

Next, the energy density of diesel and the efficiency of a diesel engine, assumed to be 45.5 MJ/kg and 0.55 respectively, are used to determine how many liters of diesel are needed to provide the energy demand. This amount of liters is converted to a carbon emission. In Table 5.9 and Table 5.10 all assumptions and results are shown.

Table 5.9: Assumptions made for total carbon emission calculation

Average wind speed [$\frac{m}{s}$]	9	**Times retour per day**	2
Average current speed [$\frac{m}{s}$]	1	**Distance harbour - mooring [m]**	9000
Sailing velocity [m/s]	2.5	**Efficiency diesel engine**	0.55
Propeller efficiency	0.6	**Energy density diesel [$\frac{MJ}{kg}$]**	45.5
Lifetime [years]	15	**Diesel density [$\frac{kg}{l}$]**	0.85
Usage [$\frac{days}{week}$]	7	**CO2 emission [$\frac{kg}{l}$]**	2.68

Table 5.10: Results of total carbon emission calculation

Engine power [kW]	182	**Used diesel per year [l]**	55000
Sailed distance per year [km]	13000	**CO2 emissions per year [kg]**	147000
Energy used per year [kWh]	325000	**Total (in 15y) CO2 emissions [kg]**	2.200.000

This 2.200.000 kg of CO2 is equivalent to about 654 average dutch cars (based on an average of 15.000 kms per year) driving for one year.

Looking at the futuristic concept, most of the assumptions will be similar. Sailing velocities, environmental data, usage and distance will be the same. The difference between the final concept and the futuristic concept is the usage of diesel engine in the final concept and the usage of a bio-fuel engine in the futuristic concept. A bio-fuel engine still emits carbon, but because the emitted carbon is coming from bio-fuels which capture carbon during its lifetime, the net emission is considered to be zero. This makes it a carbon neutral option.

Facilities

To provide the guests with meals, cold drinks, running water and the ability to use equipment like e-foils a particular amount energy is demanded. As the request of the client is to generate this energy fully sustainable by using solar panels, the assumption made is there will be no carbon dioxide emissions in running all these facilities. Therefore the CO2 emissions will be zero.

5.4.3. Decommissioning

After fifteen years of operation the lifetime of the platform as a whole is passed, but this does not mean all materials and equipment should be thrown away. As mentioned, the project will also be as sustainable as possible by reusing most of the parts of the platform. First of all the solar panels. The lifetime of a solar panel is about 25-30 years. This means the solar panels on board of the platform can be sold after their first fifteen years to new users which results in an assumed net carbon emission of zero. Also, equipment like refrigerators, freezers, ovens and other facilities can be sold to new users. However, materials like aluminium from the hull can not just be sold this way. This should be melted down to give it a new life eventually. Also the wooden floor should, after some processing, be able to be reused somewhere else.

5.4.4. Conclusion

Production

Like mentioned before it is at the moment unavoidable to emit carbon in the production stage of the platform. As the best option is to build the platform in the Netherlands, the whole package has to be shipped to Bonaire which causes a carbon emission of about 400 kilograms per container. Also the used materials, especially the production of the hull out of aluminum, will cause carbon emissions. An estimation is done and results in a total emission of 62000 kilograms CO2.

Lifetime

Looking at the mobility during the lifetime, the results of CO2 emissions are high when using an on-board diesel engine. Using bio-fuels in the future will mitigate the impact of these emissions, but this is not feasible with the technique of these days. Another option is reducing the CO2 emission by reducing the sailed kilometers. The request of the client is to sail two times a day to the mooring location and back. Because the distance that has to be sailed is estimated on about nine kilometers, a total distance of 36 kilometers must be passed a day. Reconsidering this, a better option would be sail out only once a day and come back at the end of the day. This results in a total distance of 18 kilometers sailing per day, resulting in a CO2 production of 74000 kilograms CO2 per year, halving the CO2 production over the lifetime of the platform (1103000 kg instead of 2200000 kg CO2).
The desire of the client in which the day is divided into two groups of people is still possible by pendling the people with a small boat to Pink Beach and back. Because this is just a distance of about 80 meters, the emissions will be way lower in comparison to sailing back and forth with the whole platform.

Decommissioning

As mentioned, most of the parts will be sold to new users to give the equipment or materials a new life. However, not every material can be used in its original way like aluminum. To get a clear amount of CO2 emissions produced by the decommissioning of the platform, a recommendation is to approach a company specialized in this kind of cases. Different companies know exactly how much CO2 emissions are produced by melting down materials. For now this is not within the scope of the project. On top of that is that the decommissioning phase is 15 years ahead, which means there is the possibility that several new techniques are invented in reusing materials and equipment. For now this is difficult to predict.

Futuristic concept

The futuristic concept will consist of different materials than the realistic concept and the diesel engine will be replaced by an engine running on bio-fuels. Using the same volume of materials causes a reduction in CO2 emissions during the production-phase. As shown in Equation 5.7 the total carbon emission when using aluminum is 62000 kg, where the usage of fibre glass emits 21400 kg carbon. The usage of a bio-fuel engine still causes carbon emissions, however, the emitted carbon is captured during the lifetime of the bio-fuel which makes it a carbon neutral solution.

5.5. Water System

This section will give a more in depth analysis of the water usage on board of the platform, as the input and output streams are already analyzed in **??** and section 4.3. The water usage given for this project is done on the basis of some assumptions that are made on the basis of the daily planning as discussed with the clients. The goal of this section is to give an estimation of the needed water systems for clean water production, storage and wastewater storage. For a more in depth analysis, refer to Table H.

Water demand originates from visitor consumption and from cleaning the platform and is summarized to be 9 m^3 on a daily basis, 3m^3 in the morning and 6 m^3 in the afternoon. The water production on the platform according to a system from *RO Oceanus | Hatenboer-Water* (n.d.) can produce 1 m^3 per hour and will run for 10 hours on a daily basis to also produce a surplus of water if needed. Water storage on the platform will be done by using water tanks and will have a total capacity of 3 m^3, to be able to store the water produced in the morning for the afternoon. For wastewater produced onboard, a tank of 1 m^3 will suffice.

Coming to a close, the water production is done with a RO system and storage of clean water will occur in a tank of 3 m^3 and wastewater in a 1 m^3 tank. An important aspect to take into account when reading the results is that this first estimate is highly conservative with its assumptions. In reality, not everyone will take a shower of 5 minutes and only rinse themselves quickly or drink 2 L of water. So this estimation of water consumption is on the safe side which will result in a high availability of water on the platform.

5.6. Energy System

This chapter will give some more insight into the power consumption, production and storage by means of an energy plan. This energy plan is made to translate the daily routine plans from the client into an estimation of the power consumption and need for battery storage. First, the plan of the client is analyzed and processed in categories of facilities. Then, an overview is made by means of a chart. This chart is then combined with the power production at different times of day. The difference in production and demand is then easily filled in with batteries.

First all the facilities are analyzed for the energy demand, the different types of facilities that are most demanding are the sport, housekeeping, leisure and water generation facilities. Electricity generation is also considered and when these are combined an overview can be made in the form of a daily power generation (Figure 5.6) and battery load chart (Figure 5.7). The assumptions made and steps taken to obtain these charts can be found in Appendix H and Table H.

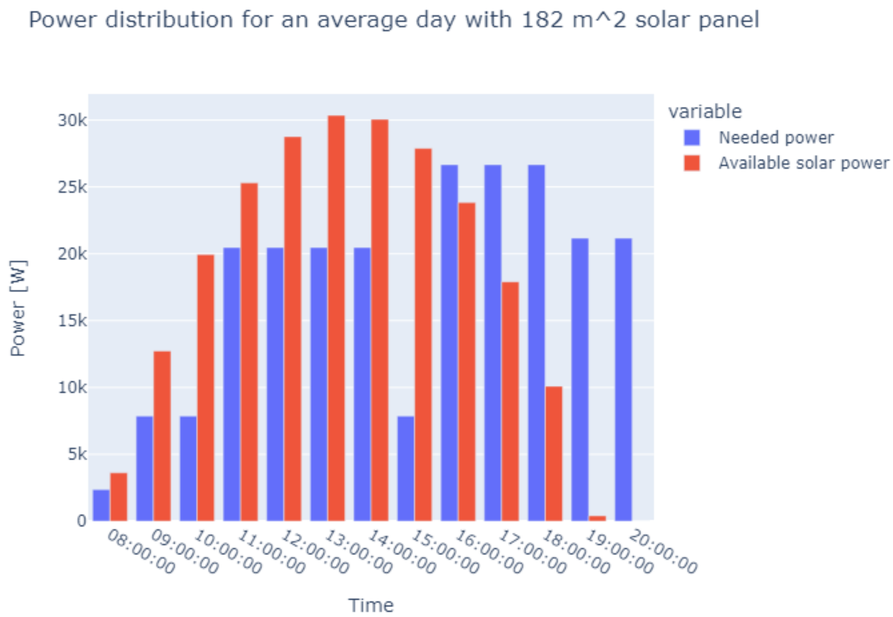


Figure 5.6: Daily solar power generation for a solar array of 182 m^2.

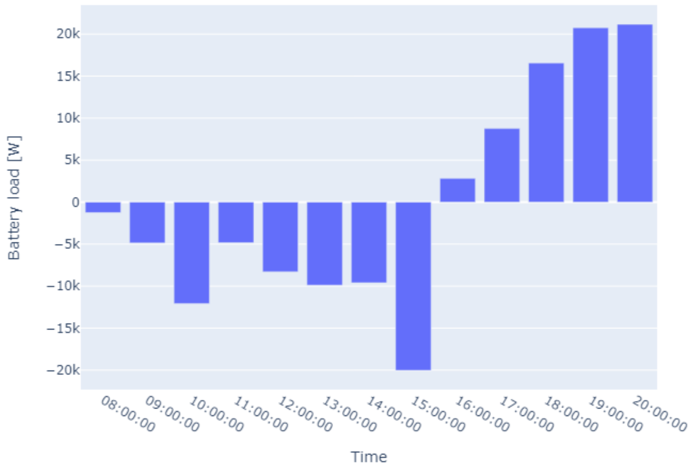


Figure 5.7: Daily load on the battery.

In Figure 5.7 above can be clearly seen that with the current plans there is a high energy demand in the afternoon and night when the sun is gone. This is mainly due to the plans for snacks and dinner requiring the kitchen facilities to be active later on in the day.

Coming to a conclusion on the energy management system, a clear approach has been given to obtaining the energy production, demand and storage capacity on the basis of a day planning. Although the storage of overproduction is technically feasible, the question is whether placing 80 old car batteries is the correct approach. An important aspect to keep in mind is that all the calculations made are on the conservative side which is done to keep a certain margin of safety. A recommendation for a further study is to find the balance of power consumption and generation, after which a more detailed and exact analysis of the energy management plan can be given. Another recommendation is to change the planning to reduce the power consumption at the end of the day to match the power consumption and generation better to reduce the needed storage.

