MOBULA

Sustainable Sargassum Removal

Bachelor's of Industrial Design Thesis Report

by

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Sustainable Sargassum Removal

by

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Abstract

The accumulation of sargassum on the Mexican Caribbean coastlines has been a problem since 2011. The increase in the population of sargassum is due to human intervention, such as the use of fertilizers, deforestation, and chemical runoffs from other countries in the Atlantic Ocean, which creates a nutrient-rich environment for sargassum growth. The accumulation of sargassum creates problems for the ecosystem and the tourism industry. Hotels lose revenue as the decaying sargassum releases organic matter and a sulfuric smell, causing headaches and nausea among tourists. Efforts to remove sargassum have been insufficient, and improper disposal of the algae risks polluting underground water sources. In addition, sargassum workers are constantly exposed to harmful chemicals and harsh environments. Sargassum, however, has the potential to be used in different consumer products, offering a solution to repurpose the algae and create a sustainable alternative. Mobula offers to gather vast amounts of sargassum from the open sea and ferry it to a land-based plant facility through autonomous means for the purpose of converting it into biofuel. This turns a problem into an opportunity for a green initiative in the local region.

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Firstly, I would like to express my sincere gratitude to my **mother and father**, who have been my pillars of strength and unwavering support throughout my life. Their constant encouragement, guidance, and belief in my abilities have been instrumental in shaping my personality and helping me achieve my goals. I am forever grateful for their sacrifices.

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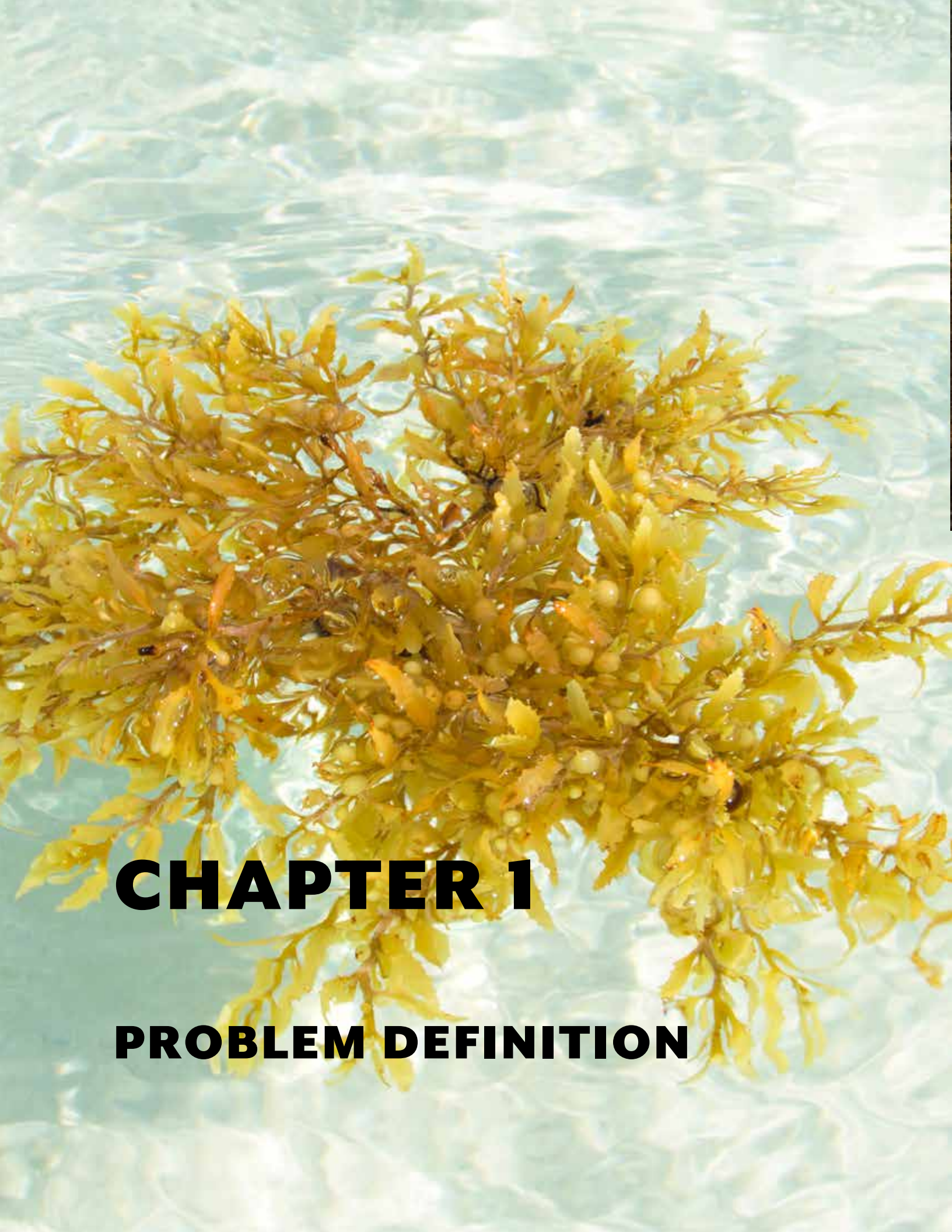


CHAPTER 1

PROBLEM DEFINITION

Figure 1 - A boat floats on the water, surrounded by sargassum, a seaweed-like algae, in Bahia La Media Luna, near Akumal, Mexico, on Aug. 5, 2018. With more algae spotted floating out at sea, experts fear that 2022 could be as bad or worse than the catastrophic year of 2018, the biggest sargassum wave to date. (Eduardo Verdugo / Associated Press)
https://www.cp24.com/world/mexico-caribbean-beaches-may-see-worst-sargassum-since-2018-1.5883226

1.1 Problem Definition

Sargassum has been accumulating on the Mexican Caribbean coastlines. Sargassum has had an increase in its population due to fertilizers, deforestation, chemical runoffs, etc. from other countries of the Atlantic ocean. This chemical pollution has created a nutrient-rich environment for the sargassum to grow. Sargassum carries heavy metals polluting the ecosystem if it is found in large quantities. Hotels in Mexico have lost revenue due to this accumulation because as sargassum decays if releases organic matter into the ocean as well as a sulfuric smell. This smell causes head-aches and nausea, so tourists frequent the caribbean hotels less than before. Mexico has had efforts in removing the sargassum but so far the temporary solution is to place a barrier 50 to 60 meters off shores to collect the sargassum on the water before it reaches the sand. Unfortunately, there is a quantity of the sargassum that is disposed improperly in limestone aquifers, or unoccupied beach areas. This creates a problem because the heavy metals, especifically Arsenic, can infiltrate the underground water and pollute the fresh water of the region.

1.2 Rational and Significance

The purpose of this part of the research plan and advisor contact is to identify key elements and components to set a clear direction for this thesis project. Outlining the elements and important research points is an effective tool to analyze and organize the information so it can be reflected in the concept development and the final solution. Through the help of research articles, interviews/surveys, and advisor meetings, it can lead the project in a proper trajectory.

1.2.1 Research Plan

The research elements of this project are problem finding, problem specification, research into different current solutions, user interaction, and sustainability aspects. The problem with sargassum is how its been affecting the coastlines of different parts of the world. This project, will be focused on the Mexican Caribbean coastlines. Sargassum has impacted marine life, the ecosystem, and the tourism industry. The problem with sargassum is that its been accumulated on the shorelines faster than its being removed. The other problem is that it's not being disposed of properly in some areas which only prolongs the ecological issues. Different ideas have been taken to remove the sargassum from the coastlines; however, there isn't enough support. When developing a solution for the sargassum it needs to have a focus on human interaction because it will be workers who will be using the final product. Since this is also an environmental problem, it needs to have a sustainable approach to the final design. That means the materials and manufacturing processes need to be environmentally friendly. There are different way to find the resources needed for this project. Most are academic articles and research papers that have information about the impact of sargassum, it challenges, and its opportunities. These articles can be found online with a school affiliation, in this case its Humber library. Contact researchers who have experience with the topic and conduct an interview, this can provide more insight on the problem firsthand. There is also Google Schoolar, an academic research database with an extended list of articles. Lastly, there is ResearchGate, a website for researchers to published their work and stay connected to one another. The plan is to read these articles that explore the problems with sargassum, what is being done about it, and its potential for its consumer products. To collect the information in an

efficient way is to read the introduction, the discussion and the conclusion. Highlight and take notes on the specific information, and analyze it. When interviewing candidates who have experience with sargassum, Taking notes and voice recording it's an efficient way to analyze the information later.

1.3 Background / History /Social Context

Sargassum has been affecting the local ecosystem and the tourism of the Mexican Caribbean coastlines since 2011. Over the years sargassum influx has been increasing due to human intervention to the environment. Due to this increase, sargassum has been collecting in large quantities on the coastlines of Mexico. Sargassum carries harmful compounds and when it decays it affects the marine life. This is an important issue to solve because sargassum is not going away so there needs to be a resilient solution to this problem. Sargassum is a macro-algae that has potential to be used as ingredients to consumer products. This can solve the issue on how to re-direct it away from the coastlines and into pre-treatment options. This option can give local business owners, who are interested in environmental-friendly products, a chance to repurpose the sargassum and turn a problem into an opportunity. Hotel owners can also use this solution to have cleaner beaches for their customers. Private companies, and government entities can also use this solution to promote environmental awareness. Sargassum is known to absorb micro-pollutants and heavy metals in its cycle through the Atlantic ocean which is why it's important to focus on the proper disposal or pre-treatment of the sargassum to make it safe for consumer products and the environment. This concept design should be big enough to collect large quantities of sargassum for pre-treatment. Since the design involves the physical labor of the user in a warm climate, it should have an full body ergonomics study to make the design as comfortable as possible for the user. Depending on the final size, it will define which areas of the body will be used mostly when operating the final product. This solution is focusing on an issue that impacts marine life and enviromental pollution. Subsequently, it will have an environmental-friendly approach to the use of energy, carbon footprint, materials, and manufactoring methods. In addition, this keeps in mind the social aspects because its main goal is to improve on the human life-style and supporting local businesses with a focus on enviromental consumer products. In the long run, this should also promote environmental awareness.

20 million metric tons of sargassum influx was reported to extend 8,850 km in length across the Atlantic Ocean and the whole Caribbean sea. The accumulation of organic matter from decaying algal masses depleted the oxygen in near-shore waters and blocked sunlight causing seagrasses and fauna mortality. This has also interfered with juvenile turtles from reaching the water and affecting their nesting. (Rodriguez-Martinez et al., 2020)

Sargassum that has been removed but not disposed of properly runs the risk of leakage into the aquifer in Mexico. Cleaning efforts have not been sufficient enough to cover and remove thousands of tons of sargassum that have accumulated on the Mexican Caribbean coast. Sargassum is known to be used in different commercial end products like fertilizer, textiles, paper, pharmaceuticals, and biogas. Lately, there has been an increase in the use of animal and human food. This means that if there are high concentrations of contaminants and heavy metals, it can pose potential health risks. (Rodriguez-Martinez et al., 2020)

There is a high variability of element concentration of As, Cu, and Mn on the Mexican Caribbean coast, and less of Cd, Cr, Pb, and Zn compared to sargassum found in Nigeria, Ghana, and the Dominican Republic. This is mostly due to the absence of major industrial mining, or heavy agricultural activities in the region. Heavy metal detected in the sargassum is likely acquired before entering the Mexican coastal waters, meaning that it would have been exposed to those metals and contaminants during its trajectory in the ocean. Sargassum captures these elements and contaminants through complex mechanisms of ion exchange, chelation, adsorption, ion entrapment in polysaccharide networks of the algae, and pH of the seawater. In addition, Sargassum also contains macro-elements and micro-elements for plants. These make proper complementary fertilizers as they enhance the growth, seed germination, and photosynthesis of crop plants on mineral-depleted soils. However, some micro-elements and micronutrients in low concentrations but are toxic in high concentrations such as As. (Rodriguez-Martinez et al., 2020)

Currently, Sargassum that reaches Mexican coastlines is removed and deposited in limestone quarries without proper treatment. The Yucatan Peninsula has a highly porous Karst aquifer that provides fresh

water to the region, the pollutants can easily infiltrate causing an accumulation of toxic elements. These can infiltrate underground rivers and reach the marine environment. Urgent measures of prevention and mitigation are needed to avoid harm to the coastal ecosystem and tourism-based economy on the Mexican Caribbean Coast. (Rodriguez-Martinez et al., 2020).

Figure 3 - taken from https://www.theguardian.com/environment/2023/mar/07/great-atlantic-sargassum-belt-seaweed-visible-from-space

CHAPTER 2

RESEARCH

2.1 User Research

Identifying the key personas to who this design is for, aids the design development to provide a user-centred experience in the final product. User research further explores the problem definition and gains insights into the needs, wants, and behaviours of the target audience for a product. This information can then be used to inform the design of the product, ensuring that it meets the needs of the users and enhances their experience with the product.

There are many different methods that can be used to conduct user research, including surveys, interviews, focus groups, and usability testing. By incorporating user research into the product design process, designers can create products that are more effective, user-friendly, and successful. (Nielsen, J., 1994). This provides the opportunity to improve human life. The focused persona in this project surrounds itself with the problem of the sustainable removal of sargassum in the Mexican Caribbean coastlines.

2.1.1 User Profile - Persona

The primary persona for this project is the sargassum clean-up workers. This occupation does not require a high level of education or essential skill. This job requires a lot of physical labour and endurance. Sargassum workers can be part of different organizations or they can be independent contractors. When they work for an organization they normally have a company which focuses on the cleanup and removal of sargassum from the shoreline. In some cases, they have access to customizable boats that remove the sargassum from the water before it reaches the shoreline.

This project takes into account three different levels of persona. Primary , secondary, and tertiary persona allows the design to map the different levels of impact that the product will have. Research by Puttin, and Adlin (2006) found that personas are imaginary people created by data from real people that influence the product design development. When using this data properly designers will:

"Increase your products' usability, utility, and general appeal."

"Streamline your teams' processes and improve your colleagues' abilities to work together."

"Enable your company to make business decisions that help both your company and your customers.:

"Improve your company's bottom line"

In the following table, people are listed to represent their level of impact for thie project:

First Persona	Secondary Persona	Tertiary Persona
• Sargassum Worker • Hotel Staff • Environmental and • Mechanical engineers • Ship Captain	• Tourist • High management hotel staff • Locals • Small business • Aquatic Activites	• Fuel consumers • Marine biologists • Socio-economic researcher • Energy Companies • Government

Table 1 shows the list of personas

Mainly the focus of this research are those who work directly with the sargassum in harsh conditions. This people are sargassum workers or hotel staff. The following demographic statistics table are anecdotal and provides additional information into the target audience:

Demographics		User Behavious		Personality
Averga Age	29 y/o	Frequency of work	Monday to Sat	Outgoing
Age Range	18 to 35 y/o	Hours of work per day	8 to 10 hours per day	Friendly
Gender	98% Male and 2% Female	Affilitation	Independent contractor or work with crew of 15 + people	hard working
Education	Secondary School to High School	Working Conditions	Harsh environment. Little protection.	Self efficient
Income	Low Income	Level of physical demand	High	Flexible
Ethnicity/Culture	Mexican	Location	Mexican Caribbean coastlines	High Endurance

Table 2 shows the user demographic information

A fictional user profile was created to fit the general description of the target audience and demographics. This user profile provides insights into the life of the persona and the behavioural aspect that influences the final design.

Figure 5 retrieved from: https://apnews.com/article/oceans-caribbean-international-news-climate-change-algae-8698c1f257b542e38f3e3decbac784bc

Manuel Hidalgo Chavez

Age: 24-year-old

Gender: Male

Education: Highschool graduate

Ethnicity: Mexican

Location: Lives near the coastlines

Income: Low income

Hours of work per day: 8 to 10 hrs

Days of work per week: Monday to Saturday

Manuel is a sargassum worker that is hired by a company that focuses on cleaning waste and algae from the coastlines of Playa del Carmen, Mexico. Manuel is a highschool gradute who intended to start working to provide for his family and make a living. He has been working as a sargassum worker for the past few years and has become tired of the harsh environment in the workplace. He works along side a crew of people to clean the coastlines. He and his crew wake up very early (around 5 am) to start the days work around 6m.

They plan to work early morning to avoid the exposure from the sunlight and heat in the middle of the day. The sargassum work in addition to the sun and heat can affect their overall performance and physical health. Manuel likes to hang out after work with his friends, and like to spend his time near the shoreline to enjoy the beach.

Motivation:

- Environmental lifestyle
- His family and friends
- Excellent job performance
- Marine life
- Environmental resilience

Goals:

- Gain more money
- Provide for his family
- Increase the interest of tourists in the region
- Improve work efficiency

Barriers:

- Harsh work environment
- Too hot under the sun
- Needs better equipment
- Low pay

Likes:

- Driving a boat
- Local food
- Living near the beach

- Aquatic animals
- Aquatic sport
- Spending time with family and friends

2.1.2 Current User Practice

Based on user interviews, data was accumulated to describe the current methods of removing and disposing sargassusm. Currently, there are different methods and proposals to target the problem with sargassum, however, most of them are private solutions, or lack financial investment to mass produce them. (Zdenek, 2022). On-land and on-water sargassum collection are two main ways of collecting sargassum. However, they both dispose of it similarly, depending on the company and locations. In some cases the dumping sites are unused, unofficial land far or close from urban areas. There has been efforts in converting the sargassum into energy and biofuel; however, there is not know initiatives that are currently undertaking the repurposing of sargassum into energy in Mexico. There lack a financial investment from companies and the government to introduce this new opportunities. Meanwhile, sargassum keep on piling up in massive quantities every year affecting the marine flora and fauna, and tourist frequent the beaches less often. Hotels spend have spent their finances into sargassum workers to clean up the beaches; however, these workers are taking a heavy-duty work load. Sargassum reaches the shore line wet, and this increases the overall weight. Efforts in workers to cover 600+ km of shore line is too much on the human body, and sargassum keeps on piling up every day. The physical labour that it currently takes has no positive outcome in the user experience.

During an interview, a sasrgassum worker was asked about the challenges of cleaning up sargassum and the following is the result:

"What are the challenges and struggles of removing the sargassum and disposing of it? One of the challenges of removing sargassum is the headaches and physical stress with the heat. It's a pain having to pick up the sargassum and place it in bags to be carried again to the disposal site. It involves a lot of bending over and carrying in multiple times a day. Most of the pain is in the lower back, arms, and legs. The challenge is also that everything is done under

the sun, mixed up with the smell, and the seasickness. It gives a lot of headaches and unpleasantness. Disposing of it is a tricky temporal solution because we are moving the problem somewhere else The disposal site is being harmed by the sargassum and is contaminated by it as well.“

This highlights the major problems with the current removal and disposing methods. Efforts in reducing the level of physical stress and environmental damage is necessary.

2.1.3 User Observation - Activity Mapping

The sargassum worker go through a series of steps in order to collect the sargassum and dispose of it. Sargassum worker who focus their efforts in cleaning up the coastlines on-land go through the following steps:

- They first get to the shorelines where the sargassum has been piling up. They usually cover the area that they were hired for.
- They use a method of collecting and transporting the sargassum. This means that they come with a crew of 3 or more depending on their affiliation and they bring a tipper truck.
- Some of the tool they user are spading fork or shovel and a wheelbarrow. This tools are easy to carry and transport from place to place.
- They come to the job site early morning to avoid the sun and heat later throughout the day.
- They start digging out the sargassum from the piles onto the wheelbarrows. Once the wheelbarrows are full, they push to get to get to the tipping truck to empty the wheelbarrow.
- They come back to teh sargassum piles and remove and transport again to teh tipping truck.
- Once they are done for the day they transport the sargassu using the tipping truck to a designated spot that is not an official dumping site, and they empty the truck there.

There are several problems with this method. When repeatedly removing the sargassum using a spading fork or shovel they constantly are in uncomfortable positions with their back, arms, and legs. This

can have an impact on their overall health. The rate of removal is minimal compared to the rate of accumulation of sargassum. This means that sargassum piles up again the next morning so efforts in removing the sargassum is not showing improvement on the problem. (Nidra, 2022).

Sargassum worker who focus their efforts in cleaning up the coastlines on-water go through the following steps:

- They get to the dock where the boat is stationed. They do a visual check to make sure there isn't any problems.
- They make sure they have all the equipment they would need, as well as essential such as food and water depending on how long they will be travelling.
- They start the engine and head out to where the big patches pf sargassum are on the ocean.
- Depending on the boat size and efficiency they may stay near the shoreline or travel further.
- When they are closed to the sargassum they beggin to start the mechanism of removal. This could be a net, conveyor belt, or water pump.
- Once they collect the sargasusum they pack it in container or net bags to be transported back to the shoreline. From there a truck with transport it on-land to a designated dumping site.

This seems to be a more efficient method given that the sargassum has not been decaying while it was still on the water. The worker is less exhausted because the collecting method is more automatic and efficient. However, the workers are still prone to the environmental challenges and seasickness. (Nidra, 2022)

From the previous information a user experience map was created. This map highlights the key point of the activities and provide ideas and opportunities.

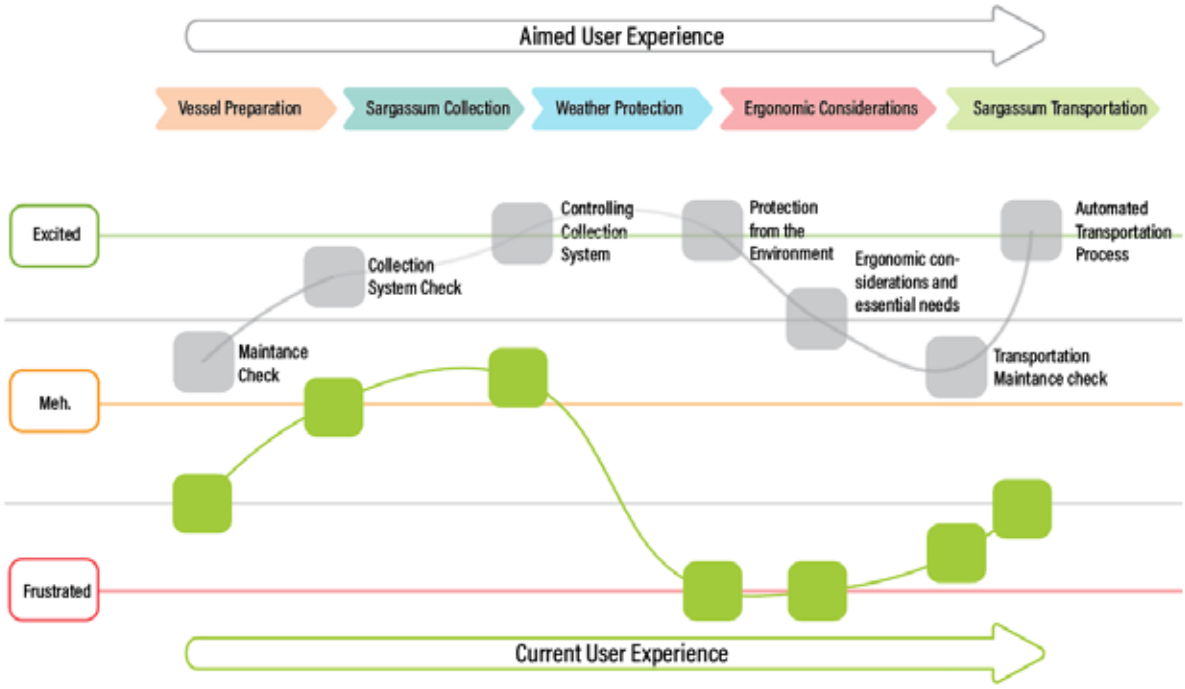


Figure 6 shows the user experience of current methods of collection and the aimed user experience.