5.7. Local Environmental Impact

In this section, the local environmental impact of the platform is analysed. To assess the environmental impact of the conceptual platform, one can look at different periods of its lifetime in use. For this research however, only the environmental impact on location is assessed to keep the work manageable. This means the impact of construction of materials, recycling and other activities that do not take place on location will not be considered.

In terms of materials used, anti fouling is one of the worst for the environment. As stated in section 4.2, paints used for this release toxins into the water which can harm marine life. For the platform, the least harmful anti fouling will have to be used. From conversations with reef renewal see Figure A, an anti-fouling approved by STINAPA, can be used.

Next to this, plastics used on the platform, think of drinking cups, food packaging etc. could end up in the water. This could end up in marine life in the form of microplastics or could restrict them in their movements, potentially killing them. A preventive measure would be to make the visitors of the platform aware of the hazards of plastic ending up in the oceans. Next to this, a physical barrier could be made in the form of a net with a mesh size smaller than the plastics ending up in the water. This could be placed outside the platform, both in the water as above, to have a redundant system.

The mooring of the platform has both upsides as downsides. The placement of the block may do harm on marine life, as the block will be dropped without too much accuracy on the seabed. In terms of coral, there is a small chance for harm, as at 60 meters or more, hardly any coral is growing. The mooring could in time serve as a shelter for marine life, potentially creating a new habitat for certain species.
In the case that the mooring system fails due to for example breakage of the mooring line, the platform could potentially be drifting towards the coast and therefore the coral, potentially destroying it. The propulsion on the boats should therefore be quickly started to prevent this, although all visitors in the vicinity of the platform should be taken out of the water due to safety reasons.

Wastewater is chosen to be stored in a blackwater tank. These blackwater tanks however could be damaged and therefore has a risk of leaking. Therefore, these blackwater tanks should be designed with a double wall to minimize the risk of leakage into the sea.

5.7.1. Activities

The activity around the platform can potentially disturb the flora and fauna in the location the platform is placed, especially at the water surface. Watersports and other human activities cause noise, traffic and therefore potentially collisions with fish and turtles. The upside is that marine life activity is lower away from the coast. The question is, if the platform would not be located at the location, where this human activity otherwise could take place.
The boat movements, moving the visitors from land to the platform, also causes noise. Therefore, the boat should travel at low speeds and sail in already assigned travel routes for boats, to minimize extra noise and harm to the marine environment.

5.8. Hidden Impact

One thing that gets more and more attention is the impact that materials used in modern energy generating devices have on the world that are not directly experienced by the people using them. An example is the conditions in cobalt mines where most of the materials used in batteries come from. Or how the rare earth elements such as aluminium and lithium are mined. This section will shortly scratch the surface of this subject by primarily looking at a selection of articles where the impact of mining of rare earth metals and labour conditions involved in the making of these materials.

According to Bai et al. (2022): ”Rare earth elements are widely scattered on the Earth’s crust, mining is difficult and extremely expensive, and the process of resource development has a negative impact on local water bodies, the atmosphere, soil, organisms, and other environmental elements that are closely related to human survival.” These consequences are mainly due to two primary extraction methods (Earth.Org (2020)):

- The removal of the top soil containing the rare earth minerals is processed using chemicals (to separate the metals). These chemicals can have a negative environmental impact
- The second method pumps chemicals directly into the earth through PVC pipes and disposes those into ponds where the metals are separated.

An example of such a process is lithium mining. Lithium can be found in the brine of a salt flat. Holes are drilled in different salt beds and is pumped to the surface. After that, the result is allowed to evaporate. According to foeeurope: ”The release of such chemicals through leaching, spills or air emissions can harm communities, ecosystems and food production.”

The other big problem apart of the soil and environmental contamination is the shear size amount of water that is used in this process. Salt planes are mostly located in places where water is scarce. An example is the Chilli salt planes. According to Garces & Alvarez (2020) : In Chile’s Atacama salt flats, mining consumes, contaminates and diverts scarce water resources away from local communities. Which means that there is also a social side to the mining of lithium.

Another case that gets attention at this moment, is the processing and mining of Cobalt. An interesting news article from the guardian named: ”Like slave and master’: DRC miners toil for 30p an hour to fuel electric cars” (Pattisson (2021)) talks about the dire working situation in cobalt mines in the Democratic Republic of Congo (DRC). They get two bread rolls (and a carton of juice) a day and work for about $ 3.50 a day. This cobalt is one of the most key parts of battery production and therefore demand is high. Meaning that the batteries proposed (both old and new) in this report have contributed to the dire situation in the DRC.

These were just some examples of the impact that mining rare earth materials has on the environment and the people living close by or working in the mines. To conclude this section, a lot can be said about the impact of the materials used in this report. More then is stated here, however due to time constraints only some of the loads of articles that exist have been used here. The conclusion is that the impact of certain systems can be bigger than the solution they propose.

5.9. Safety

In this section the safety of the floating platform has been assessed. This means looking at how safety can be maintained on the platform, looking at the stability of the platform and looking at safety when it comes to electricity and general energy related requirements.

5.9.1. Stability

One of the most important safety factors of any floating object, is it's stability, as one would not want the platform to flip over when a certain amount of people are standing on one side. To make an estimation of the stability of the platform, one has to calculate the metacentric height of the ship. The calculation for this platform can be found in Appendix G

The result of that calculation is a metacentric height of 12.5 meters. As stated before, one can calculate the rightening moment of a ship using this metacentric height. For this, the following relation is used (for small angles):

$$Restoring\ moment\ = GM * sin(angle) * gravitational\ force\ ship \tag{5.9}$$

Knowing that the total gravitational force is equal to the total weight on board times the gravitational constant, the equation is:

$$Restoring\ moment\ = \frac{(12.5 * sin(angle) * 35000 * 9.81)}{1000}\ kNm \tag{5.10}$$

To estimate a worst case scenario, where 100 people (so a weight of 8000 kg) would stand on one side, and about 3000 kg of the total construction weight is on that side as well, the heeling moment is about

$$\frac{(8000 + 3000) * 9.81}{1000} = 539\ kNm$$

and a heeling angle of:

$$\text{arcsin}\,(\frac{539}{12.5 * 35 * 9.81}) = 7.21°$$

which is considered to be acceptable in this extreme case.

5.9.2. Electricity

When it comes to safety, the electrical system is important to take into account. This is because when the system is not installed correctly, fire hazards and possible chemical reactions can take place. However, if done correctly these hazards can be mitigated. Also, using old car batteries highers the risk on dangerous situations or chemical reactions.

The platform will contain a large amount of electrical systems. These systems need to be isolated and placed in a location away from water. This to prevent possible corrosion and short circuit on contacts. Next to that, possible solutions to cool the electrical equipment such as heat exchangers should also be considered, as a lot of heat is produced by the batteries and the electrical systems that change the voltage and current for the different systems (such as the induction plate and the battery chargers).

However, as the rules and regulations around systems like these are generally strict, it is advised to hire an expert to build these kind of systems and make sure that this expert is accepted by a insurance provider.

Finally, it would be wise to invest in a good fire management system, such as special fire extinguishers that are meant for electrical systems and making sure that the bottom of the platform, or the top of the floater where the electrical equipment is placed, is isolated with fire retardant materials to keep a possible fire from spreading to fast.

5.9.3. General safety

This subsection will dive deeper into the general safety, starting with the definition of general safety. General safety contains the following:

- Safety on board: life-jackets, designated zones, fencing.
- Possible ways to get in and out of the water safely
- Making sure that people do not get close to an engine
- .. etc.

Not all items will be covered with the same depth as in the previous subsections, as these are considered less important for the technical feasibility of the platform.

Starting with the safety on board. The marina de Bonaire divides it's rules according to 7 different zones. These differ from deepwater regulations (far offshore) to near shore or even near port regulations. This platform will be sailing mostly in zone 5-6: navigation in this zone is no more than 2-5 miles from a harbour or accessible beach (*Marina de Bonaire*). This means that the following safety-equipment has to be on board:

- Life jackets for all persons on board
- 3 hand held flares
- A fog horn
- A national flag
- A signaling mirror
- A recent copy of the international code of signals
- A permanent pump that is able to pump about 30 liters per minute.

One of the other problems that has been foreseen are ways to get in and out of the water safely, without the possibility of getting stuck or damaging equipment. A straightforward solution to this problem would be to build a floating dock around the platform where people can get out of the water, after which they can safely use a bridge to get on board. This dock might also help in solving the problem of waste that gets thrown into the water, as it will keep floating waste from spreading into the ocean.

Another possible hazardous area, is the area around the propeller(s) of the engine(s). When these are spinning, one needs to make sure that there is no possibility of people getting near the propellers, or people being in the water. This can be done by designing a system with which the captain can make sure that all people are on board. By creating designated area's, one can also ensure that in case of a possible storm or bad weather people do not move to dangerous area's such as the back of the platform.

The first calculations that have been done, are done around maximum wind and water speeds. If in any event, the winds will blow harder or the water will flow faster it might be that the mooring will not hold or that the engine is not powerful enough. To prevent this, a good notice of the weather prediction should be taken every day.

One thing that is not necessarily a hazard, but should be taken into account is the redundancy of the entire system. This could range from engine failure to a general lack of electricity. The first can be solved by having two engines. If one engine fails, the other is able to still propel the platform somewhat. The second is harder to solve. This is because there are two possible reasons for this lack of electricity, namely a component failure or a lack of sunlight. Both of the clients stated that intermittency was not an import factor and therefore no back up for the electricity system is placed on board. But as soon as there is a lack of sun in a day, the platform will not be able to charge the e-foils, will not be able to produce drinking water nor will it be able to cool the drinks on board or even flush any of the toilets, which might pose problems in the future.

To conclude: safety is a large term containing many different aspects. From stability to the necessity for life jackets or the lack of redundancy in the energy system. Starting with the first, the platform is very stable, maybe even too stable, meaning that the platform could start rolling in a frequency when a large wave throws the platform out of the neutral (zero angle) floating position. An example of how a large stability can lead to dangerous situations is the situation where the MSC Zoë lost cargo above the coast of the Netherlands (Krüger & Jannsen (2020)). For the safety on board, if the propellers are not turning when people are in the water, the rules and regulations stated in *Marina de Bonaire* and finally the electric systems are build and installed by a certified expert most hazardous situations can be mitigated.

5.10. Modularity and Scalability

In this section, the modularity and scalability of the conceptual design will be discussed. The degree of modularity determines how much of the product is dismountable which makes it possible to replace and repair components. What parts of the platform can be designed modular? And what parts has to be connected permanently? These questions are considered in subsection 5.10.1. The scalability of the project determines the possibilities to move the platform to other locations in the world. Is it possible to use the exact same concept and place it in a different water with different circumstances? Or what should be adjusted to do this? These are questions considered in subsection 5.10.2.