Based on research and user surveys the pain point, ideas and takeaways are listed in the following table:

Pain Points	Ideas and Takeaways
• Hot weather. • Standing up • Sea Sick • Waiting • Hungry • bathroom needs • Watching over the machine • Boat to big to be close to the barrier • Can't pick up 100% everything • Multiple bags to tie • So much volume to work with • Too Heavy • Needs multiple people to carry • Big bags mean less space	• Cooling aid for workers • Retractable chairs • Medication • portable washroom • entertainment • food containers • Detection software • Automation Process • Narrower side belt to collect in tight spaces • Automation Tying process • Add more space

Table 3 shows the list of pain point and the list of ideas and take aways of sargassum worker on-water.

2.1.4 User Observation - Human Factors of Existing Products

Ergonomics focuses on the comfort usability of a product for humans. In their book, "The Measure of Man and Woman: Human Factors in Design", Tilley and Dreyfuss discusses the principles of ergonomics and how they can be applied in the design of products and environments to meet the needs of all users, including men and women. They discuss discusses the importance of including physical and psychological characteristics such as size, strength, perception, and cognitive abilities. It also covers topics such as anthropometry (the study of human body dimensions and proportions), design for different age groups, and the role of diversity in design. This is an important part of designing with the user in mind.

While there is insufficient data on ergonomics studies on sargassum workers, there is initiative who are working on developing feasible option in removing sargassum. The company SOS Carbon is an extension of theMechanical Engineering department at the Massachusetts Institute of Technology (MIT). This organization is responsable in developing a low-cost, low-impact solution for sargassum collection, the Littoral Collection Module (LCM). This solution can be mounted on omst small boats through an installation process. (Gray et al., 2021)

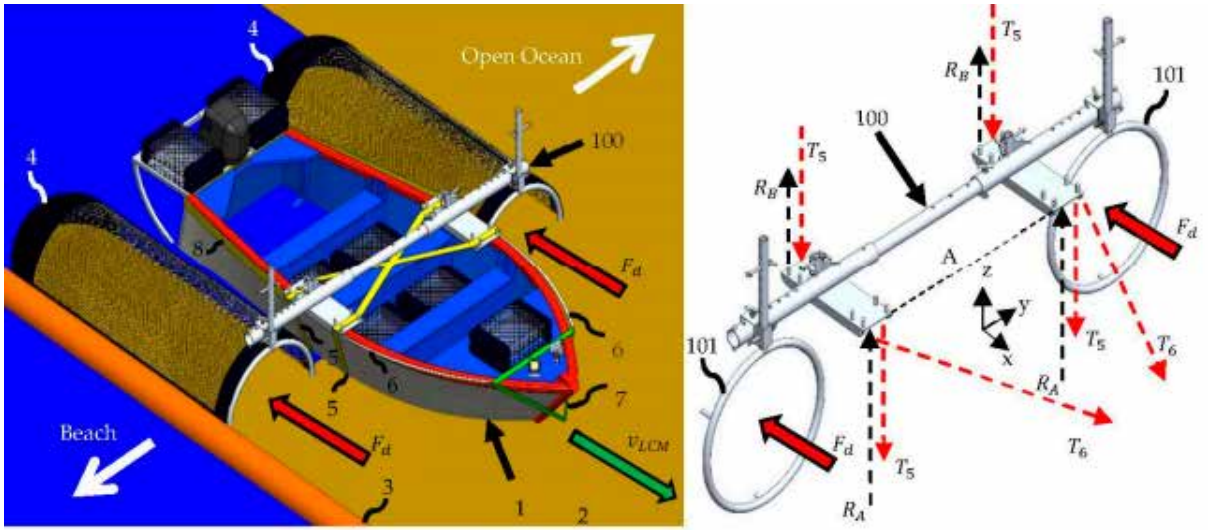


Figure 7 shows the usability of the LCM device for sargassum collection. This was retrieved from Caribbean-wide, negative emissions solution to Sargassum spp.. low-cost collection device and Sustainable Disposal Method. Phycology, 1(1), 49–75. https://doi.org/10.3390/phycology1010004

In their article about the development of LCM, Gray et al, (2021) demonstrate the research behaind their solution as well statistical analysis of the problem, the materials, the cost production, and the engineering aspect. In their listed benefits they mentioned "WORKER-FRIENDLY—LCMs eliminate occupational hazards related to manual shoveling of Sargassum amidst toxic fumes. LCMs are engineered for maximum operator safety". Their design solution allows for safe handling and installation of their device. While there is not an explored ergonomics research throughout the article, it's important to mentioned the capabilities for a user-centered aspect in their final solution. From an observational point of view, the rings to which the net is attached are extended outwards form the edge of the boat. Further research would have to justify the ergonomics aspect of their design. Overall, their solution seems to favor an environmental-centered design in

which the main focus is about the effectiveness of the device, and its environmental impact.

2.1.5 User observation - Health and safety of Existing Products.

2.1.5.1 Health and Safety (Manual Labour)

As mentioned throughout the research there are two categories of sargassum removal; on-land removal, and on-water removal. On-land removal is a physical demanding task because the manual labor can often lead to musculoskeletal injuries, particularly in the lower back and upper extremities. Several studies have examined the prevalence and risk factors for these injuries, as well as interventions that can reduce the risk.

For example, a study by Scott et al. (2009) analyzed data from the National Electronic Injury Surveillance System to examine the prevalence of shoveling-related injuries treated in US emergency departments. The study found that shoveling was associated with a high number of musculoskeletal injuries, particularly to the lower back, and that these injuries were more common in older adults. Similarly, Macdonald et al. (2004) studied the ergonomic risk factors for low back pain among manual wheelbarrow operators. The study found that the use of a manual wheelbarrow was associated with an increased risk of low back pain, particularly when the load was heavy or the work was performed for long periods of time. However, Macdonald et al. (2004) also found that the use of a powered wheelbarrow was effective in reducing the risk of low back pain and improving the overall comfort and efficiency of the work.

While on-water sargassum removal involves automatic process, in some cases it can lead to musculoskeletal injuries as well. It depends on the taks require by the crew and their clean up condicions. Kim et al. (2018) examined the ergonomic risk factors for musculoskeletal disorders among workers engaged in marine debris removal. The study found that these workers were at high risk for musculoskeletal disorders, particularly in the upper extremities and lower back, due to the repetitive and physically demanding nature of the work. Kim et al. (2018) also tested the effectiveness of various ergonomic interventions, including the use of lifting

aids and rotational tasks, in reducing the risk of musculoskeletal disorders among these workers. The study found that the use of these interventions was effective in reducing the risk of musculoskeletal disorders and improving the overall comfort and efficiency of the work.

Overall, these studies highlight the importance of ergonomics in reducing the risk of musculoskeletal injuries in manual labor. By implementing appropriate interventions and considering the physical demands of the work, it is possible to reduce the risk of injury and improve the overall comfort and efficiency of the work.

2.1.5.2 Health and Safety (Benchmarking)

Figure 8 shows the SWS75 sargassum collector boat from the Techno Products Gab company. This picture was retrieved from: https://www.tecnogab.com.mx/sws75

Techno Products Gab is a Mexican company that focuses on designing and manufacture of maintenance equipment in different sectors. On of their production lines focuses on the litter and sargassum remov-

al. In this production line, SWS56, SWS75, and SWS200 are designed to collect any litter and sargassum from the ocean using conveyor belts technology.

In the following set of pictures, a digital observation research was done for the SWS75 sargassum removal boat:

Figure 9 - Screenshots were taken from a youtube video: https://www.youtube.com/watch?v=3wdkEhylEKc&t=1s

The purpose of this digital observation was to understand the ergonomics application and user-centered design of the SWS75 sargassum collection boat. As shown in these picture, the sargassum workers are exposed to the conditions of the harsh environment. When a sargassum net bag is full, they are require to tie it up and move the bag around to free up the space for the next bag. In these pictures, the pain points and challenges are shown which informs the design for more opportunities and take aways.

While SWS75 boat uses a conveyor belt to remove the sargassum from the ocean. It also requires manual labour from the crew to place the sargassum into net bags, closed them, and move them around. This type of physical activity can lead to musculoskeletal injuries and discomforts.

2.2 Product Research

2.2.1 Benchmarking – Benefits and Features of Existing Products

Determining the benefits and features for that product category was done by benchmarking related products. Promotional media of competitor products was collected and evaluated to determine benefits and features for that product category.

Benefit: Something that produces a good result or is helpful doing a task

Feature: How the product meets a benefit. Mostly found in the technical specifications

Product 1 - SWS75 - Aquatic sweeper or harvester for litter and sargassum.

Benefits	Collection of sargassum or garbage in the sea Later be towed by another boat to the shore Crew capacity of 4 – 5 people	
Features	Method of Collection	Belt conveyor
	Size	Large boat for a crew of 4 to 5 people
	Method of Storage	7 reusable net bags
	Rate of Collection	1 bag / 20 min

Product 2 - Syrennis boats by Beach Trotters

Figure 10 retrived from: https://en.beach-trotters.com/products/cleaning-boats

Benefits	Collect all types of floating waste Cleaning on shallow waters Full of bags, they are easily loaded on the deck	
Features	Method of Collection	Two Robotic arms with rectangular nets
	Size	Personal boat for one person
	Method of Storage	Two net bags
	Rate of Collection	2 bags / 45 min

Product 3 - Ruffito 1 - Manufacturas Industriales DP

Figure 11 retrived from: https://www.acontecerrivieramaya.com/post/presentaci%C3%B3n-del-plan-de-trabajo-de-monitoreo-y-limpieza-de-sargazo-en-aguas-costeras-de-playacar

Benefits	Collecting sargassum in the sea with an 85 percent collection effectiveness High-performance drones that facilitate the location and cleaning of large patches	
Features	Method of Collection	Two belt conveyors
	Size	Extra large boat for a crew of 24 people
	Method of Storage	Metal wire cage-like containers to compact the sargassum into a cube
	Rate of Collection	42 tons of sargassum per hour

Take aways of Benefits of Benchmarked Products

- Collects sargassum
- Disposes of sargassum in containers for easier pick up
- Uses drones and satellites to track sargassum patches out in the ocean
- Ocean clean up repurposes garbage
- Works around 8 to 10 hours per day

Take aways of Features of Benchmarked Products

- Automatic methods of collectio
- Enough space for the sargassum and the crew
- Method of collection is reusable and
- Retains sargassum and garbage and filters out the water
- Rate of collection depends on the speed and the size of the water vessel

2.2.2 Benchmarking – Functionality of Existing Products

Functionality benchmarking was carried out to determine common functionality amongst the product grouping as well as market differentiation.

Characterizing the functionality was carried out using the data set collected for the features, selecting most common features, and comparing two features in an x-y graph.

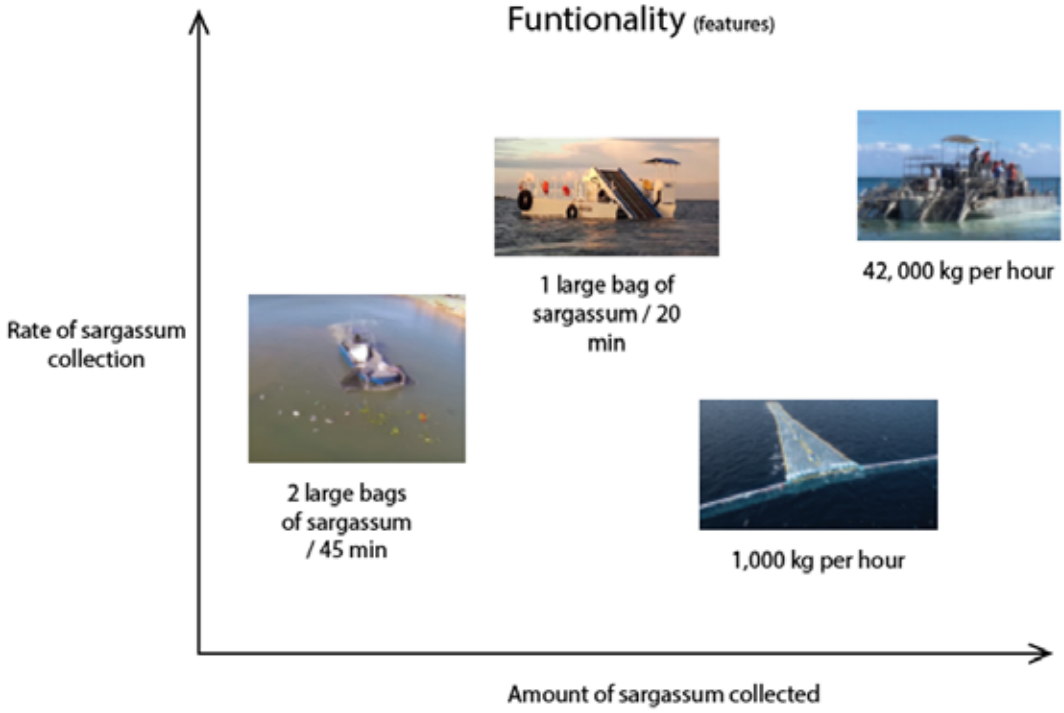


Figure 12 shows the functionality between the benchmarking products.

Take-Aways:

- Bigger doesn't necessarily mean better
- Rate of the collection depends on the accuracy to monitor big patches of sargassum
- Effort to transport the collected sargassum is important as well.

Note: Other criteria can be evaluated, for example:

- Manufacturing cost
- Carbon footprint
- Market price
- Sargassum disposal methods or plans

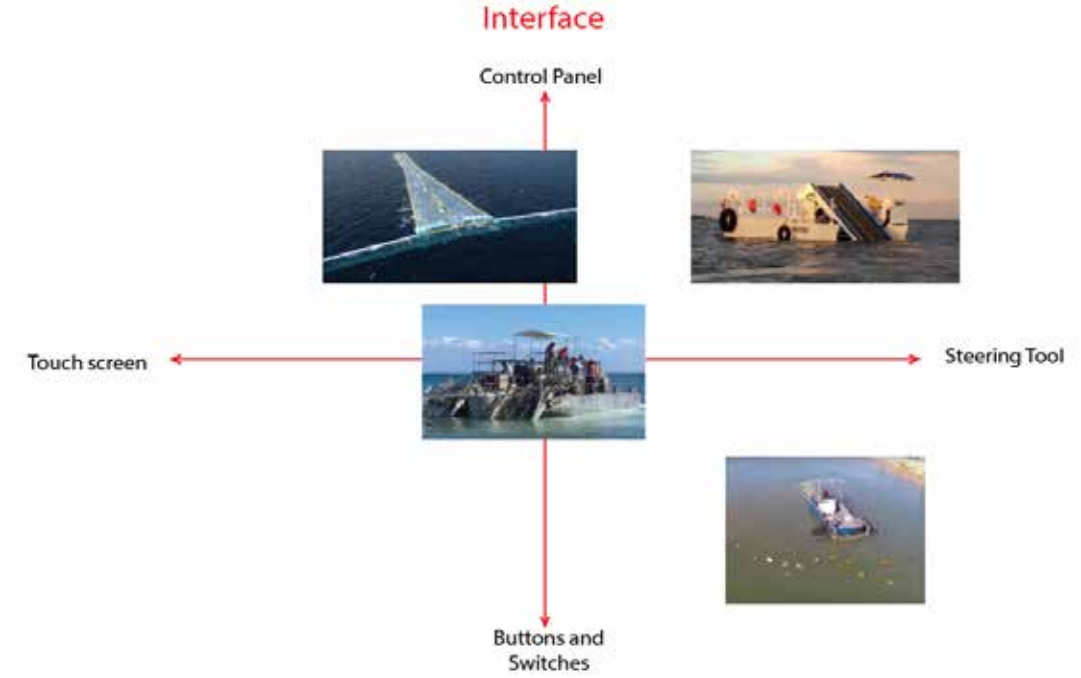


Figure 13 shows the functionality between the benchmarking products.

Design Take-Aways Interface Types:

- Push button, handles, and switches
- Dial
- Light indicators
- Digital touch display

Trends toward:

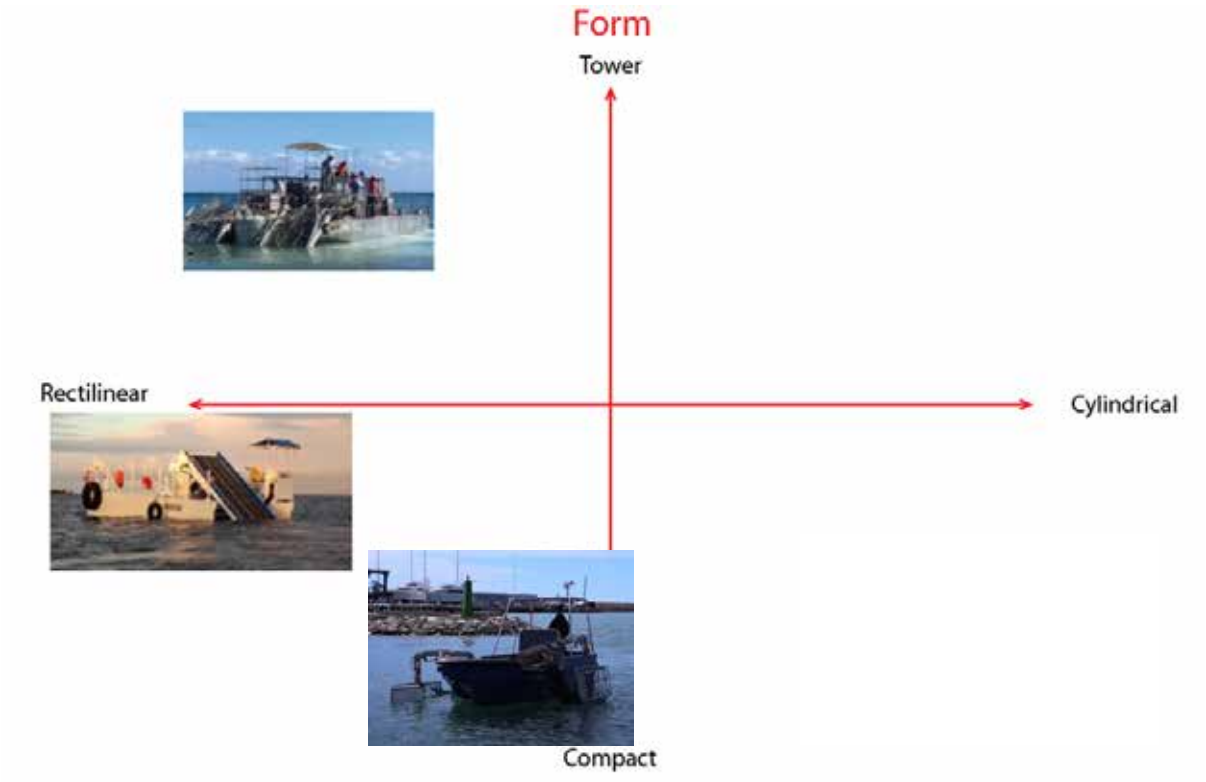
- Pilot mode
- Connectivity (to phone apps and satellites)
- Smart features

2.2.3 Benchmarking – Aesthetics and Semantic Profile of Existing Products

An aesthetic assessment was carried out to determine trends in styling for this product category, and to characterize the specifics of those styling trends.

This was assessed by benchmarking products and applying Elements of Design across products, and then comparing two features in an x-y graph.

Overall Form (categories below reflect type of product selected)			
Shape Geometric Rectilinear, Ellipsoid, Cylindrical etc)	Rectilinear	Cylindrical and rectilinear	Rectilinear and square
Repetition - Arrays of holes -Arrays of lines	Straight lines,	Intersections	Boxes
Pattern	Square grid, diagonal	Parallel lines	Diagonal
Balance (symmetry etc)	Front side	L & R ends balanced	Front and back



Design Take-Aways:

Shape and Size

- Tall and rectangular segment
- Short and cylindrical segment
- Short and rectangular segment

Repetition

- Arrays of parallel lines (metal panels)
- Arrays of diagonal lines (Conveyor)

Pattern

- Square grids
- Diagonal direction

Balance

- Axi-symmetric
- Front side more dominant

2.2.4 Benchmarking – Materials and Manufacturing of Existing Products

Steel

Steel has been a commonly used materials for boatbuilding since the industrial revolution. The mass manufacturing processes allowed for boatbuilding to have a faster production rate. Steel is produced by a combination of iron and carbon among other metals with low concentrations. Usually steel used for the hull construction is "mild steel containing 0.15 to 0.23% carbon, and a reasonably high manganese content." while suplhur and phosphorus are kept at 0.05% or lower. When producing steel panel, and structural supports manufactures perform different heat treatment methods to change the mechanical properties and modify the steel's structure. The following list shows the different heat treatments for steel in the shipbuilding industry:

- Annealing.
- Normalizing.
- Quenching (or hardening).
- Tempering
- Stress relieving

These methods are used depending on the water vessel, its functionality, and stress conditions.

High tensile Steel

For large tankers, container ships and bulk carriers high tensile steel is preferably used in their highly stress regions. This practice can lead to less thickness of various parts of the vessel. However, the nature of high tensile steel is that is susceptible to deflection. Due to the reduction of thickness in the material effects of corrosion may require more careful maintenance.