5.10.1. Modularity

Modularity is the degree in which the product, in this case the floating platform, is able to be dismounted into different components. The separation in different smaller components makes it easy to make repairs on specific components or replace components. On top of that, the platform can be much more flexible in the variety of use. For example, when a new technique in solar panels is offered, which is way more efficient and cheaper, a modular design makes it possible to easily replace the current parts. In this way, modularity ensures a longer lifetime by better repairability and allows adjustments to the platform.

To create modularity in the product it is important to make sure connections are not permanently connected where this is not necessary. In marine engineering, welding is a the most often used technique to make sure ships are solid enough to resist the forces of the sea. The downside of welding is that the connection is completely rigid and can only be detached by cutting. Therefore bolted connections are way more modular than welded connections, however in this case it is important these connection can resist environmental properties like salt water.

Looking at the floating platform, it will be necessary to weld the floaters of the hull to be waterproof and firm enough. On top of the hull most of the other connections can be more modular connections. The wooden floor can be connected to the hull by using bolts for example. Other parts like construction parts or equipment can all be bolted or connected by screws which makes it possible to disassemble. In the design phase of the platform a more detailed analysis of the modularity is possible. Here the exact connections per case can be designed.

5.10.2. Scalability

The initial goal of the platform is to be located in Bonaire. However, if proven to be succcesful, the clients have the goal to expand these floating platforms to more locations. Therefore, the design of the platform will have to be scalable.

Transport

One of the conclusions that were made from subsection 3.1.4 was that Bonaire relies on import from other countries, mostly from the Netherlands. For the final concept, the platform will have to be designed to fit in a container, from which the actual construction of the platform is done on location. The dimensions of the largest shipping container available is 40 ft long and 8 ft wide (*Mrbox*). As the floaters of the platform have been designed at 14 meters (46 ft), these will have to be shipped in parts to fulfil this need.
The fact of the dependency on import is in the case of Bonaire a downside, but provides an opportunity for the project to be scalable to more countries, as the platform will already be designed to be shipped all over the world.

Facilities

The facilities used on the platform will also be imported from the Netherlands, such as toilets, energy generation devices, energy storage devices etc. These will also be shipped by a container and therefore be scalable for other locations in the world. As the platform is a (mostly) standalone system, it is less dependent on the locations in terms of connection to the electricity grid or other utilities. Standardisation issues however may follow, as equipment will probably be standardised according to European standards. Repairs and replacement equipment will therefore probably all have to be imported from Europe.

General facilities like refrigerators, bar materials, speakers etc. will also have to be imported from Europe if the electrical grid of the platform is not suitable for the local grid. One can therefore make a choice to have local equipment with a local electricity grid (design needs to be adaptable for this), or have a European system with European equipment.

Next to the facilities onboard, the stationkeeping could also face different situations due to water depth and possibilities within the context of each location. Deeper waters would require other (and stronger) mooring types. On the other hand, a location with less marine life could provide more possibilities for for example catenary mooring systems without too much environmental impact. Concluding, mooring would be a tailor made engineering solution, requiring in-depth analysis per location.

Environmental conditions

The environmental conditions on Bonaire are, in terms of seastates, quite mild. Low wave, wind and current loads may be expected during normal weather. This has positive impact on the design in terms of engineering and materializing. However, for the design to be used in other locations, the platform should resist other loads not found on Bonaire. Once scaling up to other locations, this should be kept in mind in the engineering phase. Creating a standard design could lead to overdesigning, and therefore potentially higher costs of the platform.

5.11. Location of the Platform

For the placement of the platform, an ideal location was to be found with optimal weather conditions for both the platforms capabilities as activity requirements. For this, environmental data (mainly wind, wave, current, bathymetry and extreme weather) was required. However, concluded from section 3.3, data was scarce, leading to insufficient data for an exact location.
However, from conversations with the client and different stakeholders, a region was pointed out where the platform could potentially be placed. This region can be seen in Figure 5.8.

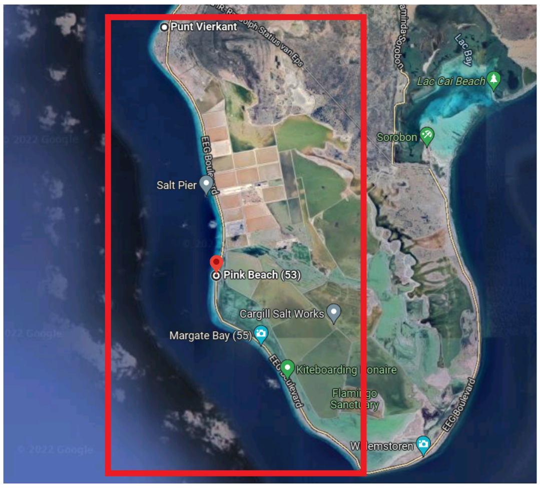


Figure 5.8: Region where the platform would be placed

For the ideal location to be determined, more research into environmental conditions, activity in the area and permissions have to be done.

5.12. Results Concept Definition

In the concept definition, one concept was chosen from the MCA from section 5.1. This concept has been worked out in terms of:

- Propulsion
- Stationkeeping
- Carbon emissions
- Water management
- Energy consumption
- Local environmental impact
- Location of the platform
- Safety
- Modularity and scalability
- Hidden impact
- Visualisation

Conclusions that can be made is that a propulsion system of 343 BHP is needed to propel the platform in case of a worst case scenario (stormy conditions). For the stationkeeping, five concrete mooring blocks of 2,4 tonnes are required to keep the platform in its desired position during operation in the case of extreme weather conditions.

In terms of carbon emissions, the platform is expected to produce 64540 kg of CO2 during production and transport and 2.2 million kg's of CO2 during its 15 years of lifetime, mostly from the propulsion from land to sea. This could be more efficient by introducing a pendling service, keeping the platform at the mooring site. For the futuristic concept, production and transport will be lower due to the lower CO2 impact of the glass fibre, resulting in 239400 kg of CO2 for production and transport. During decommissioning it has been assumed that all materials are reused, recycled or sold, therefore not contributing to CO2 emissions.

During one day, 9 m^3 of fresh water is used for showering, drinking and flushing of the toilets on the platform, requiring a RO system capable of producing 1 m^3 of fresh water per hour.

For all the activities, renewable energy is needed to provide the platform its power. This can be provided using 182 m^2 of solar panels in combination with a calculated 80 old car batteries. The question is raised whether 80 old car batteries are the best solution for the storage of energy.

For the local environmental impact, antifouling approved by STINAPA would have to be used for the coating of the hull. To prevent plastic ending up into the sea, a physical barrier is proposed with a mesh. Next to this, double walled blackwater tanks would be used to reduce the risk of leakage into the sea.

For the safety of the platform, note should be taken of the stability, as the platform could be designed to be too stable. Furthermore, for the electrical systems should be installed by a certified expers. Lastly, propulsion systems should always be turned off once visitors are in the water to prevent accidents.

In terms of modularity, the use of bolted connections instead of welds are proposed to provide a more flexible and repairable platform. For scalability, it is important that building standards have been taken into account in the design. Other standards for for example connections and piping are used in different parts of the world, which could lead to not fitting equipment and facilities. Mooring is dependent on the location and its associated environmental conditions and can therefore not be standardized. This should also be taken into account in the final design.

6
Conclusion

This report started with the following, main research question:

*Can an offshore floating platform, aimed at fast watersports, be built **as sustainable as possible** within the **context of Bonaire**?*

To answer this question, the following questions have been stated to get a clear definition of the main question:

1. What is the context of Bonaire?
2. What is, for this report, the definition of sustainability?
3. What facilities are needed on the platform?
4. How can 100% renewable energy be generated for the platform?
5. What would such a (conceptual) platform look like?

An extensive answer on the first question is given in chapter 3 where the context of Bonaire is treated on different subjects. Governmental structure, ecology, tourism, supply chain, energy infrastructure and (waste) water management are be found in section 3.1.

The other question that has been answered in chapter 3 and fell under the context of Bonaire was the question whether there is a valid need for this new system, which was a question introduced in the methodology (chapter 2). section 3.5 gives three reasons that validate the need of this platform:

- STINAPA and the government are looking for ways to reduce the impact of (fast) watersports in the marine park of Bonaire.
- the OLB has set a long-term tourist goal what shows the need for sustainable tourist activities.
- Although Bonaire has renewable energy in its electricity grid, the renewable energy share is reducing in the last couple of years. A sustainable platform like this can be an incentive for producing more sustainable energy

After performing the SWOT analysis in section 3.4, the definition of sustainability (question 2) for this project was stated. For this project, a sustainable platform will:

- Produce the least emissions as possible during its production, its lifetime in use and its decommissioning.
- Mitigate the negative effects of putting it in the water as much as possible, looking at the environment and marine life of Bonaire. Where possible, the platform will have positive impact by providing possibilities for nature restoration and research.
- Make the platform as repairable as possible with the facilities at hand on Bonaire, providing a contribution to the local economy as well.
- Mention the hidden impact of the island in terms of rare earth metals, labour conditions etc.
- Make the platform in such a way that it will be as circular as possible, meaning materials and facilities could be recycled.

In chapter 4, subquestions 3 and 4 were answered, where the options for general facilities, materials, waste handling, generation and storage of water and electricity, propulsion and stationkeeping where researched. All these options have been visually represented in a morphological map, shown in subsection 4.10.1.

From this morphological map, three different concepts and a futuristic concept have been chosen. These three concepts have been scored in the Multi-Criteria Analysis in section 5.1 which has resulted in one final concept. This concept is worked out in the final chapter, chapter 5 in terms of:

- Propulsion
- Stationkeeping
- Carbon emissions
- Water management
- Energy consumption
- Local environmental impact
- Safety
- Modularity and scalability
- Hidden impact
- Visualisation

This worked out final concept has answered the last sub question (question 5) as well as the main research question. The chosen concept consists of a trimaran, propelled by a propulsion system of 343 BHP. For stationkeeping, five concrete mooring blocks of 2.4 tonnes are required. An expected carbon emission is calculated as being 64540 kg during production and transport and 2.2 million kg of carbon emission during a lifetime of 15 years. In this concept 9 m^3 of fresh water is used, requiring a reversed osmosis system capable of producing 1 m^3 of fresh water per hour.

The required energy is provided by solarpanels using an area of 182 m^2 in combination with 80 old car batteries. Furthermore, the hull will be coated with antifouling approved by STINAPA and to prevent plastic in the water, a physical barrier is proposed. The platform is build in the Netherlands because of the knowledge and availability of materials. After the platforms lifetime, materials and equipment will be reused where possible.

Next to that, a futuristic concept is proposed which is expected to be more sustainable. In this case, bio-fuel engines are used instead of diesel engines. The hull consists of materials with less carbon emissions during the production. Other facilities will be assumed to be optimized and developed during the years.