Stainless steel is not commonly used in the shipbuilding industry because of their "higher initial fabrication costs." However, they can be found in cargo tanks containing corrosion sensitive material. In this case, a corrosion resistant coating with careful maintenance may be applied as well.

Another use of steel is the steel sandwich panels. They have gained popularity because of their lightweight construction method. There are different types of steel sandwich panels with different combination of materials. For example, steel core in form of honeycomb, which are spotted or laser welded to the steel panels, add reinforced strength and lightweight to the material. Proprietary technology of steel sandwich plate system (SPS) developed a core made of elastomer material. This material can tolerate high mechanical stress levels and recovers from deformation. This makes it suitable for marine applications.

Aluminum

Aluminum is another material used in shipbuilding mainly because of its characteristics and lightweight compared to steel. The use of aluminum can save up to 60% of weight from steel structures. In addition, aluminum has a natural high resistance to corrosion and better non-magnetic properties. Unfortunately, because the pure metal has low tensile strength it needs to be alloyed with small percentages form other materials in order to be used in the shipbuilding industry. Moreover, aluminum production has a high initial fabrication costs.

Corrosion

There are different types of corrosions that affects the materials used for shipbuilding. These types of corrosion need to be taken into account when choosing the materials for a ship. Atmospheric corrosion can start during the process of construction of the ship, and can corrode the metal both on-land and off-land. If the humidity is above 70% it can cause critical damage to the material. While the ship is under normal operation the hull is directly in contact with sea water allowing " ideal conditions for the formation of electro chemical corrosion cells." This part of the ship needs constant maintenance.

Corrosion Control

In order to protect the metal from corrosion protective measures need to be applied. There are different methods to protect the metal from corrosion. Cathodic protection are metals submerged in electrolytes

where anodic corrosion reactions are suppressed by the application of an opposing current. The two main methods are sacrificial anode systems and impressed current systems. Protective paint coatings is another method for corrosion protection. There are different types of pigment-dispersed liquid, such as

- Bitumen or pitch
- Oil based
- Oleo-resinous
- Alkyd resin
- Zinc-rich paints
- Chemical-resistant
    - ◊ Epoxy resins
    - ◊ Coal tar/epoxy resin
    - ◊ Chlorinated rubber and isomerized rubber
    - ◊ Polyurethane resins
    - ◊ Vinyl resins

While ships that are oprational are subject to fouling, This means that immersed hull and fittings in the ship can have algae, barnacles, mussels, and other shellfish growth rendering the overall performance to deteriorate. One method of anti-fouling consists of "artificially triggered voltage difference between copper anodes and the integrated steel plate cathodes." Anti-fouling paints consists of "materials toxic to marine vegetable and animal growth. Copper is the best known toxin used in traditional anti-fouling paints." However, once it dissolves in sea water, the protective coating becomes ineffective.

2.2.5 Benchmarking – Sustainability of Existing Products

In recent years there has been an increase in the use of composite materials. The most common has been glass-fiber reinforced polymer (GRP) and fiber reinforced plastics (FRP). This is due to low operating (maintenance) cost, good fatigue resistance, high specific strength, good corrosion resistance, good thermal resistance, and reduced parts count. "The use of composites enables 30–40% reduction in overall weight in

contrast to aluminium or steel, leading to a number of benefits like lower operating costs, higher fuel consumption efficiency and so reduced greenhouse gas emission (Dokos, 2013)." (Frej et al., 2021). It also allows the possibility to design and product complex and organic shapes without compromising the strength of the materials due to the freedom of fiber orientation.

"The matrix plays a critical role in determining off axis strength, damage tolerance, corrosion resistance, and thermal stability." However, the use of resins and synthetic fiber increases the overall carbon foot-print in energy production, and lack of biodegradability properties.

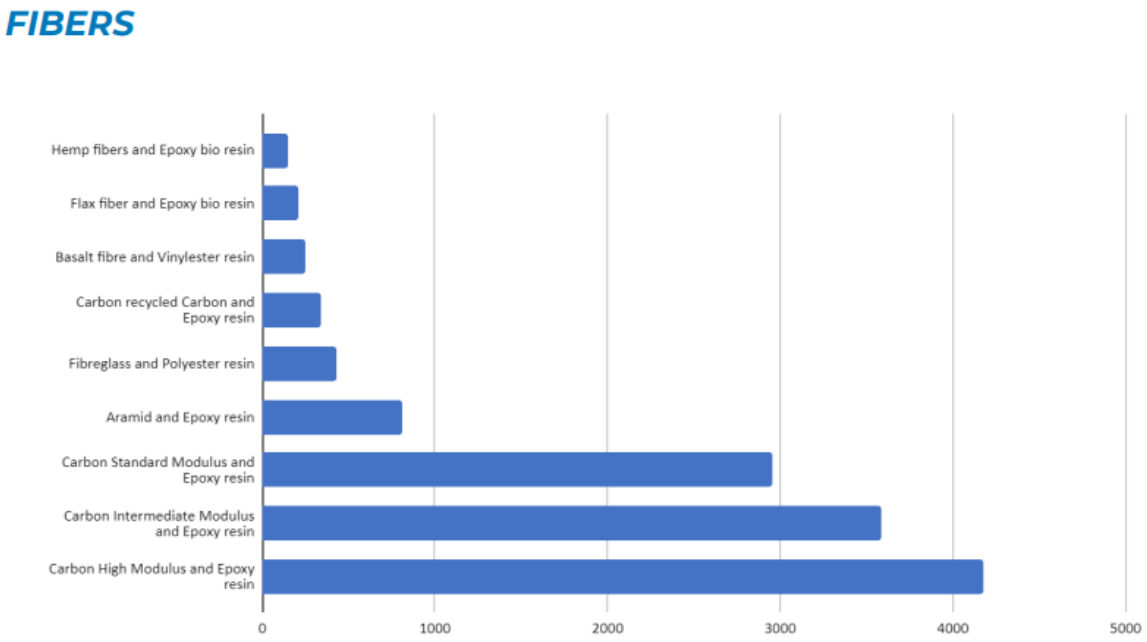


Figure 14 Compares GHG of different fibers. Source: 11TH HOUR RACING TEAM SUSTAINABLE DESIGN AND BUILD REPORT (2021) pg. 60

In the figure above, various fiber were compared to assess the environmental impacts of each one. Natural fiber offers the least environmental damaga comapred to carbon fiber and epoxy resin. Frej et al. (1993) investigated the feasibility of recovered carbon fiber and reinforce the matrix with the reusable thermoplastic Elium composite. There is a growing interest for recycling and repurposing carbon fiber due to their economic and environmental aspects. "recycled carbon fibres (rCF) from ELG Carbon Fibre's cost is around

40% less than industrial virgin carbon fibre. Some other industrial suppliers announced that their rCF is from 20% to 40% less expensive than virgin carbon fibre (vCF)." (Frej et al., 2021). Currently various applications using carbon fiber reinforced polymers (CFRP) will reach their end-of-life (EoL) stage and will be consider harmful for the environment. Finding alternatives and sustainable materials is an important research area.

Arkema has developed a reactive methacrylate thermoplastic resin called Elium as an alternative thermoplastic resin material. "The micro-molecular structure... facilitates the recycling of large-scale composite parts by recovering and reusing initially used raw

Materials (Cousins et al., 2017)." (Frej et al., 2021). This investigation concluded that recycled carbon fiber (rCF) with Elium resin only had 3% less tensile modulus and 4% tensile strength than virgin carbon fiber (vCF). This showed promising mechanical behavoiur similarities between vCF and rCF for marine applications. (Frej et al., 2021). Bel Haj Frej, H., Léger, R., Perrin, D., Ienny, P., Gérard, P., & Devaux, J.-F. (2021). Recovery and reuse of carbon fibre and acrylic resin from thermoplastic composites used in marine application. Resources, Conservation and Recycling, 173, 105705–. https://doi.org/10.1016/j.resconrec.2021.105705

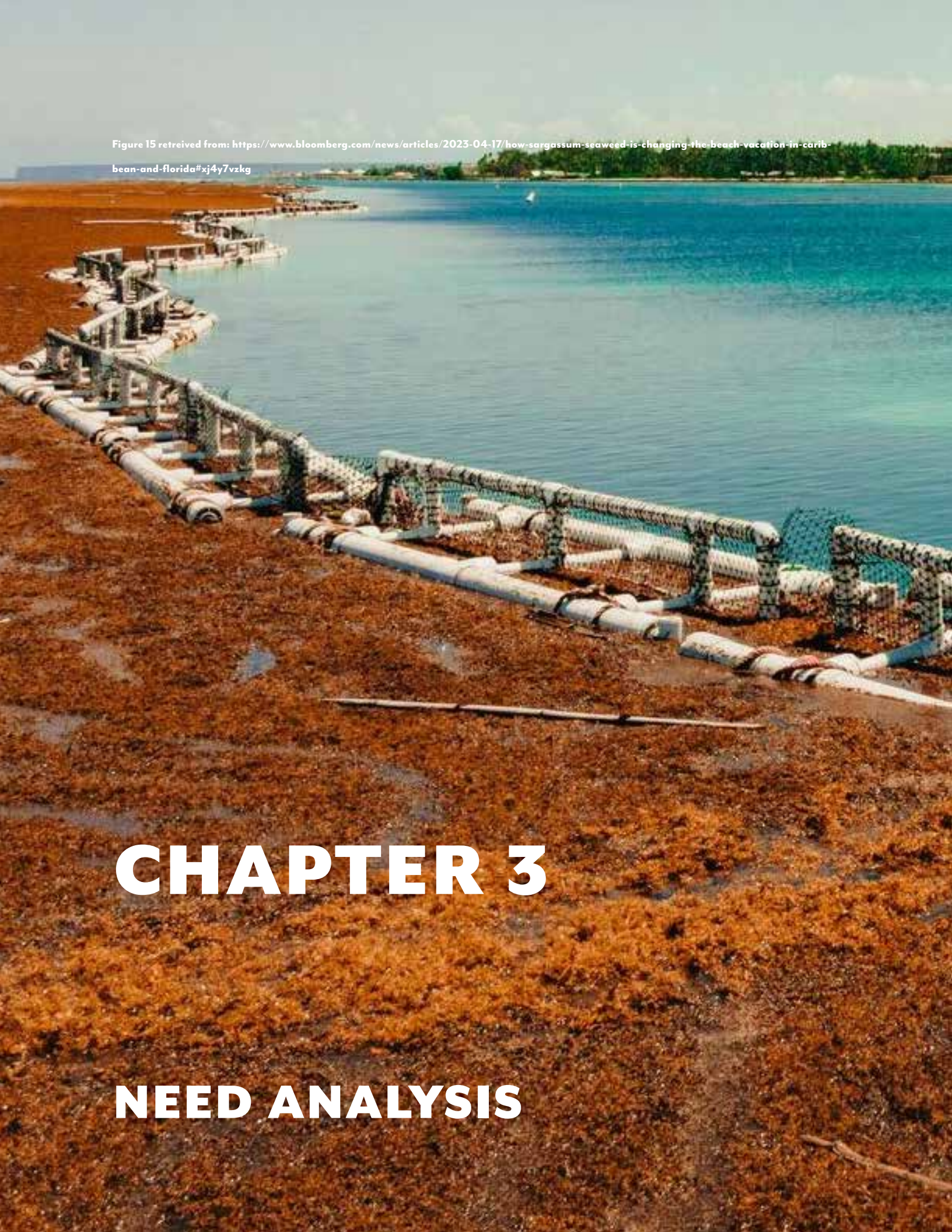


Figure 15 retreived from: https://www.bloomberg.com/news/articles/2023-04-17/how-sargassum-seaweed-is-changing-the-beach-vacation-in-caribbean-and-florida#xj4y7vzkg

CHAPTER 3

NEED ANALYSIS

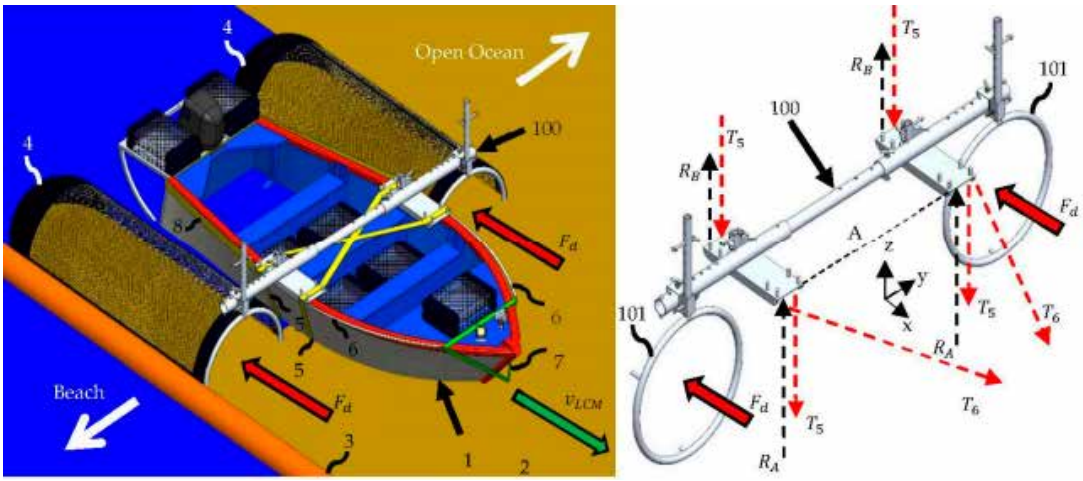
3.1 Analysis – Needs

3.1.1 Needs/Benefits Not Met by Current Products

The strategy used in this example was to look at two products separated along the cost spectrum. Aside from common benefits, other differentiated benefits would also become clear small and large sargassum collection boats. Needs Statement for a New Product. The current two products were examined: Sargassum boats - Small and Large size

Product 1: Littoral Collection Module (LCM)

Figure 16 retreived from: https://soscarbon.com/



Product 2: SWS75 - Aquatic sweeper or harvester for litter and sargassum.

Figure 17 retreived from https://www.tecnogab.com.mx/sws75

Benefits	Features
Mobility	Can go on deep and shallow water Can cover significant amount of ocean area

Effective Collection of Sargassum	High Collection Capacity High rate of collection Can run for 8 to 12 hrs. per day (depending on the work shift)
Convenience	Automatic Collection No more manual collection Faster removal of sargassum Removes sargassum on the ocean before it reaches the shoreline.
Easy to use (Sargassum Workers)	Collection methods are straightforward Easy installation process for LCM Boat can maneuver with ease

Table 3.1.1 lists the benefits and features of the selected products.

3.1.2 Latent Needs

In user needs and analysis the latent needs are the needs that user is not aware of. One type of latent needs are Fundamental Human Needs. This was done by linking benefits with Needs (using Mazlow's Hierarchy of Human Needs) in the Table following.

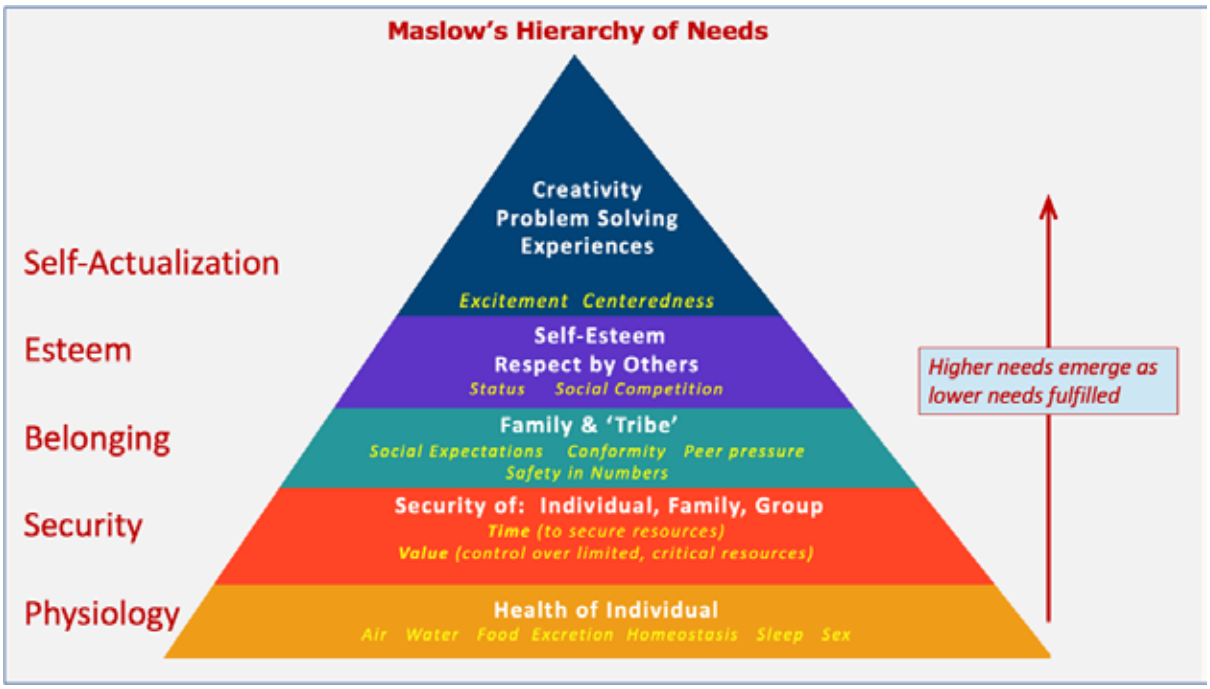


Figure 18 shows illustrate the Maslow's Hierarchy of Needs. Retrieved from https://beloved-brands.com/maslows-hierarchy/

Product- Sargassum Boat				
Needs	Benefits and Underlying Needs	Level of importance		
Basic Needs Physiological				
Food, water, shelter	Workers need a job, Sargassum needs to be removed by someone.			High

Pleasure, gratification (sensory, compulsive responses)	Worker: Feeling of being able to work a high physical stressful work, having the sargassum removed can allow them to enjoy the ocean. Hotels and Tourists: Grateful to continue the tourism-based economy		Moderate	High
Less Physical Stress	Safety, Energy, Lack of Injuries			
Safety	Protection from the ocean and sargassum			High
State, Group, Individual				
Securing resources Optimization of limited resources (cost effectiveness) · Value · Accumulation of resources (wealth)	The amount of labor needs to be equal to the amount of physical stress			High
	Health insurance		Moderate	
Less Physical Stress	Product (tool) that makes collection easier and less physical stress			High

Environmental Convenience	Being exposed to the environment for a long period of time can create health problems			High
Less Exposure to the Environment	A product that limits their exposure to the sun, salty water, and sargassum.			
	Working without coming home extremely tired			High
Energy to be able to work for Long hours shifts	Have the energy for their personal lives outside of work		Moderate	
Long-Term Physical health	Injuries over a period of time			High
	Cost of hospital bills in the long-term			High
	Care provider (personal assistance)	Slight		
Effectiveness	Sargassum Collection Effectiveness			
Percentage of Sargassum removed	A product that removes the sargassum effectively with little to no “left-overs”			High
Automotive process	An Automated process to keep the collection consistent and effective			High
Area Coverage	A product that can cover different depths of water and area			High

Long hours shifts	A product that can withstand long hours of work for years with little maintenance and care due to the crude environment		Moderate	
Disposal method	Disposal method that won't create a bigger problem in the long run			High
Fast Collection	Collection / time			
Sargassum collection / period of time	A product that collects sargassum faster to cover more are quicker			High
Fast-paced environment	A job that can keep them busy and interesting		Moderate	
	Fast disposal methods to focus more on the removal			High
Self-Actualization 'Higher order' Functions/Needs 'outer cortex'	Needs that are pre-dominantly			
Intrinsic pleasure	How to make sargassum removal interesting			High
Creative endeavors				
Experiential (extrinsic)	A job that can last a while		Moderate	
Experiential (intrinsic)	A job that wont consume their whole lives		Moderate	
Emotional	Empathy: How can I make this easier and faster			High

3.1.3 Categorization of Needs

Immediate Needs	Latent Needs	Wants and Wishes
Marketing- Existing Need Inexpensive • Can cover a lot of area • Fast removal methods • Less exposure to the sun and heat • Less physical Stress • Injury prevention • User friendly products Psychology- Human Needs & Benefits • Shelter from the physical environment • Feeling relaxed • Not bored from their work	Marketing- Latent Need • An interesting approach to remove sargassum • Where they can use different skills • Where they can learn new skills • Challenging but not overwhelming • Health care Psychology- Latent Need • Rewards after a long day of work • Motivation to wake up in the morning with excitement	Marketing- Incipient Needs • A product that automatically removal and disposes sargassum • Where they don't have to smells the sargassum or garbage • Better pay • More Environmentally friendly disposal methods Psychology- Unfulfilled Human Needs • Fun way to remove sargassum • Enjoy that time with co-workers while removing sargassum

Needs Statement 1 (before research)

The sargassum worker needs an easier and more effective sargassum removal method because removing it is physically demanding and stressful.

Needs Statement 2 (after benchmarking)

Workers need a method of sargassum removal that is automated, and effective at covering larger areas of sargassum to clean more at a faster rate.

Further needs include ease of use, comfort, and safety.

Needs Statement 3 (after benchmarking AND linking with fundamental human needs)

Sargassum removal needs to be more effective for both the workers and hotels to have an equal amount of job security.

Workers need an automated process to be able to remove sargassum without excessive physical stress. This can lead to reduced health problems and injuries in the future.

Workers need a more interesting way to remove sargassum to be mentally engaged and enjoy their work. This can lead to a healthier mental state.

Workers need a fast removal and disposal method to cover as much area as possible because sargassum comes in excessive amounts during the high season (April to September)

3.2 Analysis – Usability

3.2.1 Journey Mapping and User Task Map

User Task Map

Task: Sargassum removal on boat.	Ergonomics	Efficiency	Interaction	Satisfaction
Prepping boat	Bending to untie the rope connected to the dock	Takes a little time overall		
Quick Maintance check, Make sure everything is working porperly		Depending on the problem can take a long time	Opening cabinets, clicking buttons, pulling levers	Medium
Drive the boat	Steering wheel, manual controls in the instrumental			Medium Entertaining at first
Look for sargassum	Standing over on the side of the water vessel. Looking at a screen	Depending on the technology available		Medium Entertaining depending on the technology
Activate Machine to collect		Easy to Activate	Manual controls in the instrumental panel	High depending on how is activated
Place sargassum in net bags	bend back, tie full bags, lift heavy bags	Time consuming, Heavy work		Low Tired
Drive the collected sargassum to land	Steering wheel	Both take time and effort to transport	Manual controls in the instrumental panel	
Drive the packed sargassum to the designated site	Steering wheel. Lift heavy bags		Manual controls in the instrumental panel	Low Tired

Table 3.2.1 Illustrate the user task and its usability.