Finally, considering the sustainability of the proposed platform, it can be concluded with current technologies it is hard to build a platform without emissions, negative effects or any hidden impact. However, if the schedule and plans of the clients where to change towards a more 'nature dependent' schedule (so taking peak energy generation into account). The platform could set an example and can even be a global 'first' when it comes to making the practice of watersports more sustainable.

7

Discussion and recommendations

During the project several methods, calculations, simplifications and assumptions have been used to argue the choices made. This chapter will discuss these aspects, and where necessary, propose different solutions or methods. Next to this, recommendations are given for future research.

Methodology

The method contains a couple of discussion points. The important ones are:

- The potential oversimplification caused by a SWOT analysis: because the timeframe of a SWOT analysis is very short, one can oversimplify a problem that is actually bigger than one would initially expect. However, everything discussed in the SWOT analysis has been added in the appendix of this report. This gives possible further research or readers of the report the possibility to re-evaluate the stated conclusions in section 3.4
- The subjectivity in the MCA analysis. An MCA is used for two reasons: to take away some subjectivity in a decision process, but also to allow for a more informed discussion. The latter has not taken place, as the results are presented but not fully discussed with the clients. A more in-depth and well informed discussion after the MCA might have led to different results and is therefore recommended in further research of this and other projects.

Needs analysis

In the stakeholder analysis, interviews and conversations have taken place with multiple parties on Bonaire. These conversations have been carefully written down, from which conclusions have been deducted. However, some conclusions could rely on prejudice and could be biased, resulting in subjective or wrong information. Some parties have also not been interviewed, such as the fisheries of Bonaire. Their view and support on the project has therefore not been verified and could have led to different results.
Next to this, initial guesses of stakeholders support and opinions have later been altered during the research. The directions in which the project initially was steered can therefore seem not logical in the end.

Concept exploration

In the concept exploration, a wide variety of options have been discussed, however not every option is considered, mainly because some developments are in such an early stage that the actual technology is not feasible yet. This means that there could be more (future) options that can lead to a more sustainable platform. The recommendation here is to look at what is available around the time that the platform is going into production and choose the facilities that suit best at that time.

Concept definition

Once the final concept was chosen, different simplified calculations have been made. So is the assumption of 60% propeller efficiency purely based on experience and, as stated, quite high. For further research a more in depth analysis of the resistance of the platform should be carried out to give a better idea of the needed propulsion.

Another possible future research subject could be the behaviour of such a platform in waves. This because the calculations that are currently done are for an oversimplified static situation, but the platform will always be under the influence of waves. This means that the forces on the mooring system (and especially the mooring lines) could turn out larger or smaller then calculated in this report. The safety factors applied in the calculations do make the calculation more reliable, but still should be checked in future calculations.
Throughout the report, the platform has been designed around the requirements from the clients in terms of facilities, electricity and water demand and day planning. This has resulted in a final design which is deemed 'as sustainable as possible' with these requirements in mind. However, emissions of the platform can be reduced even further with changing these requirements.

Examples are that the daily planning can be altered in such a way that the electricity and water demand is more in line with the supply. Planning more "energy intensive" activities during the afternoon results in less installed battery storage, as solar power is more readily available. Next to this, tendering a boat between the platform and Bonaire for visitors instead of moving the whole platform will also result in less emissions.

The final point of discussion, is the one about sustainability. As stated in chapter 3, the definition of sustainability according to the UN is: "meeting the needs of the present without compromising the ability of future generations to meet their own needs." This definition does allow for freedom in interpretation and therefore sustainability is hard to precisely define. This means that there will always be room for discussion. The definition of sustainability in the scope of this project as proposed in section 3.5 is mainly focused on environmental sustainability. This means that the social side of sustainability is barely taken into account at all.

This social impact is hard to measure and mitigate, especially for students with a technical background. However, the ideas of the clients do allow for development of local business (serving local food and drinks) and will provide jobs for the local population (lifeguards, bar personnel etc.)

Other than that, section 5.8 has also shown that the solutions that are currently deemed market worthy for mitigation of the CO2 footprint of their systems (batteries and solar panels), have a large social and environmental impact on the people and areas surrounding the mines where the materials for these solutions are delved.

Continuing, as is concluded in section 5.7 whichever way one puts it, the platform will have an impact on the local environment and may therefore harm the surrounding area. It may however provide a means to control the foiling watersports in the area of Bonaire, resulting in the potential prevention of these watersports causing collisions and harm to sea life, such as turtles and coral.

Does this make the platform sustainable? Considering the definition of sustainability, it is questionable if this design is indeed sustainable. The design presented in this research is more sustainable than the current situation. However, the platform is expected to still have an impact on the surrounding area, potentially also causing harm to the reef. For this reason, the final conclusion edges on the ethical question: "How can we still grow sustainably?". This question is too big to answer in this report, but the proposed idea can initiate a movement towards 'green initiatives'. Therefore, the platform design as presented can be a promising step towards a better future.

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A

Stakeholder analysis

Stakeholders

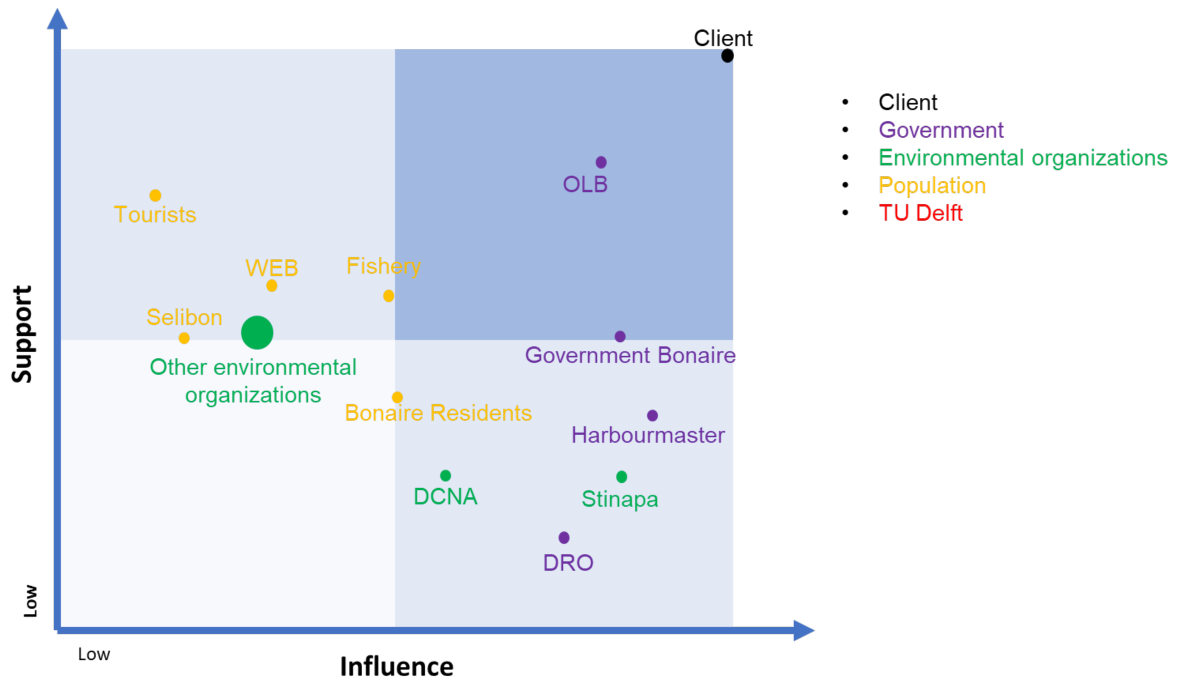


Figure A.1: Initial stakeholder mapping made before the start of the project

Client

Noémie and Roan
General goal: client and owner
Role: The client provides the requirements, demands and other information for the project.
Influence: The influence of the client is considered to be very high. The client has got high influence on what facilities and properties are needed on the platform. At the end of the feasibility study, the client determines what the following steps are in the process. However, to eventually execute the project they are dependent on many other different stakeholders like the ones discussed next.
Support: The support of the client is considered very high. They want their idea to be executed in the most sustainable, feasible and economical possible way.
Contact: regular meetings to keep client up to date and to cope with possible curveballs

Government Bonaire

General government, OLB
General goal: The general goal of the government is to run the country, providing a good way of living for the people of Bonaire.
Role: In this project different permits are needed, approvals for the use of a location, approval for using a mooring, approval for providing services to tourists and run a lucrative company. Also new policies should be written about prevention of precedents. All together, the approval of the government is necessary to execute the project. When the project is finished and the platform installed at the location, supervision is necessary, this might be in charge of the government.
Influence: The influence of the government of Bonaire is considered to be high. Together with all ministers, big decisions are made and plans like the 'Eilandbesluit' Bonaire (2010) are worked out. More about this will be elaborated on next.
Support: The support could be high, but many requirements should fit. More about this will be elaborated on next.
Contact: few contact, besides of the requests for the necessary permits

Advisor DRO
General goal: The advisor of DRO is member of the Bonaire government as advisor for spacious planning and provides advice on new policies.
Role: The support of this advisor is needed to get the final location of the platform. He also helps in writing new policies around the project.
Influence: Influence is considered to be high. As advisor of spatial planning he can obstruct the project when there is no space for the platform or when the environmental impact is too big. However, he has an advising role in writing new policies, so the final decision of executing the project has to be discussed with the minister of spacial planning as well.
Support: The support is considered to be low. Many rules and laws should be followed which means the platform should fit many requirements.
Contact: sporadically but very important

Minister of Economische Ontwikkeling, Tourisme en Financiën
General goal: This minister is a member of the Bonaire government and manages economical developments, tourism and finance.
Role: The minister manages the economical developments on the island. Building this platform attracts more tourists and will stimulate economical growth. This satisfies the goals mentioned in plans for tourism growth and economical growth Bonaire (2010).
Influence: As the platform will be working as an attractive addition for tourists on the island, the commissioner will be a big part in the final decision for the execution of the project.
Support: Because of the economical growth, attraction of tourists and creation of jobs, the support of the commissioner is assumed to be high. This information is gathered not directly but from conversations with the client.
Contact: none

Harbourmaster
General goal: The general goal of the harbourmaster is to manage all sea traffic in the water surrounding Bonaire.
Role: The role of the harbourmaster in this project is giving permission or obstruction to using the area managed by harbourmaster.
Influence: Because the harbourmaster manages the area in which the platform will be placed eventually, influence is considered to be very high. All rules about environmental impact, watersport speeds en locations should be followed strictly or permission will be denied. Support: The relation between STINAPA and the harbourmaster, or the relation between the managers of the marine park and the manager of the surrounding area is close. Therefore, a supportive STINAPA could also mean the harbourmaster is supportive. However, the platform will still be placed in the deeper waters which could cause problems for sailing routes or fishing areas. Therefore, the support is considered to be low.

Contact: few contact but very important.

Environmental organizations

STINAPA

General goal: Preservation of reefs on Bonaire

Role: STINAPA is committed to the preservation of the reefs and underwater life on Bonaire. The organization is very influential on the island and therefore STINAPA has a big role in the project. They can obstruct when the platform has negative impact on the environment. On the other side they can help in determining the optimal location or provide information about local flora and fauna. Also STINAPA is in charge of the placement of moorings round Bonaire, this means STINAPA is needed to place a mooring.

Influence: STINAPA is considered to have a high influence in the project. As mentioned they can obstruct easily when there is impact on the environment. Also a mooring line is needed which means approvement by STINAPA is required to execute the project.

Support: The support of STINAPA is expected not be very high because they are afraid of impact on the environment caused by the platform. On the other hand, the floating platform can help solving problems of STINAPA. Foiling is getting more popular which means more damage can be done by the swords used to foil. The platform gives an option for zoning the fast watersport which can easily then be regulated.

Contact: Often

DCNA

General goal: Preservation of reefs on Bonaire and surrounding islands.

Role: Providing information about flora and fauna in the whole Dutch Caribbean.

Influence: None directly since STINAPA is the executive branch from DCNA and so DCNA and STINAPA are basically the same party.

Support: Same as STINAPA.

Contact: Very little.

Recycling Bonaire

General goal: The goal of Recycling Bonaire is to investigate in ways to recycle waste, develop new programs to reduce waste and carry out plans to make use of more reusable materials.

Role: Recycling Bonaire can contribute to the project by providing information of ways to process waste generated on the island. Also the materials used to build the platform can be reusable materials provided by Recycling Bonaire.

Influence: The influence of the eventual execution of the platform will be low. However, the founding can contribute to different facilities on the platform like waste processors.

Support: If the platform is build of reusable materials and all waste will be captured, the support of Recycling Bonaire is expected to be high. However, when these things are not taken into account, the support could be low.

Contact: on request

Blue Destination Bonaire

General goal: Blue Destination Bonaire is an organization which wants to become a leader in preservation of Bonaire's natural assets and resources.

Role: In the project organizations like Blue Destination Bonaire should be taken into account and could be cooperated with. The organization wants to be the impact of the platform be as low as possible or even zero.

Influence: The influence is considered to be low.

Support: The support could be high when the platform also has benefits for the natural assets. For example moving the area for foilers or contributing in research.

Contact: few, on request.

No Waste Caribbean Vibes
General goal: The goal of No Waste Caribbean Vibes is collecting small plastic waste on and around the island and recycle the plastics, melt it and sell it as little souvenirs. This is done to reduce the plastic in the sea.
Role: The role in the project will be small. However, some cooperations can be started, for example using their plastic in the design of the platform.
Influence: Low influence
Support: Neutral support
Contact: few contact

Reef Renewal Bonaire
General goal: Reef Renewal Bonaire is committed to restore the coral reefs around Bonaire.
Role: Advice and information about coral growth and preservation is obtained by the organisation. Reef Renewal also hosts educational sessions which raise awareness among school children about coral preservation. In this way cooperation could occur between the clients and Reef Renewal.
Influence: Reef Renewal Bonaire will not be decisive in the final execution of the project.
Support: The organisation does not have anything against the project as was the conclusion of a meeting. The platform is also placed in too deep water to give any realistic use for Reef Renewal.
Contact: On request

Debris Free Bonaire
General goal: Debris Free Bonaire is an organization which works with many volunteers to clean up the sea and land from garbage.
Role: Like the other environmental organizations Debris Free Bonaire wants the sea to stay clean which means they will watch our project and demands it to be garbage free.
Influence: The influence is considered to be low.
Support: Low support, the organization could be scared of more garbage dropped off the platform.
Contact: few contact

Population
Tourists
General goal: Visitors of the platform.
Role: Using the platform for watersports.
Influence: Influence on possible facilities on the platform.
Support: The platform provides activities for the tourists which causes a high support of the tourists.
Contact: During the stay on Bonaire tourists will be contacted on a daily basis and inventorize to possible demands.

Residents of Bonaire
General goal: visitors of the platform.
Role: Using the platform for watersports.
Influence: The influence is considered to be low, but residents can share their ideas of possible facilities on the platform.
Support: The support of the residents is divided..
Contact:

Fishery/Piskabon
General goal: Piskabon is the organisation which represents and protects the fisheries of Bonaire and their interests.
Role: In meetings with different stakeholders turns out that the organization called Piskabon represents the fishery and owns different markers at sea. These markers show areas in which the platform could not be installed.
Influence: The influence of the fisheries in the project is considered to medium in influence. However, in some ways these fisheries should be taken into account. The space at sea is limited, so the pos-

sibility of entering the same areas is there. Besides that, cooperations with the fishery can be set up. Installing a platform at sea causes shadow, grow of plants and therefore attraction of fish. This means in multiple ways the platform and the fishery overlap which means they have influence.
Support: If agreements are made and the fishery can use the benefits of the platform, the support of the fishery can be high. However, the watersports and the placement of a platform can scare off the fish which lowers the support of the fishery or can create a no-fishing area.
Contact: the fisheries should be taken into account, but the contact will be low.

Selibon
General goal: Selibon is the organization on Bonaire which collects waste, transports it and processes it.
Role: The waste generated by the platform has to be collected and processed by Selibon, as it is the only waste collector of Bonaire. Selibon could be useful in building the platform by reusing products Selibon collected.
Support: Neutral support
Contact: On request

Water- en Energiebedrijf Bonaire (WEB)
Goal: The goal of 'Water- en Energiebedrijf Bonaire' is providing sustainable energy to the island of Bonaire. The energy is generated by the use of windturbines, solar panels and diesel plants. Also, WEB provides the water purification for drinking water.
Role: The role of WEB in our project could be providing information about generating green energy. Also a cooperation with WEB could be realised with the purification of water for the platform.
Influence: The influence of WEB in this project is considered to be low. WEB can be used for information or tools but will not be decisive in the realisation of the project.
Support: The support of WEB is be neutral.
Contact: on request, few

B SWOT Analysis

Appendix SWOT Analysis

B.0.1. Political

WEAKNESSES		STRENGTHS	
		Roan has connections	1

THREATS		OPPORTUNITIES	
Extra enforcement needed from harbourmaster		New watersport zones outside coastal area	1
"Foute" Wout		Potential subsidies/relationship with the Netherlands	5
Political system-->if someone doesn't want it, it doesn't happen	1	Boost for the economy of Bonaire	2
Favoritism in politics	1	Potential for "blue destination" stamp	3
Protection policy from naturepark	2	Connections with Adnan-->influential person	4
Instability of Bonaire's government			
DRO (Dienst ruimtelijke ordening) counteracting (Frank van Slobbe	1		
Policy drafting takes a long time	4		
STINAPA controls moorings, doesn't want a new mooring system	3		
Lobbying only possible if governance "likes" you			
Nature & Policy is very "narrowminded"	2		
Project is from dutch people, is "not good" from local perspective	5		
Wrong political party in control			
Everything "new" is directly "wrong" (Bonaire view)			
For new events you need permission			
Potential blockade due to precedence effect			

Figure B.1: SWOT Analysis: Political

B.0.2. Economical

WEAKNESSES		STRENGTHS	
If Roan's business have financial troubles, we are more reliant on investors	1	Roan has established some succesfull business on Bonaire, providing certaint	1
		The platform will provide jobs on Bonaire	2
		The platform will cause economic growth	3

THREATS		OPPORTUNITIES	
Inflation may cause rise in costs of the platform	3	There are already a couple of interested investors	1
Decline in tourists due to high flight ticket prices (??)		The growth of tourism on Bonaire provides more available money	2
Decline in tourists (covid) may cause troubles		Subsidies for sustainability	3
Finding investors	1		
Containers (import) are expensive	2		
Materials are becoming more expensive	3		
Potential competition for such a platform	4		

Figure B.2: SWOT Analysis: Economical

B.0.3. Social

WEAKNESSES		STRENGTHS	
"white" investors/business owners	1	Reasonable favor factor within Bonaire	1

THREATS		OPPORTUNITIES	
Local food availability is uncertain (stock and agricultural earth)	2	Lots of rich Dutch people	
Gender gap-->how do we get woman to work?		Chance to reduce "apartheid" (jobs for locals)	5
Potential enlargement of "apartheid"	1	Criminality is low	
How to be inclusive for everyone in terms of pricing and entertainment? Local vs tourist	1	Dutch share of population is growing	
How to get people together with 2 white people at the table?	2	Growth of population in general	
"post-colonialism" ideas on Bonaire	1	Opportunities for internships	2
(growth of) the gap between poor and rich might cause friction	1	Working together with local food/drinks/activities	1
(Locals don't do a lot with the sea/water)		Leisure is part of life in Bonaire	3
Commitment employees towards working		Different target audiences possible	4
in some cultures, working on a "boat" is "low"			

Figure B.3: SWOT Analysis: Social

B.0.4. Technological

WEAKNESSES		STRENGTHS	
Import of materials from Netherlands	1	Lots of knowledge about watersports	3
		Building and development in the Netherlands	1
		Modularity	2

THREATS		OPPORTUNITIES	
Repairability on the island might be a problem (knowledge/materi	3	Lot of solar power	1
Scarcity of materials on the island	1	Demonstrator for solar power and storage	2
The climate is harsh on materials (sun, sea, wind)	4		
No local tech support/support centre for	3		
Not a lot of innovative tech on the island	3		
Lifecycle is unknown			
Little knowledge about energy storage on the island			
Mooring is restricted by STINAPA	2		
Capabilities of the harbour might cause restrictions	5		

Figure B.4: SWOT Analysis: Technological

B.0.5. Environmental

WEAKNESSES		STRENGTHS	
foiling is in principal not beneficial for nature	2	Solution for the pressure of tourism and watersports at beaches and the coa	1
Risk of greenwashing			
What is sustainable?	3		
manufacturing/shipping materials costs a lot of CO2	5		
Putting something unnatural (platform) in the water is already bac	4		
Anti-fouling is bad for the environment	4		
(human) Waste ending up in the water/in the reef	1		

THREATS		OPPORTUNITIES	
Hidden impact (??)		Making the platform recyclable	5
Hurricanes/reversals/natural disasters	3	People are pro-sustainable-->everything sustainable	
No/little recycling on Bonaire	1	STINAPA considering prohibition of fast watersports in marinepark	1
Climate change causing less wind for kite/windsurfing		Platform could be used for research	3
Harsh climate	2	The platform can cause awareness of environment etc.	2
		Set an example for other boats/project on/out of Bonaire	4
		Solution for foiling problem around Bonaire	1

Figure B.5: SWOT Analysis: Environmental

B.0.6. Legal

WEAKNESSES		STRENGTHS	
Patent on a sustainable platform is hard to establish-->risk of competition/imitations	2		