Gains:

- Job security
- Cleaner beach

Pains:

- Frustration of not being remove with ease
- Frustration at transporting the collected sargassum
- Frustration at the exposure of the environment

Usability & Ergonomics

- Chronic bending
- Tired exterior limbs

- Too much standing
- Lower back pain

Efficiency

- Inability to move fast (big ship)

Interaction

- Control panel can have less cognitive overload
- Satisfaction

3.3 Analysis – Human Factors

3.3.1 Product Schematic –Configuration Diagram

This report aims to identify the major areas of design that involves full-bodied human interaction and major body parts. An ergonomics study was conducted to analyze and determine the challenges and opportunities of the design concept. The important areas of interaction in the water vessel design are the living areas, and the control and working stations. These areas required the use of diagrams and 1:1 mockups to determine dimensions and user touchpoints. This investigation is important because it creates a user-friendly environment that will allow the user to perform essential tasks in a comfortable position. Throughout the report, the distance between objects, the maximum reach distance, and height clearance, the visibility angle, and the location of the objects were evaluated on how they interacted with the human body. The mockup allowed for a more real-life experience that allowed the user to interact with the touchpoints and dimensions. The results aided to show areas that allowed the user to perform their task in a comfortable position. It also highlighted areas that require further improvement and exploration. Considering the challenges and opportunities of the design, the ergonomics study will aid the design concept to create an environment that will reduce stressors and negative experiences and improve the user experience.

Keywords: ergonomic evaluation, full-bodied human interaction, industrial design, human factors

Literature Review

Research by Alvin and Deyfruss (1993) supports the importance of understanding human factors as an essential part of industrial design. The complexity of the human body requires a deeper understanding of full-bodied interaction to create a space that is comfortable and satisfactory. Since the user is interacting with the product, it's important to consider all people of all ages and ethnicity. This will impact the dimensions of certain parts of the design.

The ergonomics study requires taking into account a 99-percentile male and a 1-percentile female. The reason why it makes sense to design in this range is that it offers a range of heights and abilities for the human population. This will differ depending on the product and the intention of the design (Alvin and Deyfruss, 1993).

Methodology

Objectives

The objective of the ergonomic evaluation was to analyze the full-bodied human interaction design and full-bodied ergonomics of different components of the sargassum water vessel. This water vessel design contains different interaction points in different locations. This ergonomic evaluates the current interaction points of major body parts and the study highlights the main touch points and can aid to identify challenges and opportunities.

Decisions to be made

There are three major interaction points inside the water vessel. The following shows the interaction locations that utilize full-bodied ergonomics. These observations will determine challenges that can be improved and the opportunities that can be enhanced for the user experience.

1. Control Room Panel
2. Kitchen area
3. And Dinning or Desk area

Description of Users Targeted by Product

In current methods, there is a significantly higher percentage of males over females who work to remove sargassum. Due to its natural heaviness and the extreme heat of the location, this job requires people who can work under these conditions. The majority of men who work to remove sargassum are between 18 and 35 years old. These people are local to the area so they are aware of the problem and where to dispose of it.

Evaluation process

The evaluation process consisted of an ergonomic 1:1 mockup of the 3 different interaction points. The first mockup shows the kitchen area, specifically the counter and cabin touchpoints. This allowed the user to be observed in the following situations:

1. The optimal height between the counter surface and the user.
2. The positions of the arm using the counter in different actions (in this case, cutting a banana)
3. The visual clearance of the counter from the eyesight (distance between the cabinet and the counter)
4. The depth and height of the cabinet. This shows if the user is able to reach the top and the back with minimal effort.

The second mockup shows the control panel area, specifically the instrumental panel and sitting position. This allowed the user to be observed in the following situations:

1. The height between the floor and the seat of the chair
2. The optimal degree of how the chair leans back
3. The comfortable distance between the arms and the control outputs
4. The visual clearance between the user sitting down, the front window, and the control instrumental panel.

The third mockup shows the dining and desk area, This allowed the user to be observed in the following situations:

1. The distance between the top of the table and the floor
2. The distance between the seat of the chair and the floor
3. Comfortable arm and back positions while sitting down

Description of User Observation Environment Used in this Study

For this study, the different interaction points were explored where the users perform their tasks and interact with their surroundings. The observation was carried out in the author's home.

Location and Timeframe

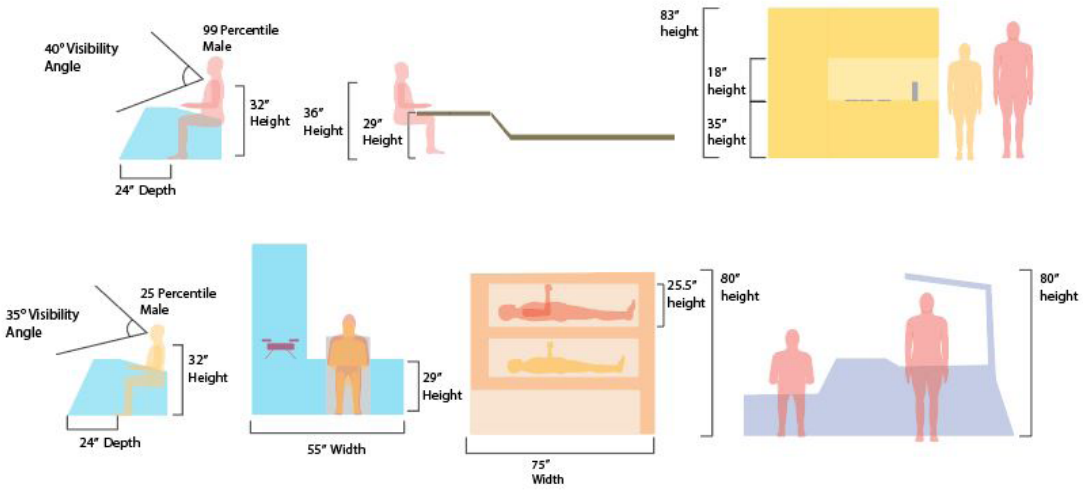
Date of Observations: December 4th, 2022 (Observation 1,2,3)

Location of Observations: Author's home (Observation 1,2,3)

Results and Analysis

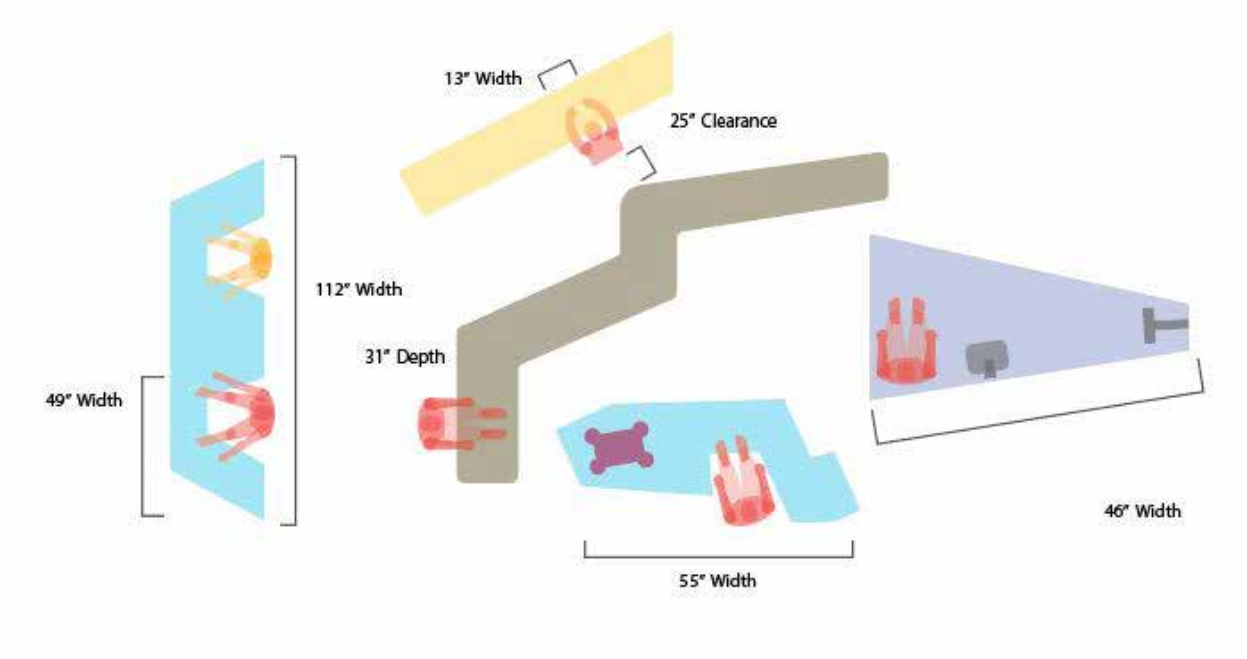
Kitchen, Dining and Sleeping Bunk beds

Side View

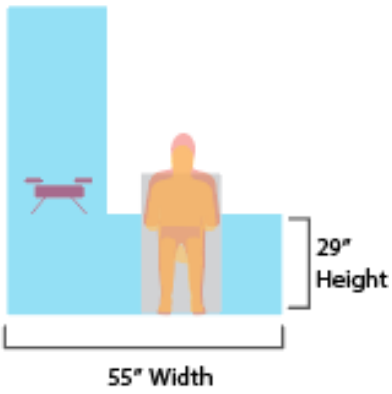


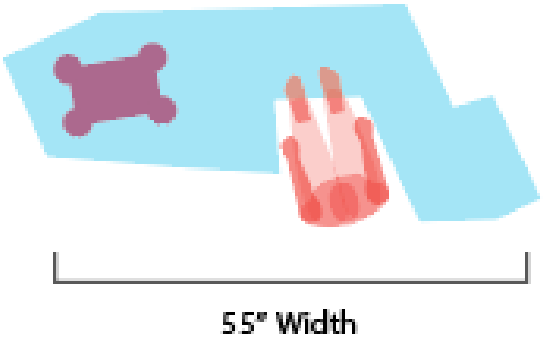
This diagram shows the kitchen area using a 99% male figure. This space is where the user will eat, relax, or work. This accommodation takes into account the height of the chairs, the tables, the counters, and the cabinets.

Top View

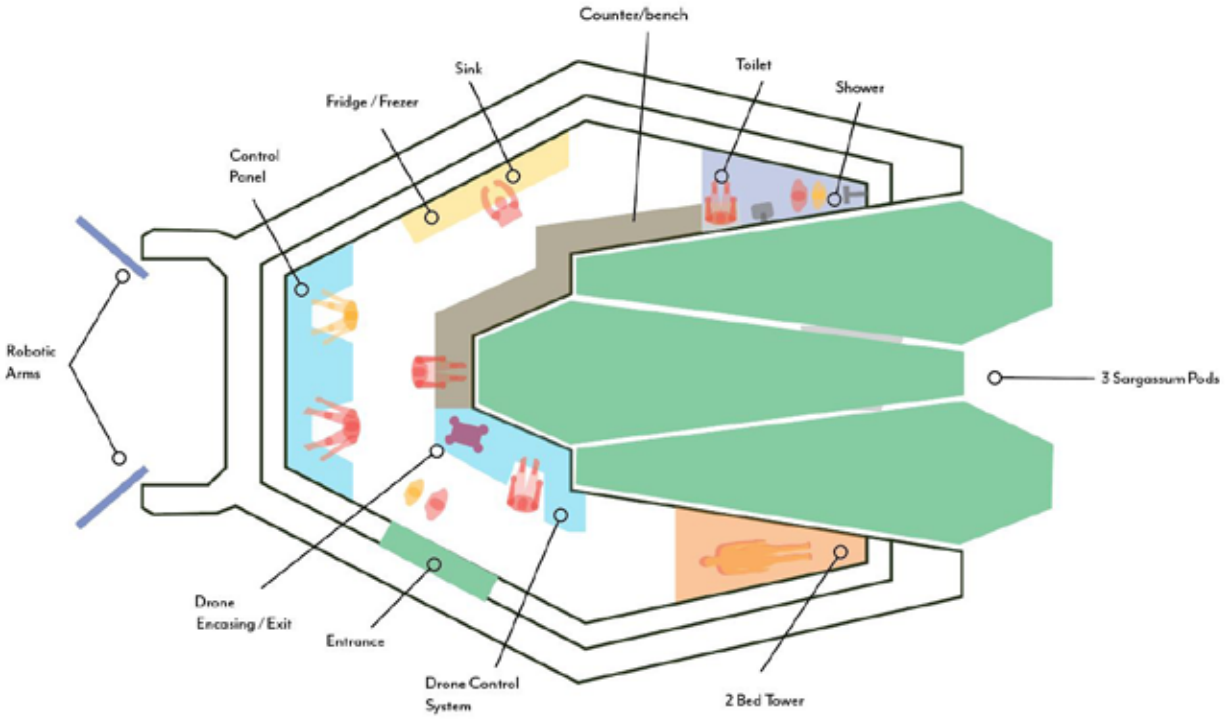


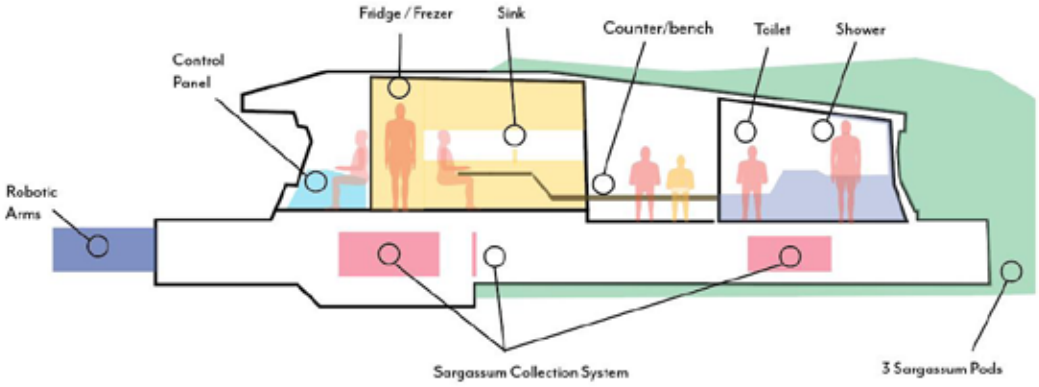
In this top view of the kitchen, the user has enough space to walk behind the pulled-out chairs, and there is enough clearance between the chairs and the counter. This diagram shows the dimensions of the table that can sit 3 people at a time. The kitchen space has enough room for a small sink, stove, fridge/freezer, and cabinets for storage.





The drone control room is a place for the user to sit in front of a wrapped desk and control the drones automatically or manually. The display screen on the desk is tilted at a comfortable degree where the user can still read the information and see the drones across the space. In the top view, the user has enough space to reach the manual controls without much effort. This means that the range of motion of their arms can cover a large area of the desk. This can allow the user to sit comfortably with a straight back; thus minimizing back pain and muscles sores.


Counter/bench
Sink
Toilet
Shower
Fridge / Frezer
Control Panel
Robotic Arms
3 Sargassum Pods
Drone Encasing / Exit
Entrance
Drone Control System
2 Bed Tower


Fridge / Frezer
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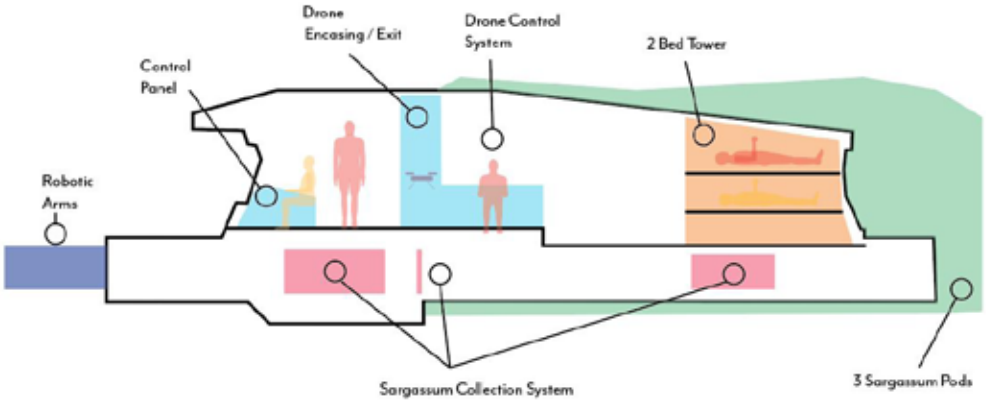
Control Panel
Robotic Arms
Sargassum Collection System
3 Sargassum Pods


Drone Encasing / Exit
Drone Control System
2 Bed Tower
Control Panel
Robotic Arms
Sargassum Collection System
3 Sargassum Pods

3.3.2 Ergonomic – 1:1 Human Scale Study

1:1 Scale Mockup

The user in these pictures is a 50% Male

Figure 3.3.2.1 Control Panel Ergonomics Study

Figure 3.3.2.2 Control Panel Ergonomics Study

Figure 3.3.2.3 Control Panel Ergonomics Study

In this set of pictures, the user is seated in front of the control panel. In this concept, the panel wraps toward the user for easier access to the control outputs. Where the hands and arms rest there is a closer reach to those manual controls. The display screens are further back aligned with the curved and degree. This

degree allows the user to have a clear view of the outside and control the robotic arms. The display screens will indicate to the user all the information required for them to perform proper tasks using infographics and UI display.

The chair has an inclination for the user to relieve stress from their back when seating for a long period of time. This inclination is not too low which will prevent them from having a clearance view and not to high which will be uncomfortable for them. The height of the seat can be adjustable so that is high enough for different percentiles to be comfortable and allow them to perform their tasks properly. This figure is working with a user of the 50% male

Figure 3.3.2.4 Dining Table Ergonomics Study

Figure 3.3.2.5 Dining Table Ergonomics Study

In this set of pictures, the user is seating in front of the dining table. This concept allows the user to perform essential tasks such as eating, writing, working, etc. The user is in a seated position and placing his hands on top of the table. This indicates that the arms are rested on the table at a comfortable position and there is enough space between the knees and the top part of the table. The chair has a lean in the back support; however, it does not lean as much as the one in the control panel area. This chair has a more straight-back support to allow the user to perform tasks using a flat surface on the table without much effort.

Figure 3.3.2.6 Kitchen Counter Ergonomics Study

Figure 3.3.2.7 Kitchen Counter Ergonomics Study

In this set of pictures, the user is standing in front of the kitchen counter. The user is a 50% male who is cutting up a banana on top of the counter. This picture shows the distance between the counter and the floor so it can be comfortable for the user when they are standing up. The user is able to look down on the counter to see what they are doing without having to bend down or extend their arms to reach. Their elbows are a little higher than the counter so the user can still perform their tasks without raising their arms or shoulders which can be exhausting after a period of time. Figure 3.2 shows the user reaching for a plate inside the cabinet above the counter. The height between the cabinet and the counter is high enough that allows the visual clearance of the whole counter from a standing point of view. The cabinet is high enough that lower percentiles will not struggle to reach the items inside. The user in the image is capable of seeing the top inside part of the cabinet when standing up. The depth of the cabinet is sufficient to store items and essentials and is still at a reachable distance from a standing point of view. The user does not need to lean at an uncomfortable angle to reach the back of the cabinet.

Limitations and conclusions:

Identifying critical human dimensions affecting product use were as follows:

1. The space between the chair and the control panel is limited to a swivel.

2. The height of the control panel can limit the visibility of the sargassum.
3. The height of the cabinet can be lifted slightly to add more space to the counter.

Some Ergonomic Issues That Are Still Not Yet Resolved:

Some areas of the ergonomic study that still needs alteration are the manual controls and their location, the height of the control panel needs to be adjusted, the space between the cabinet and the counter, and the optimal distance between the pump and the user. The manual controls and their location can identify the position of the controls and their maximum reach for the user. Depending on the manual controls, there needs to be clearance between the controls and determine if the user is pushing, pulling, or turning a control input. The height of the display screen is important because it allows the user to be informed and gives enough view to see the sargassum outside the water vessel. The height needs to be low enough to cover different percentiles height, and still be able to display the information at a comfortable angle. The cabinet and the counter can have a slightly higher distance to allow for bigger objects to sit on top of the counter without obstruction issues. For higher percentiles, it will allow them to see the surface of the counter without the need to bend down.

Alternate possibilities for the future:

Based on the necessity of the design concept, the following alterations can be explored in the future:

1. the water pump and the lower floor can be reconsidered and possibly discard it. This will allow the space to be more compact and focus on the autonomous collection process.
2. A more resolved control panel that maximizes the space and has room for the user to exit the seat

This study has aided the design development to identify the challenges and opportunities for the user and their space. This design concept has successfully covered the major body parts and full-bodied interaction points. Further alteration can be improved and create an optimal space for the user to perform their tasks.

3.4 Analysis - Aesthetics and Semantic Profile

Figure 19 shows the aesthetics inspiration for the final design

Scott Robertson is a well-known industrial designer known for his unique sketching style and futuristic designs. His work is often inspired by the sleek and futuristic aesthetic of science fiction, which is reflected in the smooth, aerodynamic lines and futuristic features of his designs. Robertson's sketching style also plays a role in his aesthetic inspiration, as his loose and expressive line work adds a sense of movement and dynamism to his designs. In addition, futuristic water vessel design is often inspired by the sleek and futuristic aesthetic of science fiction, as well as the desire to create functional and innovative designs that push the boundaries of what is currently possible. Some references for this aesthetic include science fiction movies and literature, as well as real-life advances in technology and design. For example, designers may be inspired by the futuristic water vessels depicted in popular science fiction franchises such as Star Wars and Star Trek, as well as the high-tech, efficient designs of modern military and research vessels. Overall, the aesthetic inspiration from Scott Robertson and futuristic water vessel design comes from a combination of science fiction and real-world technological and design advancements.