THREATS		OPPORTUNITIES	
New legislation required for containing the new market	3	Patrol for harbor master possible from platform	1
Legislation in Eez bonaire can cause trouble	1		
Insurance might cause trouble	2		
Monopoly position floating island may cause problems	4		

Figure B.6: SWOT Analysis: Legal

C

Facilities

Category	Object	Power (Watt)	Costs (EUR)	Amount
Housekeeping	Refrigerator	250	2500	1
	Freezer	300	1000	1
	Induction cooker	3000	1500	1
	Oven	3000	500	1
	Salt to fresh water filter	0	2000	1
	Barbecue	0	1000	1
	Dishwasher	1200	2000	1
	Quooker	2200	1500	1
	Toilet	0	500	4
	Shower	0	300	3
	Water Tank	0	3000	1
Garbage processing	Garbage Bins	0	1000	3
	Waste press	0	1000	1
Sewerage	Storage tank	0	500	3
	Onboard Pump	1200	500	1
Sports	Boat docking stations	0	3000	1
	Efoil charging stations	3000	10000	6
	Efoil docking station	0	750	6
	Floating jetty surrounding platform	0	10000	1
Lights	Deck lighting	500	2000	1
	Emergency lights	25	50	1
	Top light	25	50	1
	Anchor light	25	50	1
Other	Beamer	300	500	1
	Charger (phone/laptop/camera etc.)	100	10	10
	DJ booth	100	4200	1
	Speakers	600	3000	1
	Fans	60	60	6

Figure C.1: List of facilities

D
Floating Platform Design Tool

Floating Platform Design Tool

The goal of this tool is to give project developers a quick and easy way to compare different concepts for floating platforms and their facilities, while having an easy overview of different key factors such as costs, CO2 emissions, electricity and water usage.

D.0.1. Flow of the current program

The program currently has a list of facilities that are being considered, a deck layout and an output. These are all displayed in one sheet of the Excel workbook. Multiple copies can be made of the template sheet to compare different concepts.
The deck layout is to be determined by the user, but the idea now is that a cell is equal to a square meter. The deck layout is interactive where the user must fill in a cell with the facility name from the list of facilities. Then the format of the cell will change automatically with the color of the facility name. An example of the deck layout can be seen in Figure D.1.
The list of facilities can be expanded by the user of the program, the list for now only includes the facility name, energy, cost, CO2, water, weight and amount. These facilities are organized per category and are color coded.
There are some assumptions made about the usage of water onboard the platform, which is represented by the pink box in Figure D.2. These assumptions can easily be adjusted by the user and the results are added to the Totals section, the golden box in Figure D.2.
The results are obtained by counting in the deck layout how much of a certain facility is filled in. This amount is then displayed in the list of facilities and is then multiplied by all the facility arguments (cost, energy, etc). This sub-total is then added up per category and then summed up in the Totals section. The results section also contains a leftover section, which basically counts the empty boxes and gives an indication for how much leftover space there is where visitors of the platform can have for themselves.

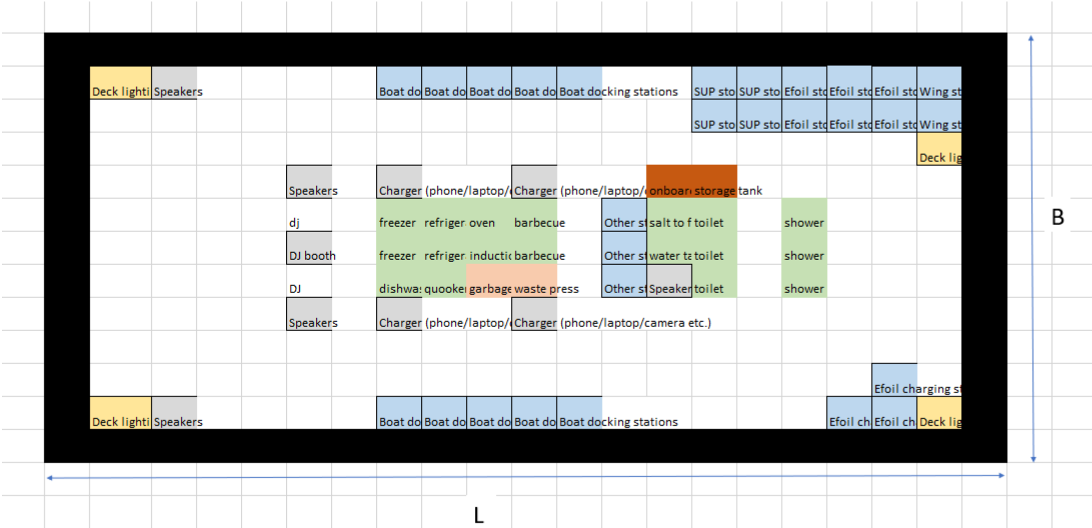


Figure D.1: Example of deck Layout from the Excel Tool.

Totals		
energy	115.7	kWh
cost	104100	EUR
co2	0	kg
water	1290	L
weight	13935	kg
leftover	352	m^2

Explanation

- Facilities need to be added manually!

- Fill in the boxes with the facilities that are stated in the list of facilities organized per category.
- One box is equal to 1 m^2.
- The output is stated on the left in gold coloring
- There is a second floor added which is represented by the second recangle.

Assumptions

There are some assumptions made about amount of people onboard and the according water usage. These assumptions are about water used per flush,
per rinse of materials and people, and for consumption.

Assumptions							
	usage [L]	amoun	total			people	100
Toilet	6	100	600			efoils	6
Shower	3	100	300			sub	6
Rinsing	5	18	90			wings	6
Drinking	2	100	200				
lpclean	100	1	100	+			
		TOT	1290				

LIST OF FACILITIES PER CATEGORY

category	Housekeeping												Totals per catergory	
facility	Refrigerator	Freezer	Induction cooke	Oven	Salt to fresh	Barbecue	Dishwasher	Quooker	Toilet	Showe	Water Tank			
energy [kWh]	3000	7200	9000	9000	0	0	6000	4400	0	0	0		energy	48800
cost [$]	2500	1000	1500	500	2000	1000	2000	1500	500	300	3000		cost	21900
co2 [kg]													co2	0
water [L]													water	0
weight [kg]	200	200	30	30		60	70	20	50	5	1000		weight	2235
amount [-]	2	2	1	1	1	2	1	1	3	3	1			

category	Garbage Processing		Totals per catergory	
facility	Garbage Bins	Waste press		
energy [kWh]	0	0	energy	0
cost [$]	1000	1000	cost	2000
co2 [kg]			co2	0
water [L]			water	0
weight [kg]	20	100	weight	120
amount [-]	1	1		

Figure D.2: Example of facilities, results and assumptions.

D.0.2. Discussion Points

There are some disclaimers when using the Floating Platform Design Tool. This tool is solely designed to give an initial estimation of the lay-out, cost, CO2 emissions, water usage, electricity consumption. Some of these facilities are based on assumptions which can be found in Appendix C. The accuracy of the tool is quite low when comparing it to a 3D modeling program. But the goal of the tool is not to precisely model the platform, it is to give the user an initial estimation on costs, usages and layout of different concepts for floating platforms. For a more definite design, another company which is able to deliver technical drawings should be hired.

E

Thought process MCA

Thoughst whilst scoring the different concepts

Whilst the concepts were scored, different considerations were made. This appendix will dive deeper into those considerations, splitting the thougts per requirement that is to score.

Ecological impact (local)

1. *Energy generation:* All concepts score equal, because the local impact is negligible. All concepts will get a score of 1
2. *Energy storage:* All concepts score equal, because the local impact is negligible. All concepts will get a score of 1
3. *Buoyancy:* If we look at where the buoyancy comes from, a trimaran is worse for the environment than a catamaran. Purely because there is more hull surface area on a trimaran then on a catamaran, which means more anti-fouling and paint, which means more impact on the environment. Therefore concept one and three get a score of two (cause the impact is not negligible) and the trimaran will get a score of three (the impact is larger)
4. *Station keeping:* Because each concept is moored, the impact is equal. It is very bad at the start, but after a couple of years the life on the seabed might be restored back to it's original state assuming that the mooring line will not touch the ground and the cement blocks will not move. All concepts will get a score of 3
5. *Waste water treatment:* Because neither of these options will pump water overboard, the environmental impact is equal for all concepts. All concepts will get a score of 1.
6. *Materials:* All equal as well. A note here is that the production of Aluminium will cost rare earth minerals and it is an energy intensive material, therefore the global impact will not be zero. All options get a score of 1.
7. *Mobility:* In these concepts there are two concepts that are self propelled and one concept which is towed. The towed concept is worse than the self propelled concpet as the towed propeller would have to move two ships. Assuming that the towing ship has an outboard engine one can also assume that the propulsion system is optimized for high speed propulsion resulting in heavy cavitation (and thus noise) when towing. This noise has an considerable impact on the environment. Therefore concept two and three get a score of 3, but concept one gets a score of 1
8. *Water generation:* For the ecological impact, the reverse osmosis process is worse than the reusage of water. This because the reverse osmosis will pump water through a filter, after which the salt has to be discarded meaning a minimal (but might be noticeable) impact on the local environment. This results in the concept one having a score of two and a score of three for concepts two and a score of one for concept 3, as this concept will get it's water from shore.
9. *Water storage:* Because concept three uses a large water tank, the impact is negligible. Concepts one and two both use a local production facility which entails noise and waste and thus a higher environmental impact.

COtwo emissions

1. *Energy generation:* Each of the offered options have the same impact when it comes to COtwo emissions. During there lifetime the produced COtwo is equal to zero, but during there production each choosen option (solar and wind) produce some COtwo (small compared to the grand total). Therefore a score of two for each concept.
2. *Energy storage:* The production of COtwo for new battery packs is substantially more than when one would re-use old batteries. Therefore a score of three for concept 1, a score of two for concept two and a score of four for concept three
3. *Buoyancy:* The resistance of a catamaran is lower than that of a trimaran (more surface area in the water). Therefore concept one and three get a score of 2, but concept two gets a score of three.
4. *Station keeping:* The production of concrete costs CO2, but as all concepts use concrete blocks, all concepts will get a score of two.
5. *Waste water treatment:* Because the grey and black water treatment system requires more power (and thus the installation of more batteries and solar panels) concept one gets a score of 3. The other concepts get a score of 2.
6. *Materials:* all materials are equal, but as aluminium is a COtwo heavy product (when producing it) the score for each conept will be equal to 4.
7. *Mobility:* Towing a system will always require more power than propelling the system itself (for example due to the fact that two systems have to be towed). Therefore, concepts two and three get a score of three (because self propelling is still not without COtwo emissions.) and concept one gets a score of 4
8. *Water generation:* The system using the 're-usage' option has to have more installed power. Therefore this concept will score worse than the concept with just a reverse osmosis system. Thus a score of three for concept one and a score of two for concepts two and 3.
9. *Water storage:* So, assuming the power generation on the island will be kind of like described in subsection 3.1.5, the concept using water that is generated on land will score worse (the large tank option) then the other systems. Therefore concept three gets a score of three, whilst concept one and three get a score of two.