3.5 Analysis – Sustainability: Safety, Health and Environment

Sargassum to Bio-fuel

Due to the harmful impact on the environment from non-renewable energy such as fossil fuel, there has been an increased interest in renewable energy such as solar, wind and bioenergy. This thesis aims to design a transportation unit that harvests the accumulation of harmful quantities of sargassum from the Mexcian Caribbean coastlines and repurpose it through biorefinary to produce biogas. Sargassum is a macroalgae naturally found in the Atlantic ocean, due to climate change there has been bloom of large quantities that affect the marine life and the tourism industry in Mexico. Macroalgaes has been an interest in the scientific community as a sustainable energy source. This means that pelagic sargassum has the potential of becoming bio-fuel in the coming years. (Alvalo-Betancourt et al., 2021). Alvalo-Betancourt et al. (2021) concluded in their research that "the high influx beaching of these algae in the Mexican Caribbean coast in recent years has made it possible to estimate that its removal of only one month from 600 km of coastline that can could theoretically supply the annual bioenergetic needs of residential heat of 79,163 inhabitants in said region. Its viability as a solid biofuel, considering a comparative analysis with other bioenergetic fuels, is shown through potential benefits in terms of costs and emission generation, because it is a marine residue with an imperative need for removal. With proper transformation management, Sargassum spp. Could be converted into densified materials such as briquettes or pellets, generating a new market in the bioenergy industry."

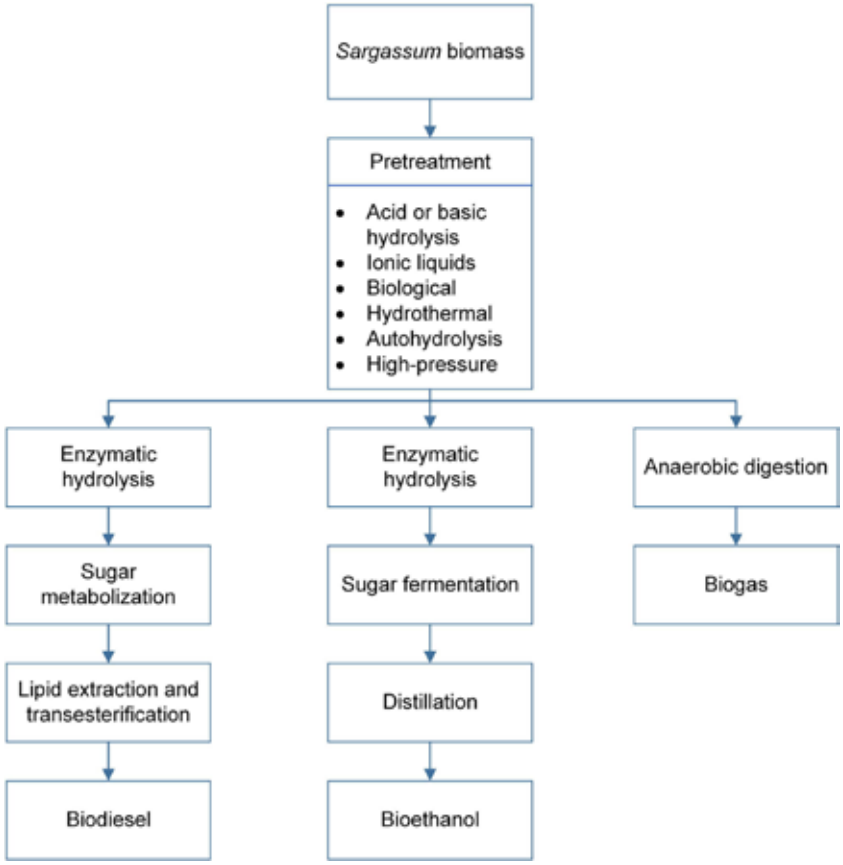


Figure 20 shows the different process to create biodiesel, bioethanol, and biogas using sargassum. Image taken from: Orozco-González, J. G., Amador-Castro, F., Gordillo-Sierra, A. R., García-Cayuela, T., Alper, H. S., & Carrillo-Nieves, D. (2022). Opportunities Surrounding the Use of Sargassum Biomass as Precursor of Biogas, Bioethanol, and Biodiesel Production. Frontiers in Marine Science. https://doi.org/10.3389/fmars.2021.791054

Orozco-González, et al. (2022) reported in their research the following.

"Thompson et al. (2021) adjudged that pelagic Sargassum from the Caribbean can be used for optimized biogas production when using hydrothermal pretreatment coupled with anaerobic co-digestion with food waste. Food waste was mainly composed of noodles, bread and rice, vegetables, meat, coffee, tea, fruits (24.8%), and eggshells in the study. The composition of the biogas obtained will diverge depending on the pretreatment applied prior to digestion. Hydrothermal pretreatment on Sargassum biomass reduced the presence of hydrogen sulfide (H2S) in biogas from 3 to 1%, relative to the untreated biomass (Thompson et al., 2020a)"

Orozco-González, et al. (2022) concluded that there are different factors regarding the success of sargassum into biofuel. Economic restrains can affect the feasibility of creating a sargassum-based biorefinery, factors such as local transportation, biomass availability, and initial investment. Moreover, to

create an environmentally friendly bioenergy, there needs to be most if not all usage of all sub-products and residues from biorefineries. Lastly, further research regarding sargassum as a biofuel needs to be conducted to develop viable processing methodologies.

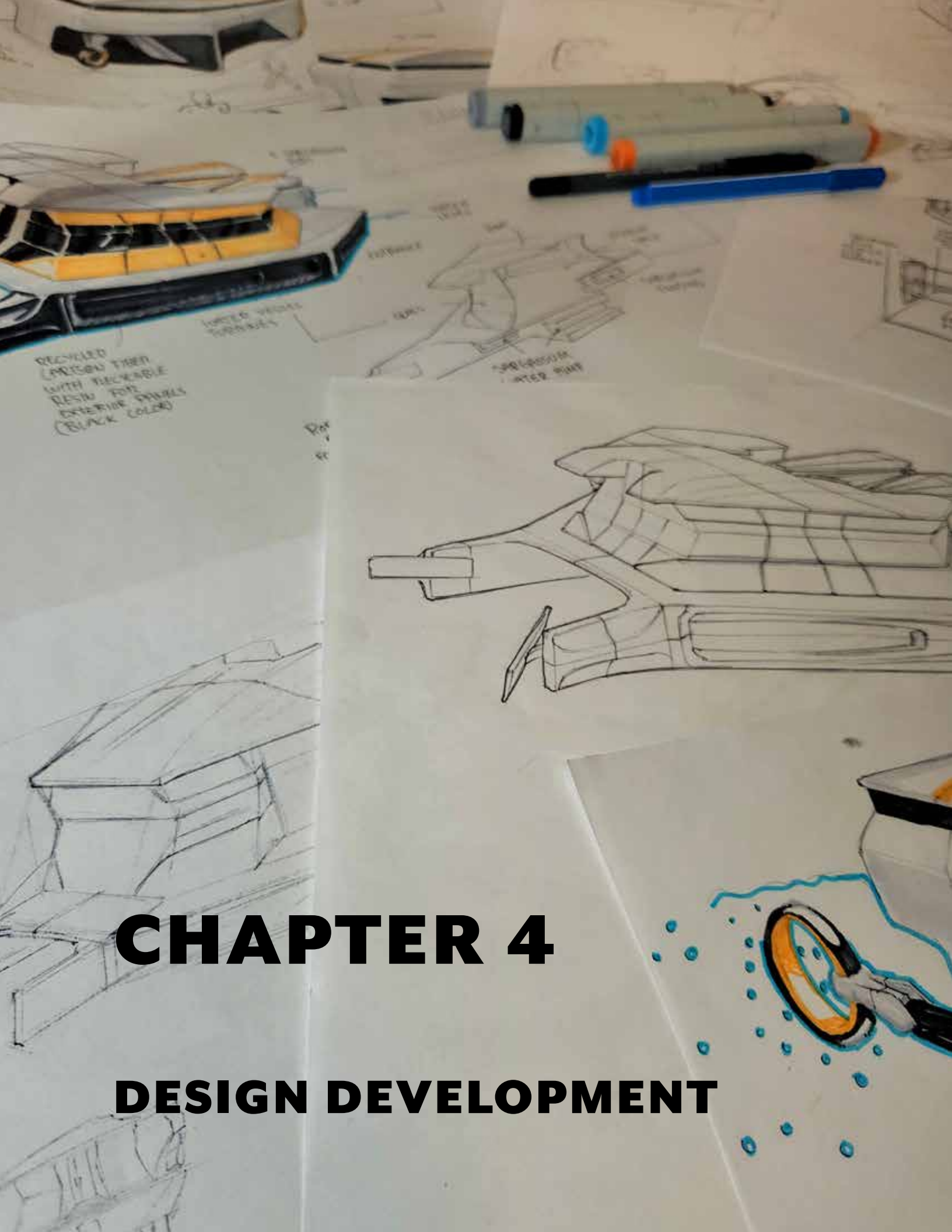
Safety and Health of the User

There has been little to no research on the overall health of sargassum workers. However, there is annedotial research in which people have been interviewed in terms of their personal experience working with sargassum. Sargassum start to deteriorate once it reaches the shoreline creating a hazard zone because of its sulfuric smell. This can cause people close to the shore to have headaches and feel nauseous. On the contrary, sargassum workers are known to remove the sargassum by hand using a rake and a wheelbarrow. They work in direct contact with the sargassum. Sargassum is known to carry toxic contaminentns in addition to sea water and metal such as As. There hasnt been any research regarding long-term exposure to sargassum specifically for the workers.

Mochizuki (2019) mentioned, in his research, that there needs to be more studies on the affect of Arsenic (As) metal exposure because there has been evidence point at neurotoxicity. He stated the following:

"Several studies have shown that As exposure induces peripheral neuropathy or neuritis [4,58–60]. The type of neuropathy caused by such extremely long exposure to low As concentrations in water has gradually become clear over the last decade. For neurological impairments, it has been suggested that mild peripheral neuropathy may occur by drinking As-contaminated water at the level of 10 ppb [6]. On the other hand, there is no study showing that CNS impairments occur due to drinking As-contaminated groundwater in adults [4,6,61] except the DPAA exposure of the Kamisu city incident [24]." Mochizuki, H. (2019). Arsenic Neurotoxicity in Humans. International Journal of Molecular Sciences, 20(14), 3418–. https://doi.org/10.3390/ijms20143418

Sargassum is know to carry a variety of heavy metals as it travels across the Atlantic ocean. During their travel, sargassum patches absorb contaminants from industrial sites located near the shore. The contaminants can include heavy metals such as As and other chemical that can be harmful to humans and the environment. When working with sargassum, it's important to clean out the toxic material from sargassum in order to repurpose it. (Orozco-González et al., 2022).



CHAPTER 4

DESIGN DEVELOPMENT

4.1 Ideation

4.1.1 Mind Mapping

The first part of the design development was to understand the user, the problem definition, and the intent. To begin with, a mind map was created to aid design thinking and possible solutions further. The critical part of this exercise is to lay out all the available information and create a research-based solution. In the following figure, a mind map was created identifying the technological, social and demographics, economic, environmental, values, and political areas found in the research:

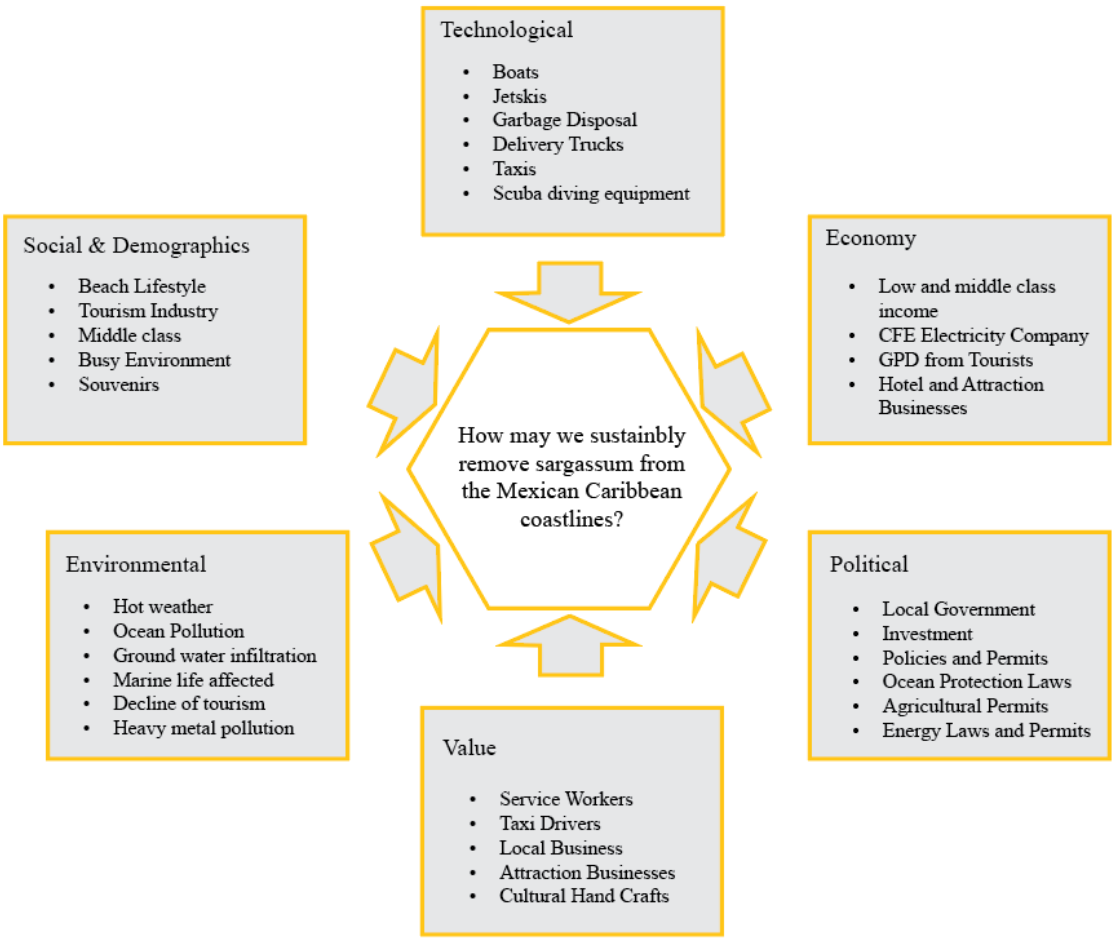


Figure 21 Mind Mapping

Another step was to expand on details of possible solutions and organized them based on their potential and level of impact. These details are not defined, they are meant to expose all ideas at the moment and organized them in a proper matter. In the following graph, solution datils are organized based on their level of impact and feasibility:

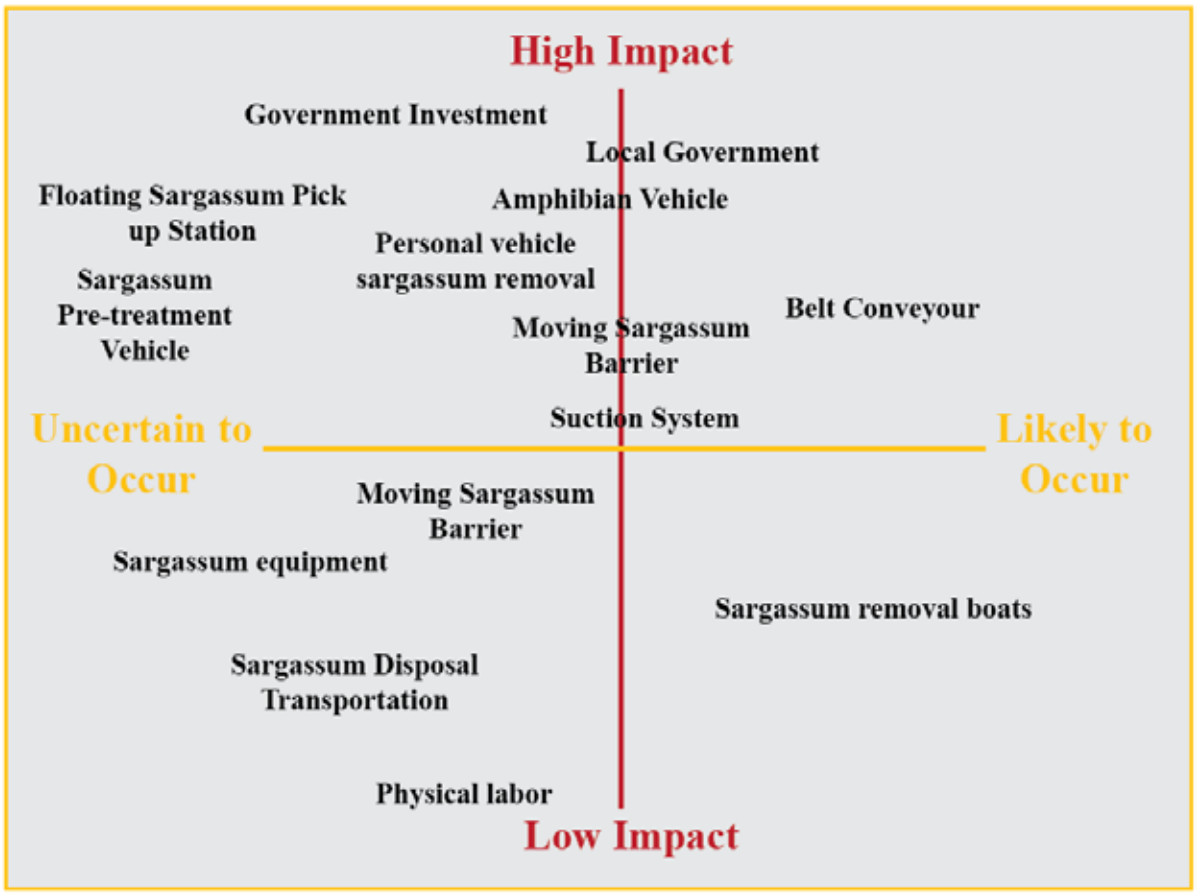


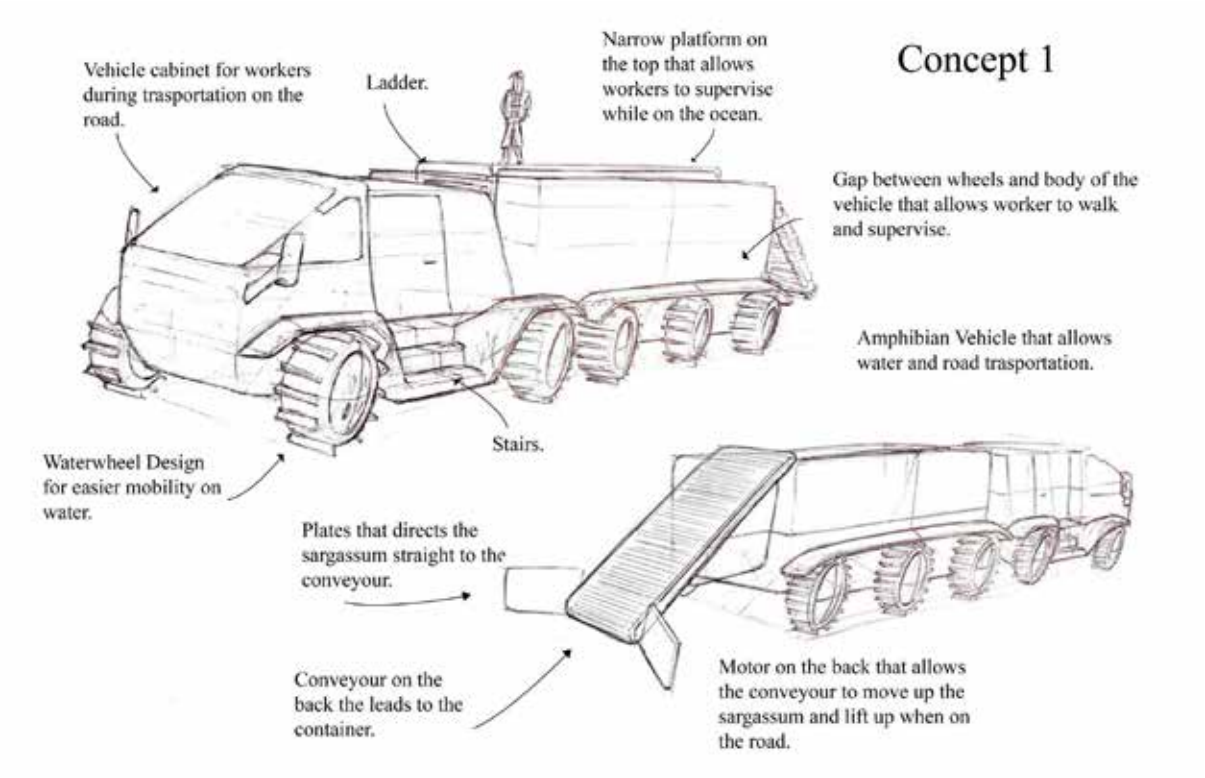
Figure 4.1.1.2 Impact Graph

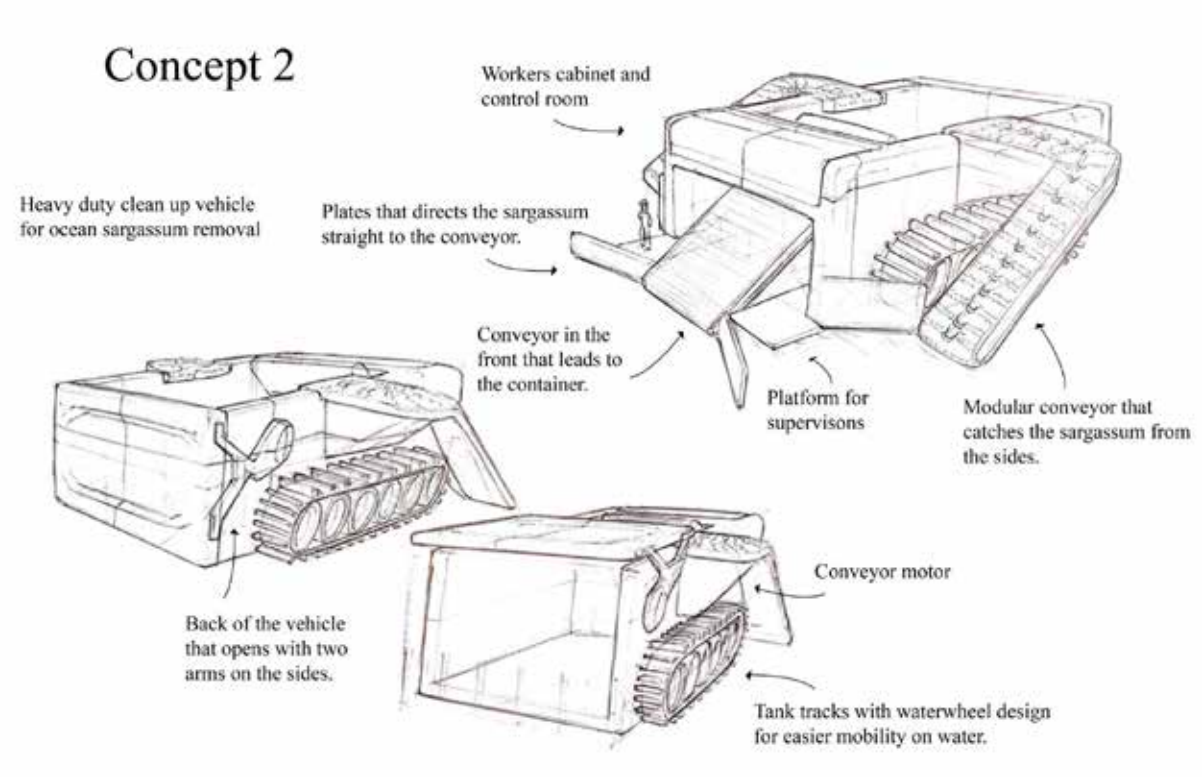
4.1.2 Inspiration Board

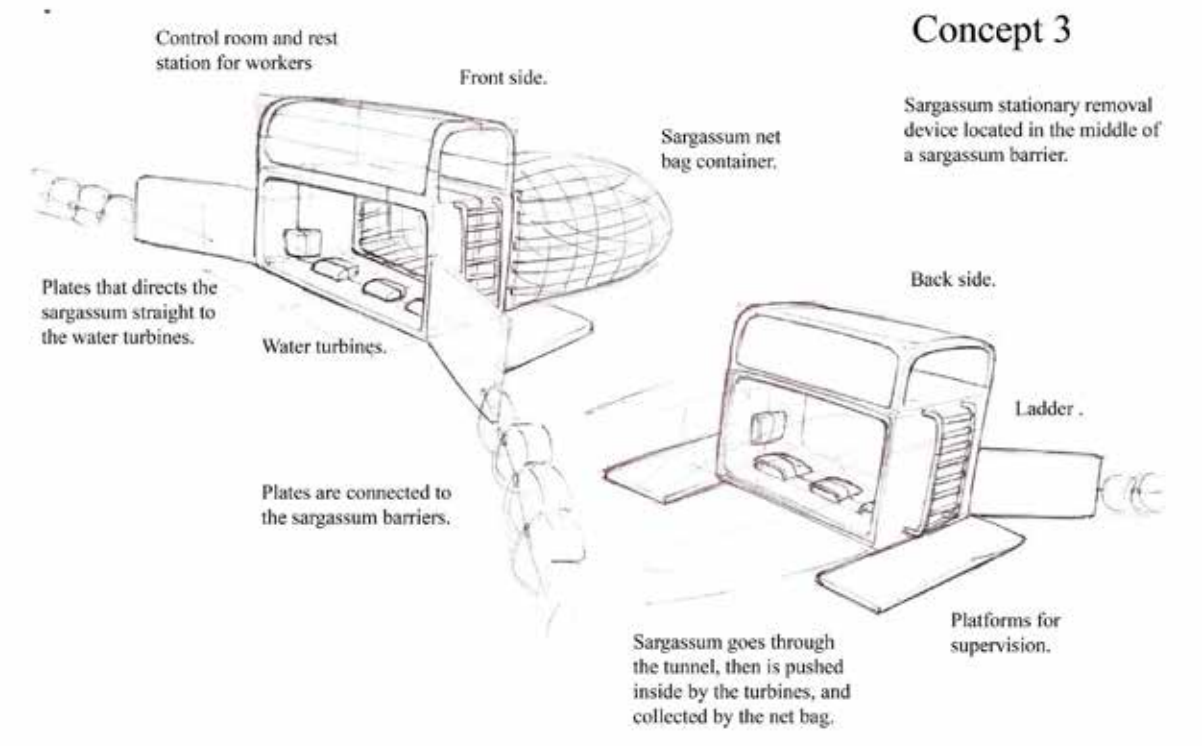
Figure 19 Inspiration Board

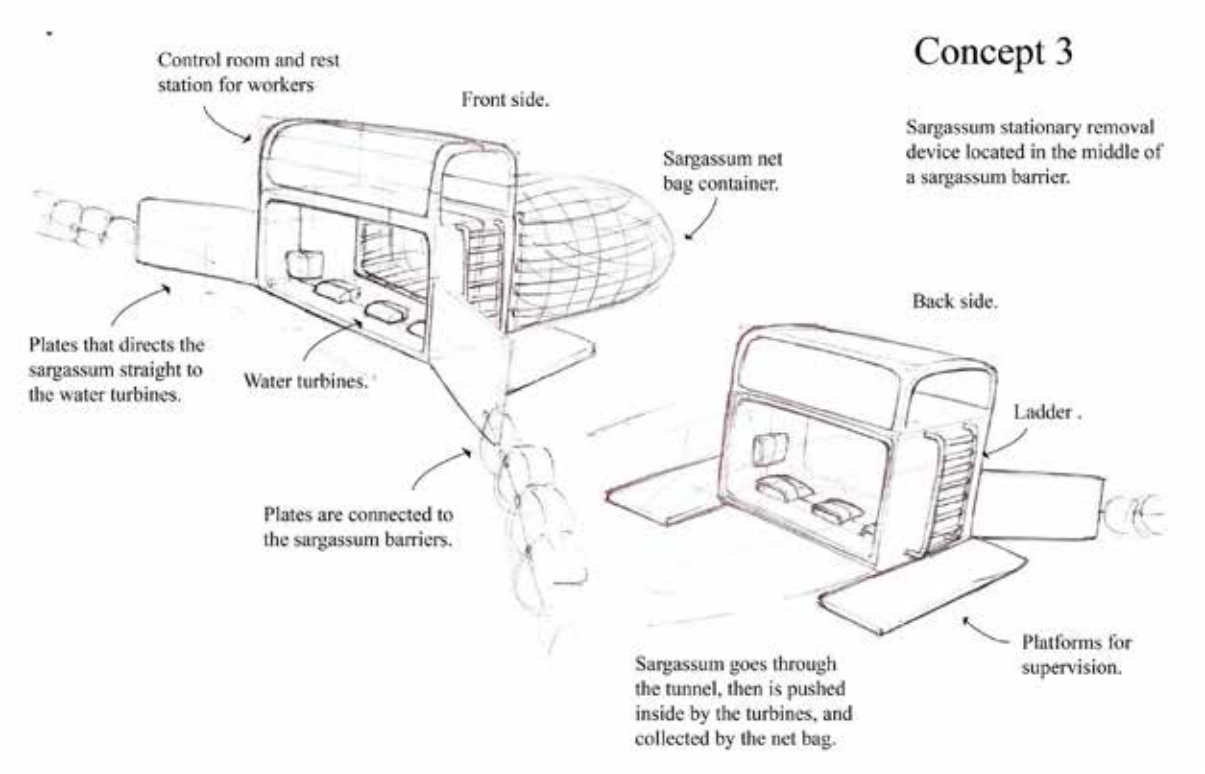
This inspiration board allowed the design development to follow a design language. The main focus of the inspiration board is the details on the exterior shape. This later defines the design development as a water vessel with an aerodynamic form, transportation usability and spacious interior. These are given by different ideas from sci-fi concepts, futuristic design sketches, and water vessel shapes.

4.2 Preliminary Concept Exploration




Concept 2
Workers cabinet and control room
Heavy duty clean up vehicle for ocean sargassum removal
Plates that directs the sargassum straight to the conveyor.
Conveyor in the front that leads to the container.
Platform for supervisons
Modular conveyor that catches the sargassum from the sides.
Conveyor motor
Back of the vehicle that opens with two arms on the sides.
Tank tracks with waterwheel design for easier mobility on water.


Concept 3
Control room and rest station for workers
Front side.
Sargassum net bag container.
Sargassum stationary removal device located in the middle of a sargassum barrier.
Plates that directs the sargassum straight to the water turbines.
Water turbines.
Back side.
Ladder .
Plates are connected to the sargassum barriers.
Platforms for supervision.
Sargassum goes through the tunnel, then is pushed inside by the turbines, and collected by the net bag.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Control room and rest station for workers
Front side.
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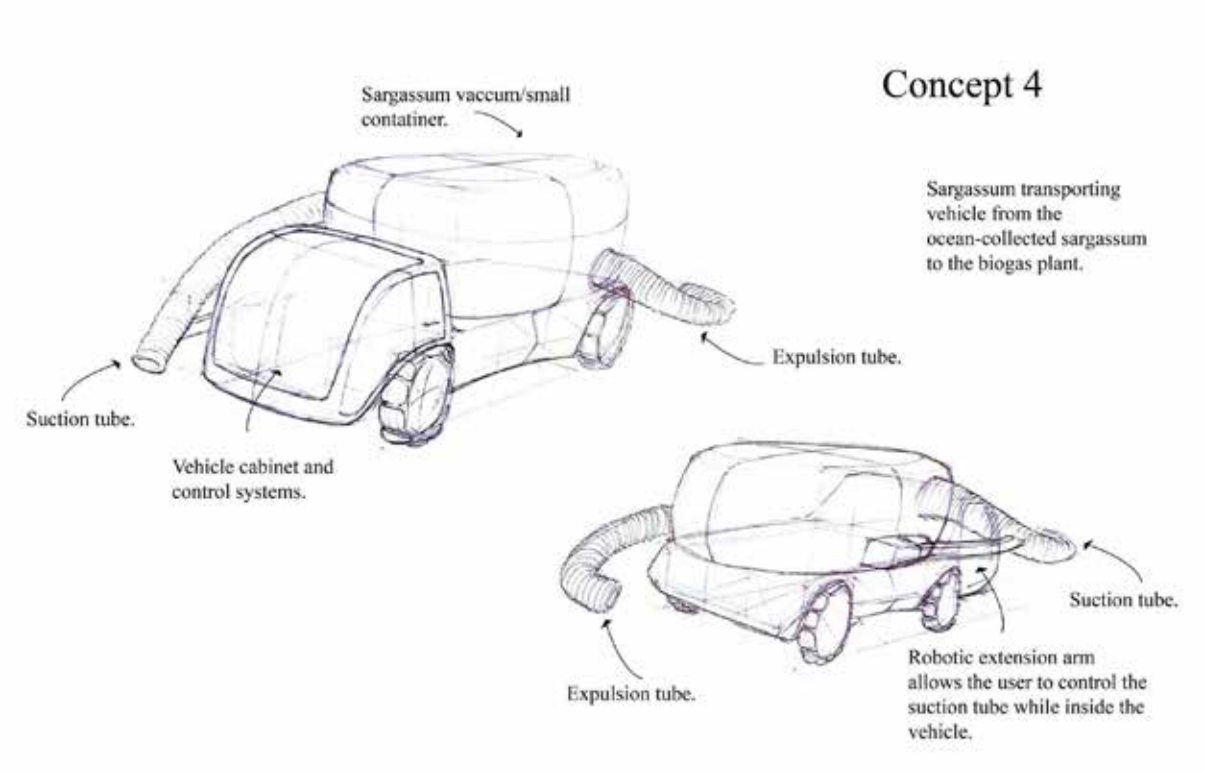
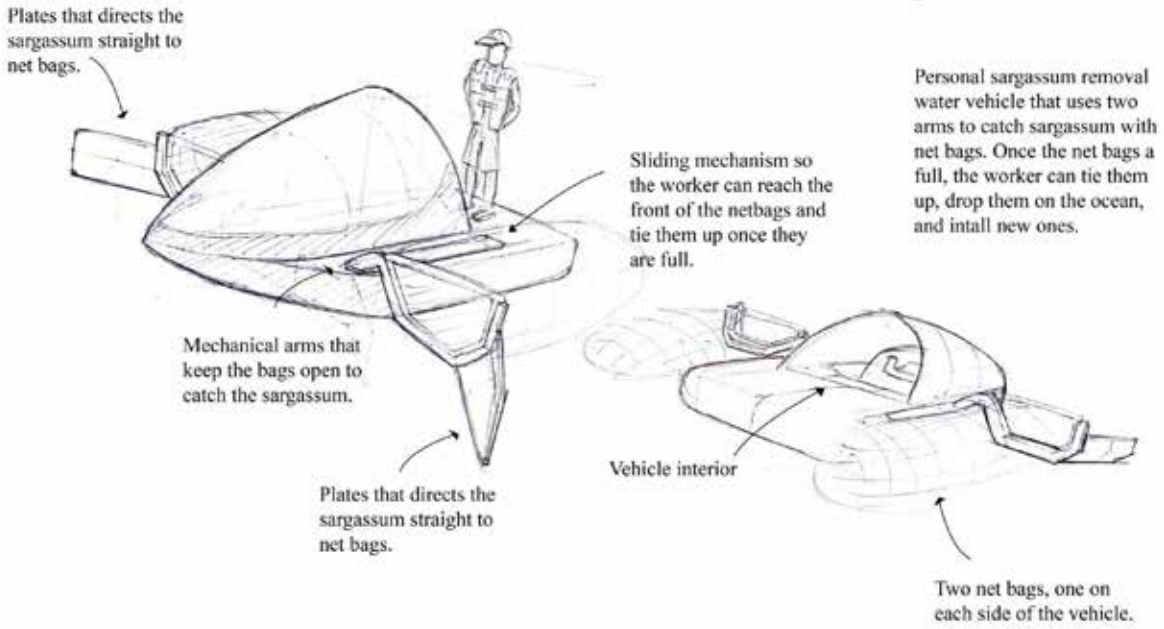
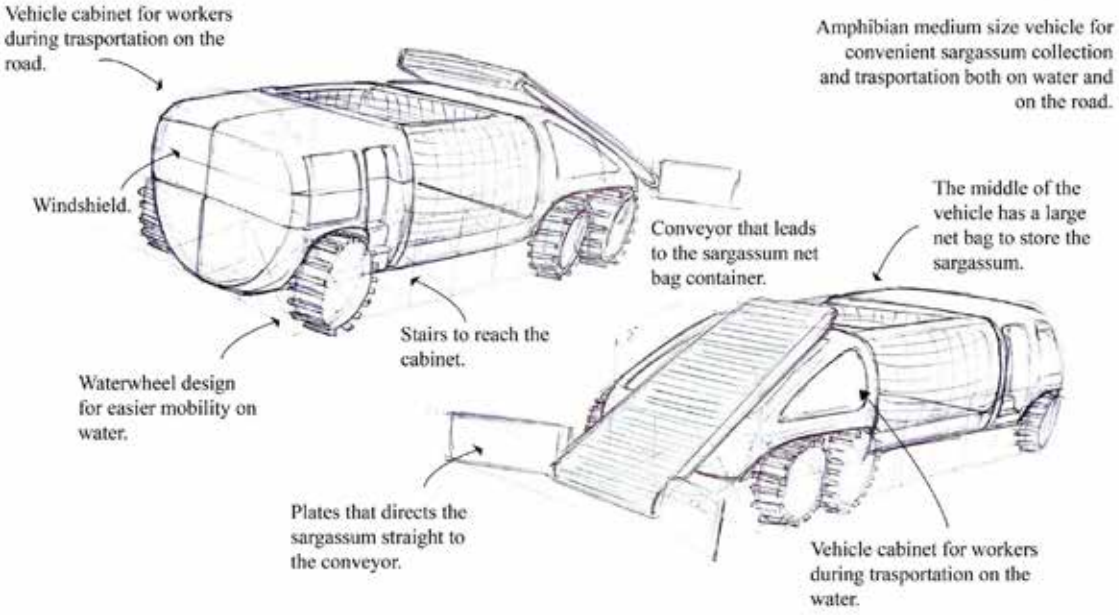
Back side.
Plates that directs the sargassum straight to the water turbines.
Water turbines.
Ladder .
Plates are connected to the sargassum barriers.
Platforms for supervision.
Sargassum goes through the tunnel, then is pushed inside by the turbines, and collected by the net bag.


Concept 4
Sargassum vaccum/small contatiner.
Sargassum transporting vehicle from the ocean-collected sargassum to the biogas plant.
Expulsion tube.
Suction tube.
Vehicle cabinet and control systems.
Suction tube.
Expulsion tube.
Robotic extension arm allows the user to control the suction tube while inside the vehicle.

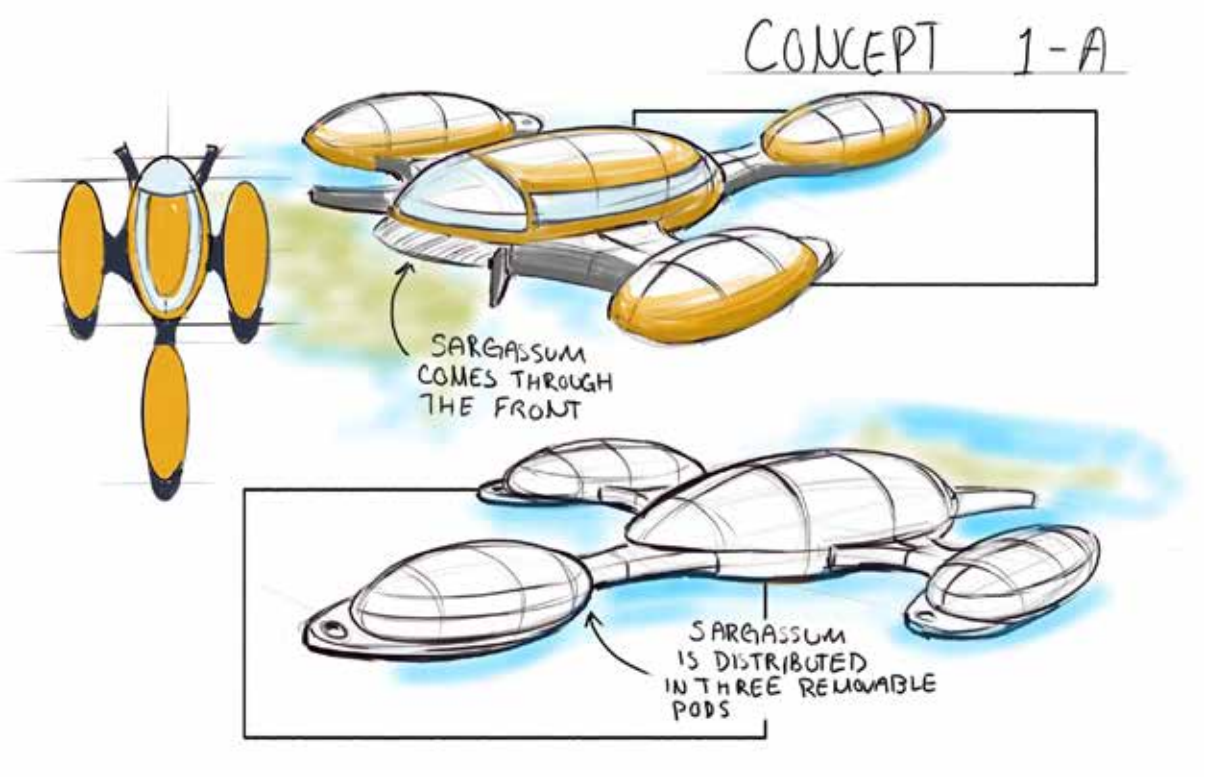
Concept 5

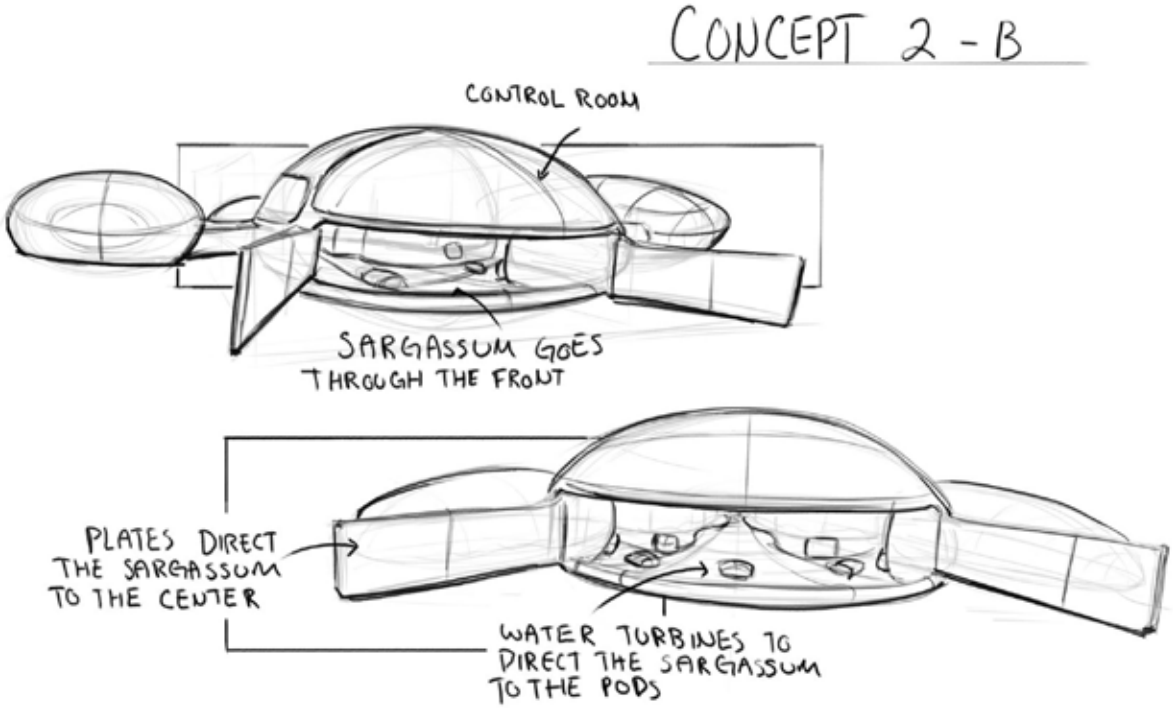


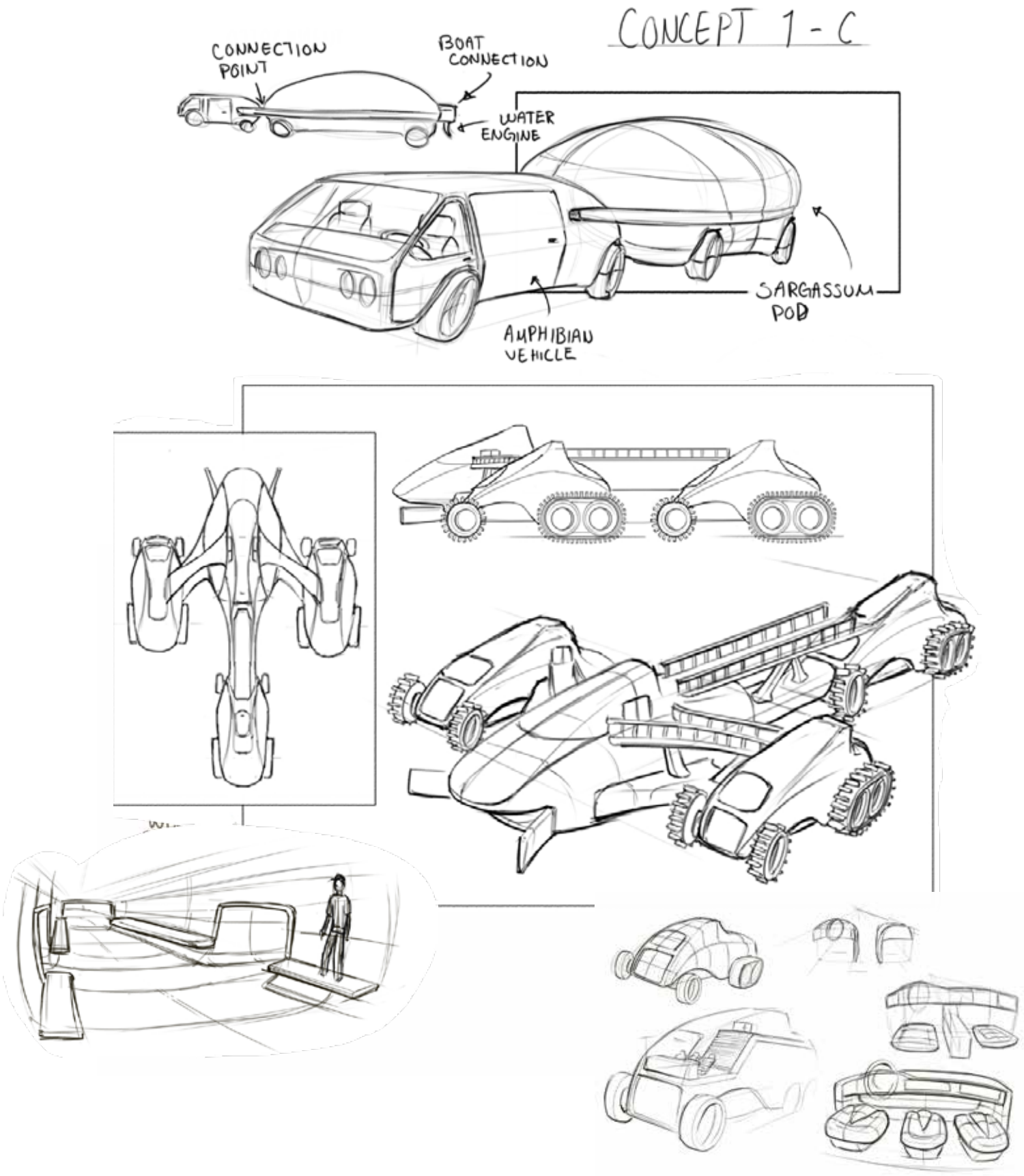
Concept 6

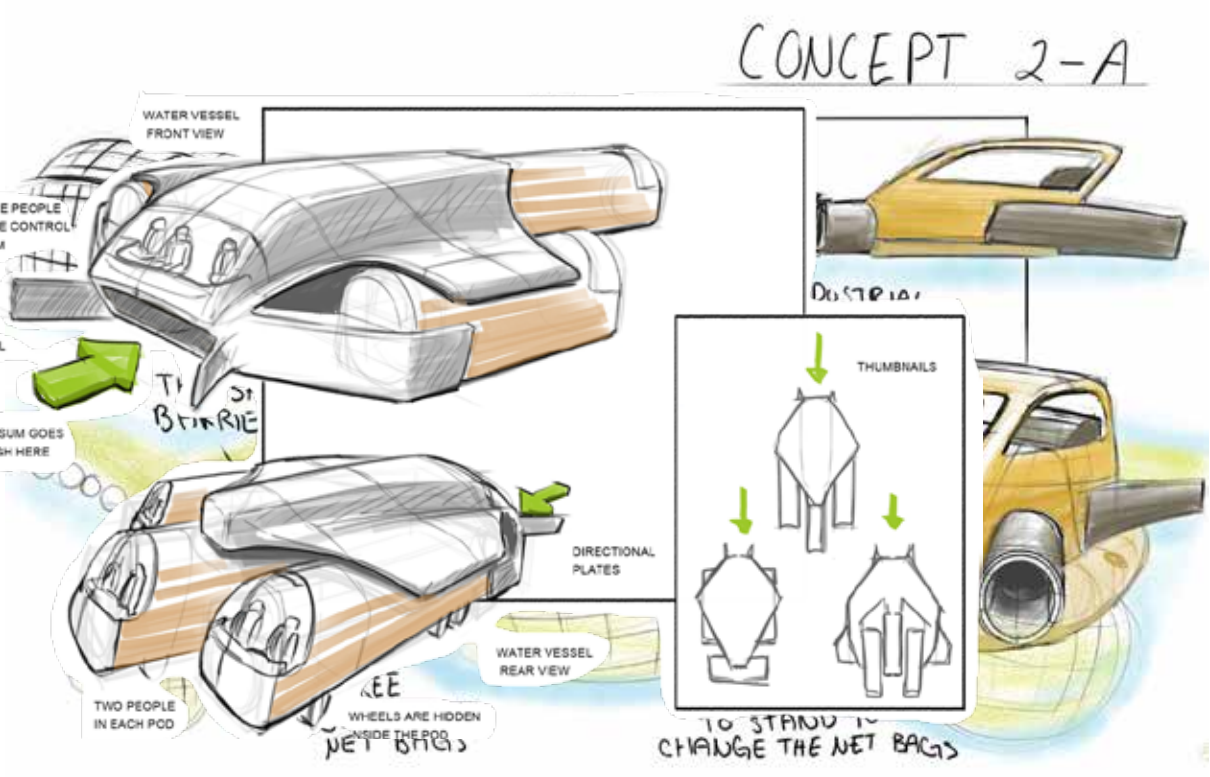


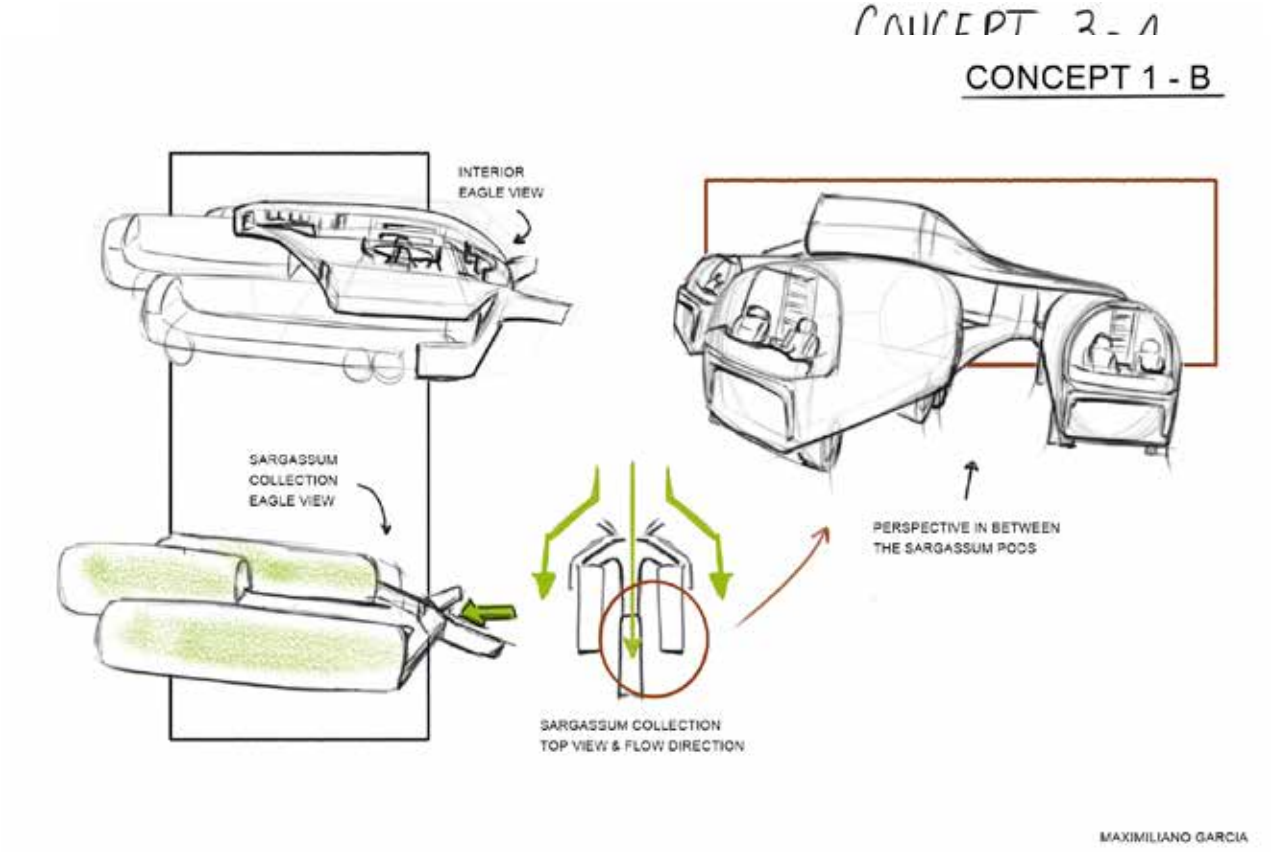
4.3 Concept Refinement

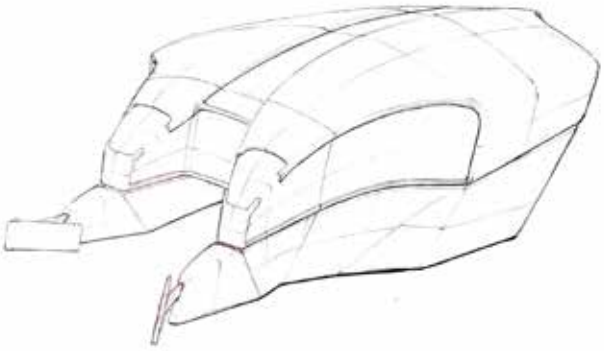




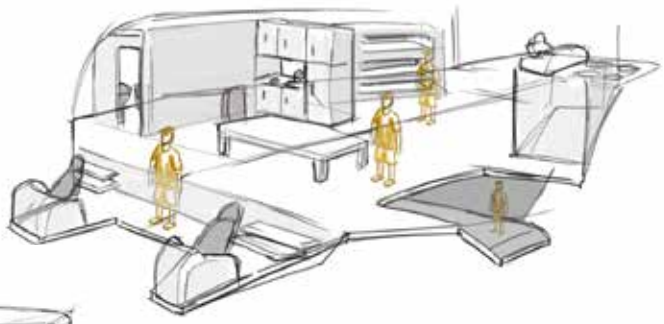

CONCEPT 1 - C
CONNECTION POINT
BOAT CONNECTION
WATER ENGINE
SARGASSUM POD
AMPHIBIAN VEHICLE

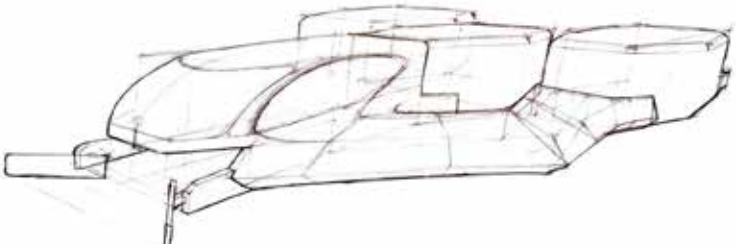

CONCEPT 2-A
WATER VESSEL FRONT VIEW
THREE PEOPLE IN THE CONTROL ROOM
DIRECTIONAL PLATES
SARGASSUM GOES THROUGH HERE
THUMBNAILS
DIRECTIONAL PLATES
WATER VESSEL REAR VIEW
TWO PEOPLE IN EACH POD
WHEELS ARE HIDDEN INSIDE THE POD
CHANGE THE NET BAGS

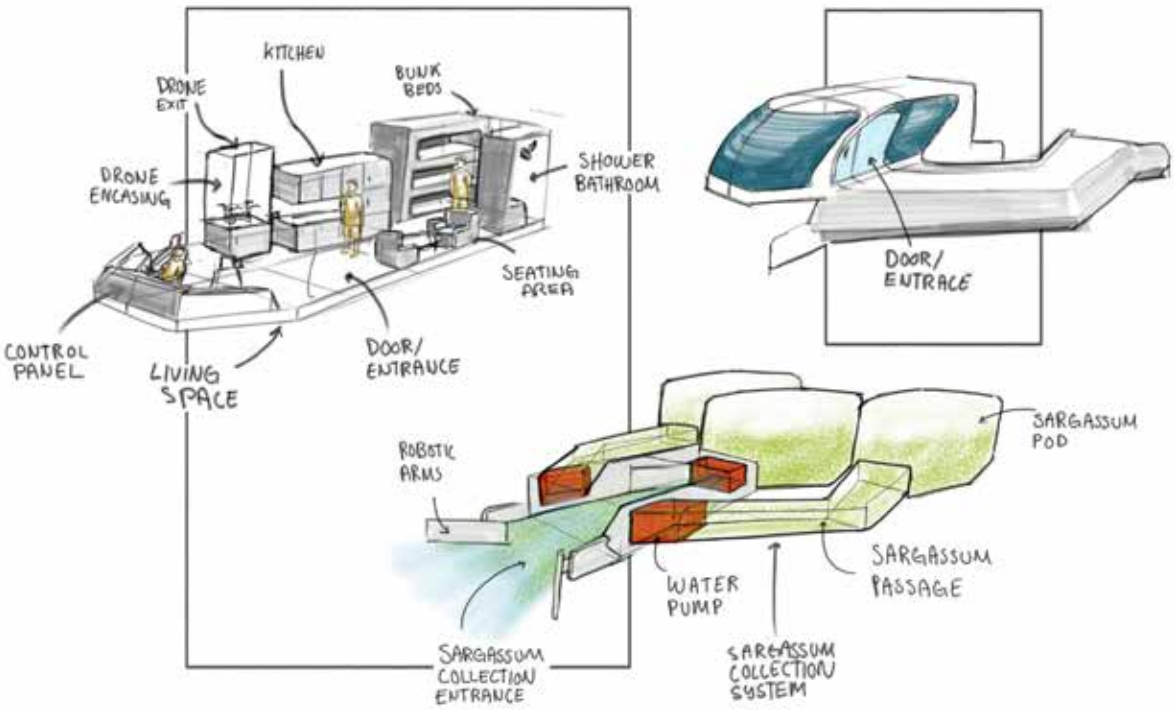

CONCEPT 1 - B
INTERIOR EAGLE VIEW
SARGASSUM COLLECTION EAGLE VIEW
PERSPECTIVE IN BETWEEN THE SARGASSUM PODS
SARGASSUM COLLECTION TOP VIEW & FLOW DIRECTION
MAXIMILIANO GARCIA



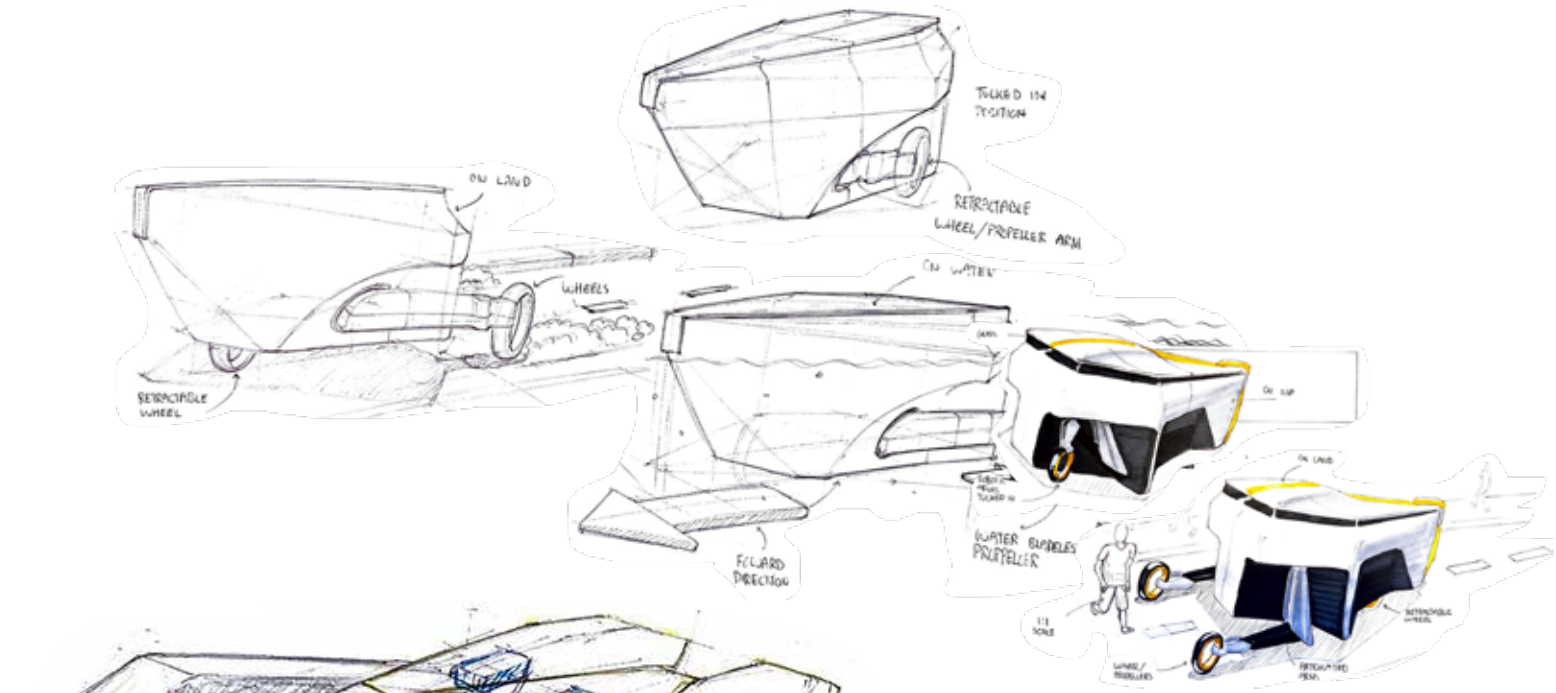

CONCEPT

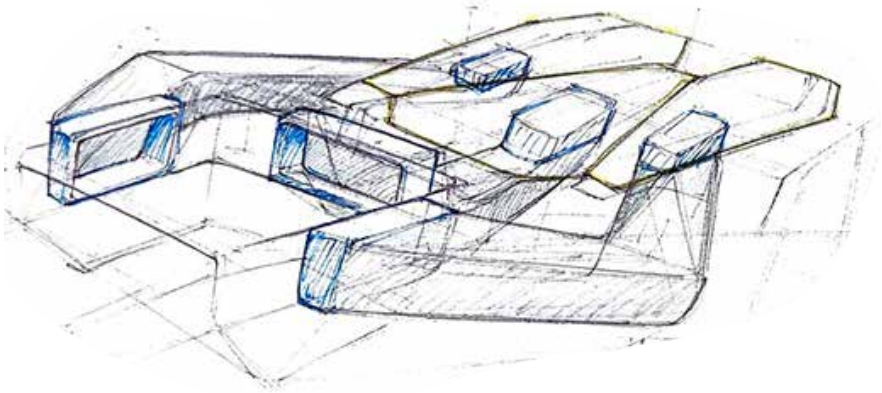


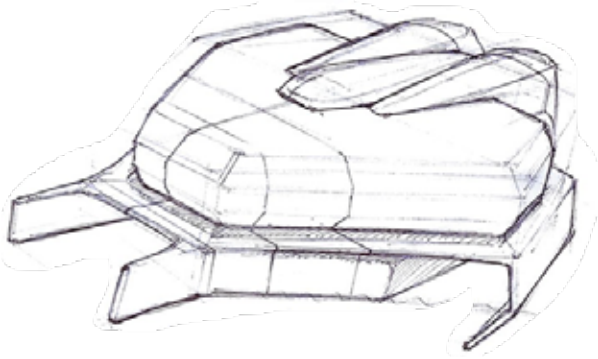


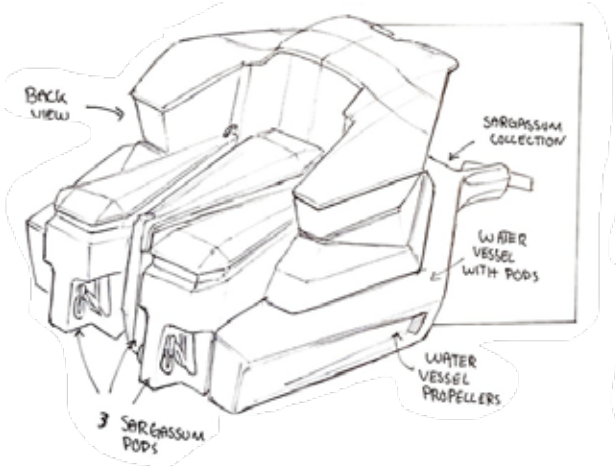

KITCHEN
DRONE EXIT
BUNK BEDS
DRONE ENCASING
SHOWER BATHROOM
SEATING AREA
CONTROL PANEL
LIVING SPACE
DOOR/ ENTRANCE
DOOR/ ENTRANCE
SARGASSUM POD
ROBOTIC ARMS
SARGASSUM PASSAGE
WATER PUMP
SARGASSUM COLLECTION ENTRANCE
SARGASSUM COLLECTION SYSTEM