Technical feasibility

1. *Energy generation:* Concept three is considered to be worse as small wind turbines are less efficient.
2. *Energy storage:* A new battery pack is considered to be more feasible as it will have better quality storage and is readily available. Therefore concept three scores lower.
3. *Buoyancy:* For load distributions and moments, trimarans offer the best option, therefore concept two scores higher
4. *Station keeping:* Mooring is considered to be readily available and feasible for this application. Therefore all concepts get the lowest score
5. *Waste water treatment:* A greywater tank requires extra piping and systems, it therefore scores worse.
6. *Materials:* Aluminium is considered to be widely available, however not easy to machine.
7. *Mobility:* Towed combustion engines are considered to be available on Bonaire, while an onboard engine will require extra designing for the platform.
8. *Water generation:* Reusage of water will require extra piping and systems, while reverse osmosis is a readily available technology.
9. *Water storage:* A small tank is less heavy, therefore contributing less to take into account in the design.

Leisure area

1. *Energy generation:* Energy generation is considered to be not contributing to a reduction of leisure area due to roof area for both wind as solar.

2. *Energy storage:* Old batteries are considered to take up more space than a dedicated battery pack. Therefore, concept three scores lowest.
3. *Buoyancy:* A trimaran has one extra floater which could be used for storage. Therefore concept two scores lowest.
4. *Station keeping:* Stationkeeping is considered not to take up leisure area.
5. *Waste water treatment:* Two systems will take up more space than one, so the blackwater tank (concept 2) scores lowest.
6. *Materials:* Is considered not to take up leisure area
7. *Mobility:* Engines onboard takes up leisure area, so concept one scores lowest due to tugging
8. *Water generation:* Water generation does not take place in concept 3, so it does not take up leisure area. Concept one has two systems and therefore takes up more space (therefore has the highest score)
9. *Water storage:* A small tank will take up less space than a large tank. Concept three therefore scores higher.

Repairability

1. *Energy generation:* There is local industry for solar panels when it comes to installation and repair, and not so much windmills.
2. *Energy storage:* Old car batteries are easily repairable as the system is quite modular. This is due to the availability of local car batteries.
3. *Buoyancy:* Same score as the same material is used for all concepts.
4. *Station keeping:* Same score as the same type of mooring is used for all concepts.
5. *Waste water treatment:* Grey and black water tanks have more moving parts and so are more prone to breakdowns, so concept one & three score lower than concept 2.
6. *Materials:* Aluminium is hard to repair and weld so all three concepts get a bad score.
7. *Mobility:* Towing is done by an external vessel which removes the burden of repair from the client, which is why that concept one scores best.
8. *Water generation:* Re-usage scores worse than only Reverse Osmosis, due to a complicated system. But a RO system is also quite complex so both solutions score quite high.
9. *Water storage:* Not relevant for this criteria.

Safety

1. *Energy generation:* Wind turbine scores higher than a solar panel due to moving parts.
2. *Energy storage:* Old battery packs are more unstable and could malfunction quicker than a new battery pack.
3. *Buoyancy:* Not relevant for this criteria
4. *Station keeping:*
5. *Waste water treatment:* Grey and black water tanks are more unsafe if system fails.
6. *Materials:* Not relevant for this criteria
7. *Mobility:* Towed situation scores worse due to the chance of collision when towing.
8. *Water generation:* Not relevant for this criteria
9. *Water storage:* A small tank scores better due to avoiding still standing water, stability for the vessel and bacterial/ mosquito growth.

Modularity/scalability

1. *Energy generation:* All options are scalable, as you just expand your area of solar panels/wind turbines. Defect solar panels and turbines can be replaced.

2. *Energy storage:* A car battery is considered to be more readily available than a battery pack, so it gets the lowest score (concept 2).
3. *Buoyancy:* A catamaran has one less floater, so it will be easier to transport in terms of scalability to other countries.
4. *Station keeping:* Mooring is scalable, as there are a lot of systems available.
5. *Waste water treatment:* A combination of systems gives more options in modularity. In terms of scalability it is considered equal. Therefore giving concept one and two the better score.
6. *Materials:* Materials are considered to be independent of scalability and modularity.
7. *Mobility:* The dependency on towing of an external party makes scalability harder than an own propulsion system. However, towing is often available in different options, so it scores on modularity. Therefore, same scores are given.
8. *Water generation:* Reverse osmosis and reusage scores best as no dependency on external parties is given, therefore it makes it more scalable. Next to this, it is a double system.
9. *Water storage:* A small tank in combination with local production scores better as it creates independency from location choice.

Other harmful emissions

1. *Energy generation:* To produce silicon for solar panels a lot of chemical byproducts are created, so the solar scores high.
2. *Energy storage:* New batteries are worse than old batteries due to lifetime extension. Using old batteries can be seen two times less harmful for the environment.
3. *Buoyancy:* Not relevant for this criteria
4. *Station keeping:* Not relevant for this criteria
5. *Waste water treatment:* Not relevant for this criteria
6. *Materials:* Are relevant, but they are all equal, thus get an equal score
7. *Mobility:* Not relevant for this criteria
8. *Water generation:* Not relevant for this criteria
9. *Water storage:* Not relevant for this criteria

Circularity

1. *Energy generation:* Solar panels do (probably) have a longer lifetime than the platform itself. However, the elements used in a solar panel are hard to recycle. Wind has this problem to, but has more materials that are reusable. Therefore the concept with wind and solar will score lower than the concept with purely solar power
2. *Energy storage:* So buying a new battery pack is worse than buying one that is already build. The expectancy is that both the new and the old system will not deliver enough to re-use after decommission of the platform. Therefore concept one scores two, concept two scores three and concept three scores 4.
3. *Buoyancy:* The hull shape is not applicable for this requirement. Thus a score of one for each concept.
4. *Station keeping:* just as the bouyancy, this is not applicable. Thus a score of one for each concept.
5. *Waste water treatment:* As this is mostly about where the water is
6. *Materials:* Aluminium is a recyclable material, but it is hard to recycle. Therefore, all concepts will get the same score of three.
7. *Mobility:* A towed system is more circular than an installed system. Outboard engines generally do not have any reusable parts after twenty years and depending on the maintanence that they have gotten, are not that great to use any more. Therefore the towed concept (1) gets a score of 3, and the other two concepts get a score of 4.

8. *Water generation:* A system where water re-usage is in place would not have to use less osmosis filters and is therefore, over it's lifetime, more circular than the other concepts. So a score of two for concept one and a score of three for concepts two and three.
9. *Water storage:* every concept is the same, because a tank is a tank (regardless of his size). Therefore a score of one for every system.

Costs

1. *Energy generation:* The cost for each of the systems is somewhat similar, therefore all concepts score 1.
2. *Energy storage:* The costs of a new battery pack is higher than that of an old system. Thefore concept one gets a score of three, concept two a score of two and concept three a score of 4
3. *Buoyancy:* As the expentency here is that a trimaran will cost more in the sense of materials, the score of concept two is higher than that of concept one and three.
4. *Station keeping:* the costs of the mooring system is the same for every concept. Therefore the score here is two for each.
5. *Waste water treatment:* The system with just a black water tank is cheaper then a grey and black water tank due to the filtration system that is needed. Therefore concept one and three get a score of 3, but concept two will get a score of two
6. *Materials:* aluminium is a very expensive material. However, each of the concepts uses aluminium. Therefore all concepts will get a score of 4.
7. *Mobility:* So, this is a hard one. The costs for a propulsion system (tanks, engines and fuel) are high, but peak at the build of the system. However, a towed concept that has to be towed twice a day will be even more expensive, assuming that one would have to pay the 'tower'. Therefore concept two and three wil get a score of two and concept one wil get a score of three.
8. *Water generation:* The systems build for water re-use are very expensive. Therefore this concept will lose, the internal (so on the platform) reverse osmosis system will be expensive as well, therefore this concept get's a score of two. For now, water is cheap on bonaire, so a concept that (in this case concept 3) uses this principle will get the highest score.
9. *Water storage:* A smaller water tank is in building costs cheaper than a large water tank. Therefore a score of three for concept three and a score of two for the other two concepts will get a score of 3.

Intermittency

1. *Energy generation:* Because the combination of solar and wind is better then pure solar power, the score for concepts one and two are 3, the score for concept two is a two.
2. *Energy storage:* Here concept three wins, as a new battery pack is more reliable then an old one. Therefore the ranking is as follows, concept one: three points, concept two: four points, concept three: two points.
3. *Buoyancy:* The hull shape is not a question of intermittency, therefore the accredited score here is equal to 1
4. *Station keeping:* The way the ship is currently moored is not of influence of the intermittency of either the power or water availability, therefore the score here is one for each of the systems.
5. *Waste water treatment:* a grey and black water system is slightly worse than a black water storage tank. This is because a grey water system requires filters that can break down and only allow a certain amount of flow. Therefore the score for concept one and three are 1, but concept two gets a 2.
6. *Materials:* Materials are also not important when it comes to intermittency, therefore this is also not part of the discussion. All concepts get a score of 1
7. *Mobility:* The towed concept (concept one) will score lower here. This is due to the fact that a self propelled ship can leave and sail to anywhere at any moment. Therefore concept one will get a score of 3, whilst the others will get a score of 2.

8. *Water generation:* Assuming the fresh water tank on board is big enough to provide for each and every person on the platform, a process in which water is produced externally has the best intermittency score, as there will always be water. The system having reverse osmosis and water re-usage finds a small back up in the other system if one of the systems fail. So the score here is: three points for concept one, four points for concept two, two points for concept 3.
9. *Water storage:* So, as the tank size is already taking into account in the previous statement, this requirement will not be scored. Each concept gets the same score of 1

F Resistance components

Bare Hull Resistance

The bare hull resistance is calculated using Equation 4.5:

$$R_{BH} = R_v = 1/2 * \rho_w * V^2 * S * C_T + 1/2 * \rho_w * V^2 * A * C_D$$

Where S and A can be calculated using RHINO, C_D and C_T can be estimated, resulting in:

- $S = 86\ m^2$
- $A = 3.22\ m^2$
- $C_T = 0.0004$
- $C_D = 0.7$

Which would finally lead to a resistance of:

$$R_{BH} = 1.507 * V_{water}^2 \tag{F.1}$$

This V_{water} can either be the current that the ship experiences, or the sum of the current and the ship speed.

Wind Resistance

The second factor is the wind resistance as defined in Equation 4.3

$$R_{AA} = 0.5 * \rho_A * V_R^2 * A_V * C_{AA}$$

Where ρ_A and C_{AA} have been previously defined. Without taking the sketch of the final product, the worse case scenario would be that wind would not be able to blow throug the superstructure. The maximum size of this superstructure is equal to 10X2.4X2 (BXH where H is for two stories, assuming the wind comes from the front). This is equal to an area of about 48 m^2, which in it's turn results in a R_{AA} of:

$$R_{AA} = 0.0294 * V_{wind}^2 \tag{F.2}$$

This wind speed can either be the true wind speed when the platform is lying still, or the total wind speed when the platform is sailing.

G

Calculation of the metacentric height

The metacentric height gives an idea of the righting moment of the ship, thus the force available to restore the ship to it's original position if weights shift on board. This is done with the following equation:

$$GM = KG - KM \tag{G.1}$$

Where:

- KG is the distance between keel and center of gravity. This has to be estimated.
- KM is the distance betweel keel and metacentre, this point is calculated as:

$$KM = KB + BM \tag{G.2}$$

where:

- KB is the centre of bouyancy, which is equal to the centre of the volume. RHINO is used to calculate this center.
- BM is the distance from the centre of bouyancy to the metacentre, the equation to calculate this point is:

$$BM = \frac{I}{V} \tag{G.3}$$

where:

- I is the area moment around an axis (a mathematical term to express the amount of force needed to turn something around an axis). This can be estimated, or taken from the design in RHINO.
- V is the volume of the under water ship, which is already calculated and equal to 34 m^3

Combining Equation G.1 till Equation G.3, gives the following expression:

$$GM = KG - (KB + \frac{I_{xx}}{V}) \tag{G.4}$$

Where:

- KG is estimated to be around 3.5 meters. This means that the centre of gravity lies around the ceiling of the 'ground floor'. One can change this number to whatever one finds feasible, the effect is namely 1:1 on the total stability.
- KB is calculated by RHINO and equal to 0.85 meters
- I_{xx} is calculated by RHINO and is equal to 519 m^4
- V is calculated in section 5.2 and equal to 34 m^3

H

Energy and Water Systems

Energy System

The entire energy system is based on a 'standard' planning as provided by the clients. This planning can be found in Table H.1.

Table H.1: Dayplanning

08:30 - 08:50	09:00	09:30	10:00-12:00	12:00-15:00	15:00-16:00	16:00-20:00	20:00
50 persons on board, having drinks and music	leaving port	arriving on location	e-foiling (6 efoils)	Lunch is prepared and served	Charging of the e-foils	Efoiling with music, kitchen snacks, deepfrying and drinks	boat sails back to port

To start, the sport facilities have a power consumption that originates from the charging of the e-foil batteries. The e-foil batteries have a capacity of 2.1 kWh and assuming that a battery takes 2 hours to charge, the power consumption is 1.05 kW. These e-foils will be used twice a day so must be charged during midday. As a back-up the advice is to purchase a second set of batteries for the e-foils, so for the 6 e-foils there should be 12 batteries so that when 6 are in use, the other 6 can charge. So the battery capacity is 12*2.1 = 25.2 kWh.
The method of charging will be to charge one set at the start of the day and use the other pair that will be filled up from the day before. When the first set is depleted and the second set is fully charged, the batteries should be switched around to charge the empty ones. This translates to one charging action in the morning, and one in the afternoon. Secondly, the housekeeping facilities are analyzed and the kitchen will be opened from lunch until dinner while serving snacks in between. For lunch, not all kitchen utilities will be used and it can be assumed that the oven and induction cooker are unused as the assumption is made that a cold lunch will be served in the form of sandwiches. For the snacks until dinner; from 16:00 to 20:00; it can be assumed that all kitchen utilities will be in use. This will be conservative as the utilities won't be in use the whole time.

Furthermore during the afternoon there will be music and the lights will be turned on. This means that a DJ booth, speakers and deck lighting must be powered. There are some constant power consumers, namely; the fridge, freezer, emergency lights, top light and anchor light. Thirdly the Reverse Osmosis system is modelled into the system. The power consumption of the pump that drives the system is 5.5 kW and is operational for 10 hours. These energy consumptions are added up per hour and plotted in the same graph as the solar power generation. Furthermore the battery load can be estimated by taking the difference in energy production and demand.

From the Battery Load diagram the over- and underproduction can be determined. The idea is that the overproduction can be captured in batteries and used when the solar panels are producing less than demanded. The overproduction is 70.8 kWh and underproduction is 70.1 kWh.
For this case a car battery is assumed to be a 100 Ah, 12V battery which translates to 1.2 kWh. As stated before, old car batteries usually have 70-80% of their original capacity due to damage over its lifetime. Assuming the worst case scenario of 70% capacity, a capacity of 0.84kWh is taken per old car battery. This would equate to 80 old car batteries having to be used to store all overproduction in a day. Each battery is assumed to have the following dimensions: (LxWxH) = 0.3 x 0.18 x 0.19 m and a weight of 10 kg. Totalling out to a volume of 0.82 m^3 and weight of 800 kg. It would be best not to stack

these batteries in a small space as the temperature can become quite high and maintenance must be done. One proposal would be to make 6 beds of 2x7 batteries and spread these beds out over the hulls as to also distribute the weight.

The alternative electricity storage method to using old car batteries is a new battery pack. Such a new battery pack can be compared with a very common battery pack used in electric vehicles. The Tesla Model S has a battery pack with a capacity of 100 kWh, which according to the battery load diagram is enough to fill in the gaps when energy is required. Utilizing one of these batterypacks would give enough storage capacity. The dimensions for one of these batterypacks is as follows: (LxWxH) = 1.85 x 0.29 x 0.09 m which equates to 0.0486 m^3 and a weight of 550 kg.

Water System

This section in the appendix contains a more in depth analysis of the water demand, usage and storage by means of calculations and assumptions. The conclusions are used in section 5.5

H.0.1. Water demand on a daily basis

Assumptions must be made to give an estimate on the water usage onboard the platform. According to the planning from the client there will be a total of 150 people visiting the platform. All these people will need to take a shower or rinse themselves, drink clean water and use the lavatory. The assumed values are 50 L for a shower assuming 9 L per minute and a shower of roughly 5 minutes, 2L for drinking and 3 L for flushing. This results in 55 L water consumed per person, per day. When comparing this with the planning, 50 people will board in the morning and 100 in the afternoon. The morning demand is 2.75 m^3 and afternoon demand is 5.5 m^3, totalling to 8.25 m^3.
There is also another water demand, for rinsing the watersport equipment. Per piece of equipment, 10 L of water is needed. When counting the equipment, there are 6 pieces each of e-foils, sups and wing boards. This equates to 180 L water for rinsing. For the overall cleaning of the platform 100 L of water is needed. This equates to a total 280 L and 0.28 m^3.
In total there is a daily water demand of 8.53 m^3. To be conservative however, this daily water demand will be rounded off to 9 m^3. Since there are two shifts of people onboard, and the morning being half the size of the afternoon shift, the morning demand is assumed as 3 m^3 and afternoon demand as 6 m^3.

H.0.2. Water production and storage

To supply this daily water production, the water demand will be supplied by a Reverse Osmosis (RO) system that has a production capacity of 24 m^3 per day, so 1 m^3 per hour (*RO Oceanus* | *Hatenboer-Water*). The energy demand for the Oceanus system from Hatenboer Water is 5.5 kW to produce 1 m^3 per hour this translates into an energy consumption of 55 kWh. A more detailed analysis
Since the energy potential is highest during midday, that is also when most water production will occur. The RO system will constantly be on from 9:00 till 18:00. Running for 10 hours on a day which is estimated to produce 10 m^3 of water. In the afternoon 6 m^3 is needed and only 3 m^3 will be produced, this leads to a minimum water storage of 3 m^3 to keep up with the water demand.

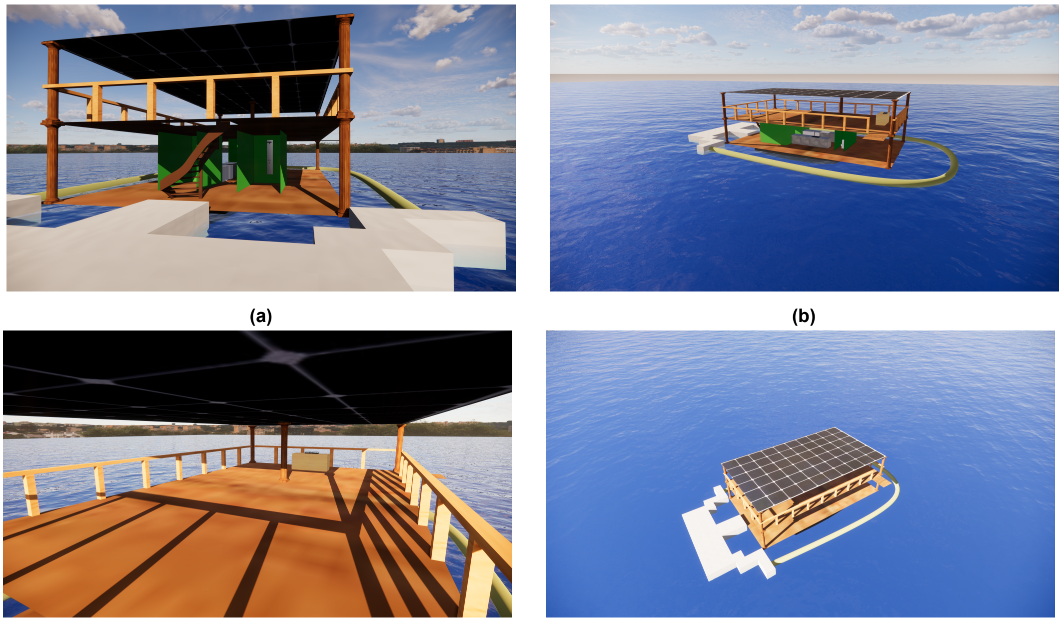
H.0.3. Wastewater

Another important aspect to take into account is the wastewater being produced on the platform. For this concept an important assumption is made, namely that the shower is only used for rinsing. This entails that there are no soap or shampoo is allowed in the shower. The wastewater coming from the showers is then directly dumped into the water, avoiding the use of the blackwater tank.
One flow of wastewater that is captured in the blackwater tank is the water originating from the toilets. Assuming 3 L water per flush of clean water and 3.5 L of wastewater per flush going into the blackwater tank, if 150 flushes are made then 525 L of wastewater is produced per day. This equates to 0.525 m^3

of water and will be stored in a blackwater tank of 1 m^3. This tank can be emptied at the end of every day when going back to port.

hat has a pump with a power of 5.5 kW running for 10 hours which equates to an energy consumption of 55 kWh. This water is produced during times when the solar potential is the highest, in the afternoon. A later detailed analysis on energy management can be found in .

Renders of the final design



(a) (b) (c) (d)