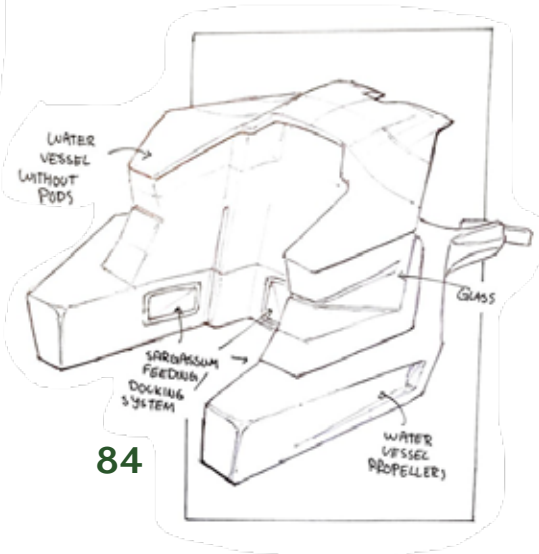
4.4 Detail Resolution

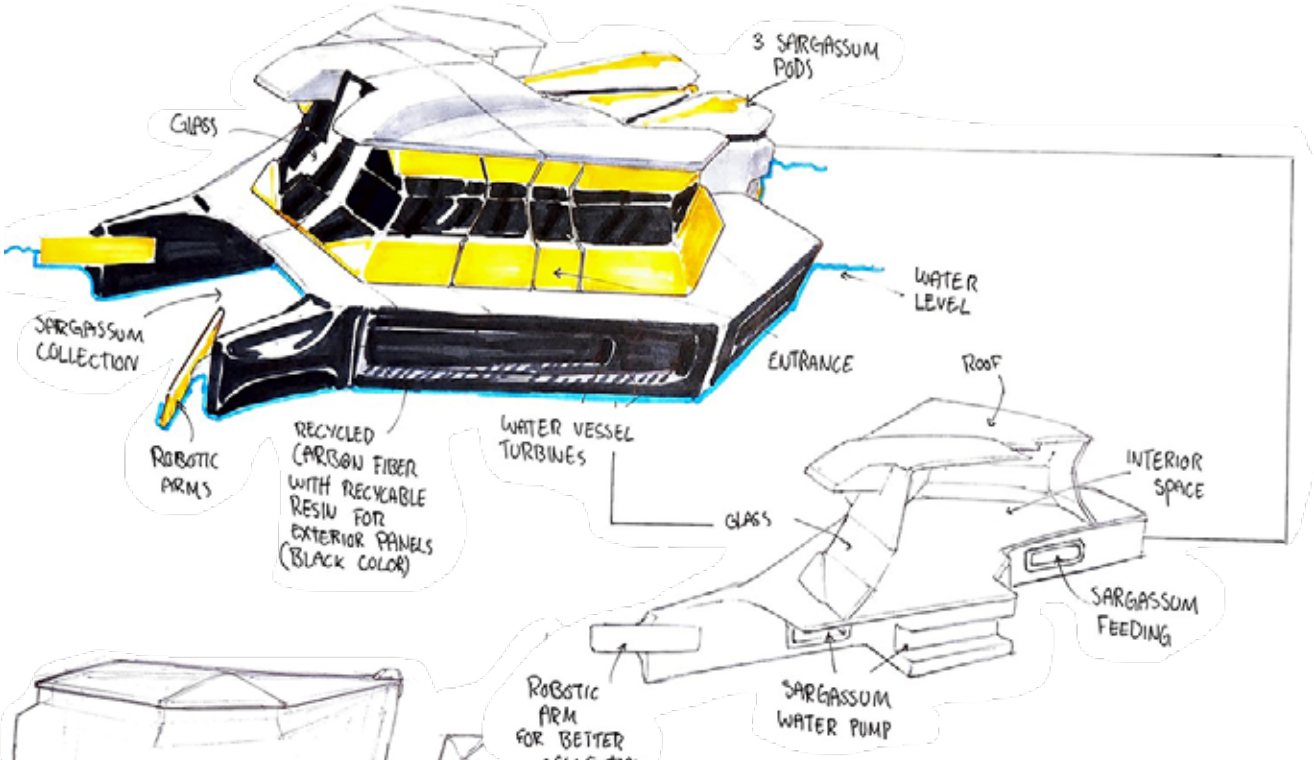


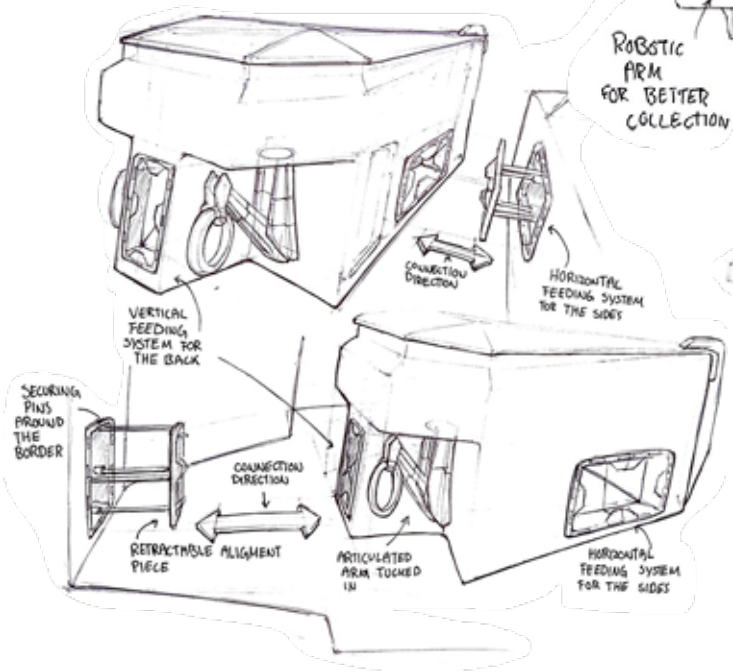


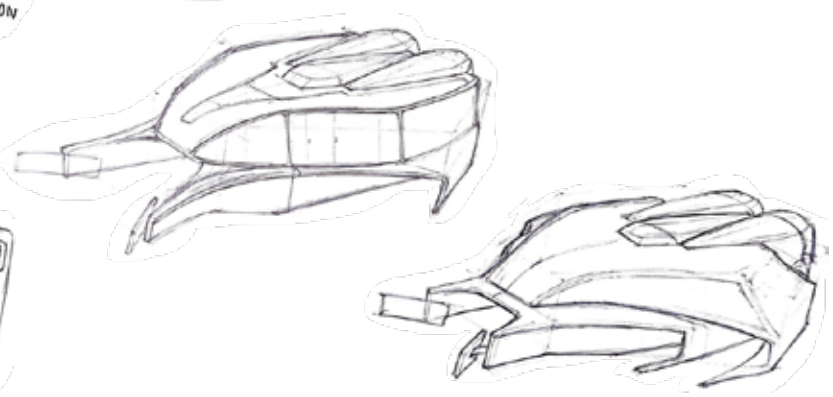


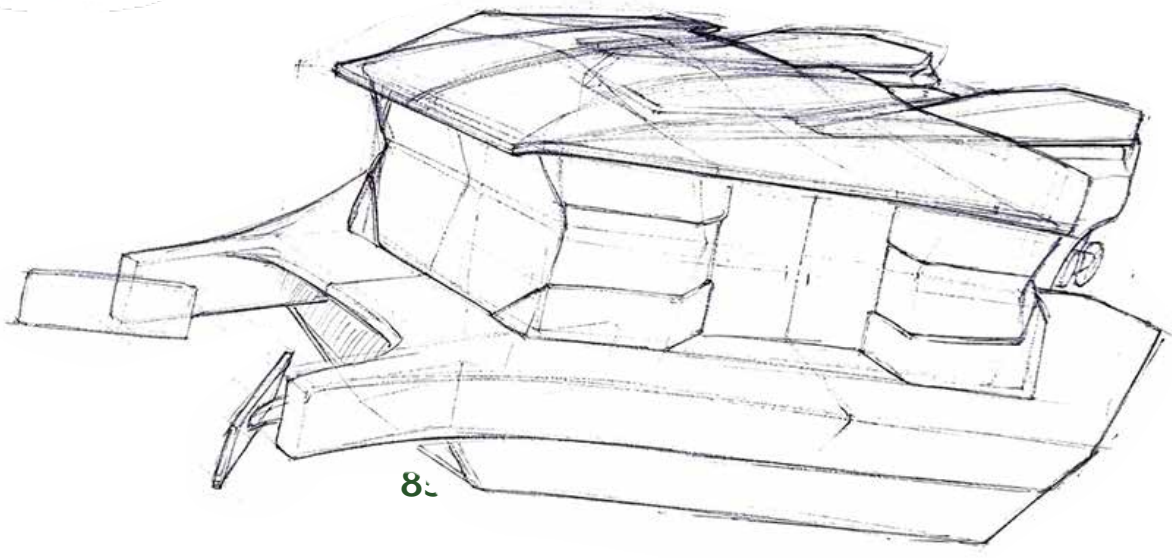




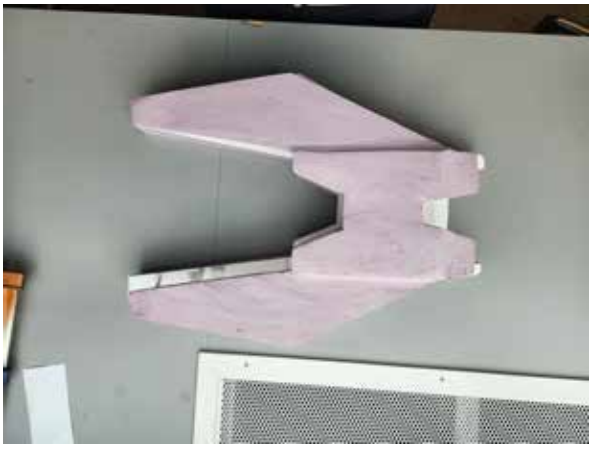

3 SARGASSUM PODS
GLASS
WATER LEVEL
SARGASSUM COLLECTION
ENTRANCE
ROOF
ROBOTIC ARMS
RECYCLED CARBON FIBER WITH RECYCABLE RESIN FOR EXTERIOR PANELS (BLACK COLOR)
WATER VESSEL TURBINES
INTERIOR SPACE
GLASS
SARGASSUM FEEDING
ROBOTIC ARM FOR BETTER COLLECTION
SARGASSUM WATER PUMP

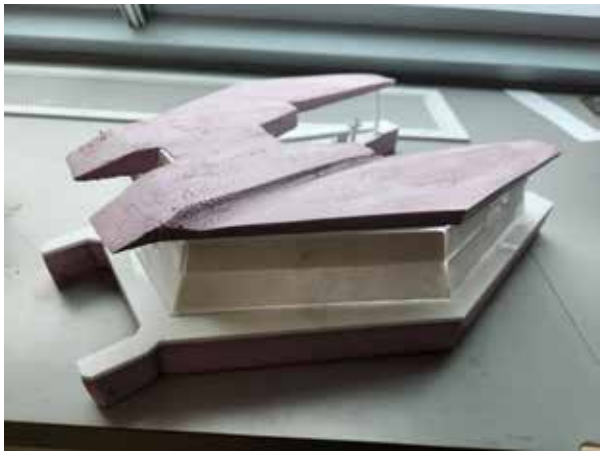

CONNECTION DIRECTION
HORIZONTAL FEEDING SYSTEM FOR THE SIDES
VERTICAL FEEDING SYSTEM FOR THE BACK
SECURING PINS AROUND THE BORDER
CONNECTION DIRECTION
RETRACTABLE ALIGNMENT PIECE
ARTICULATED ARM TUCKED IN
HORIZONTAL FEEDING SYSTEM FOR THE SIDES

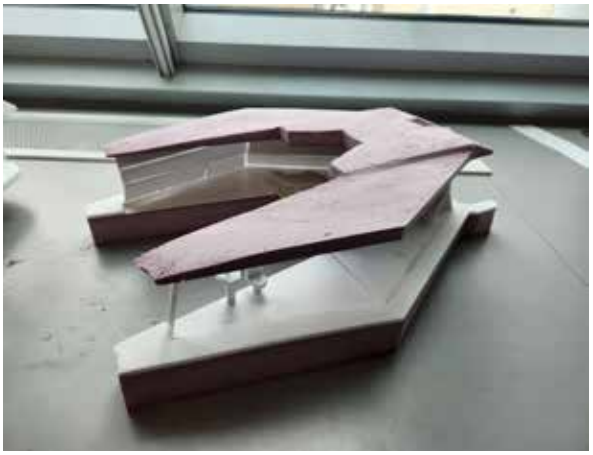


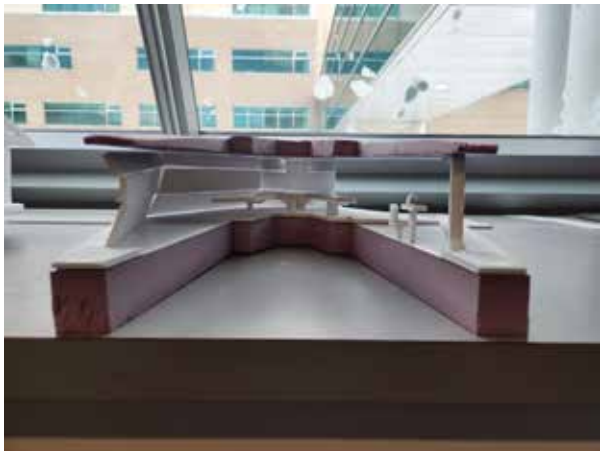


4.5 Sketch Models





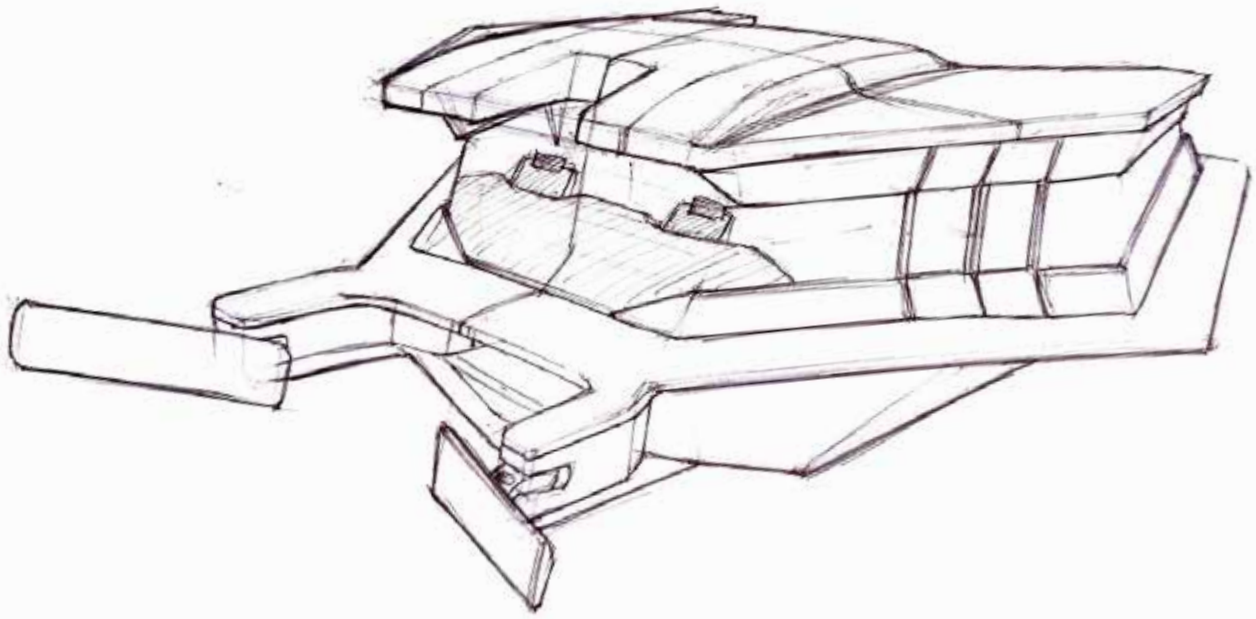




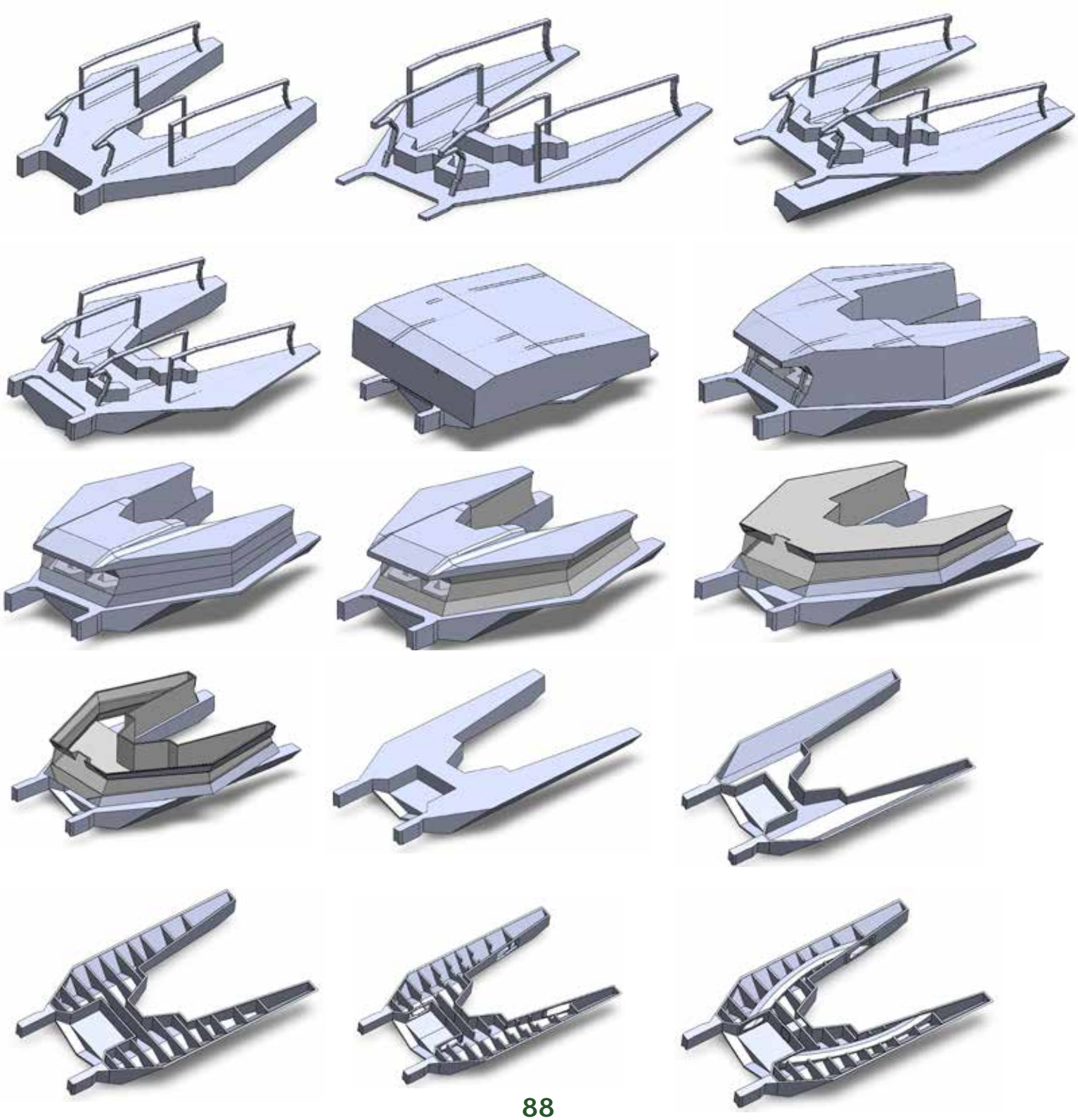
4.6 Final Design

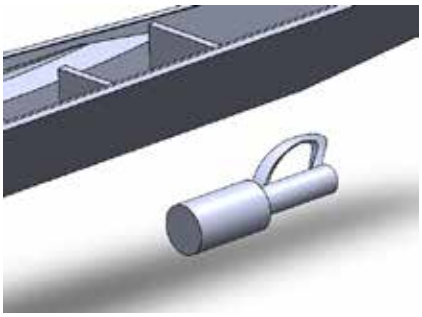
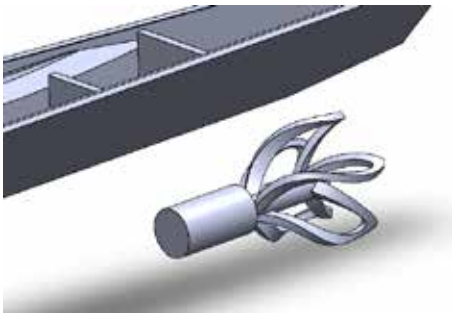
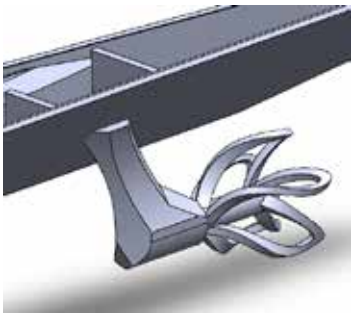
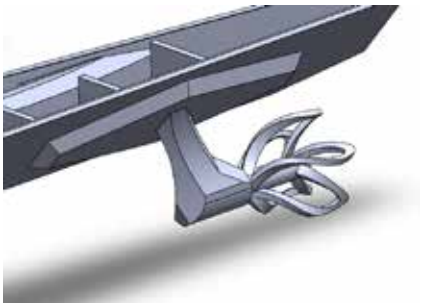
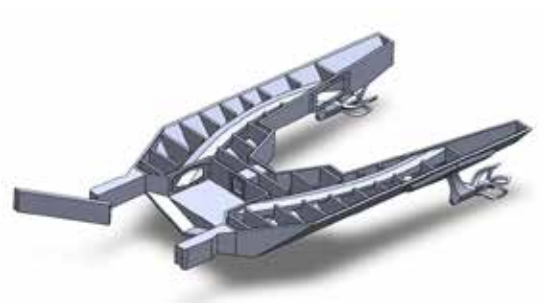
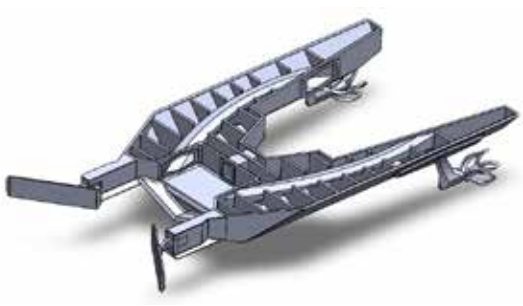
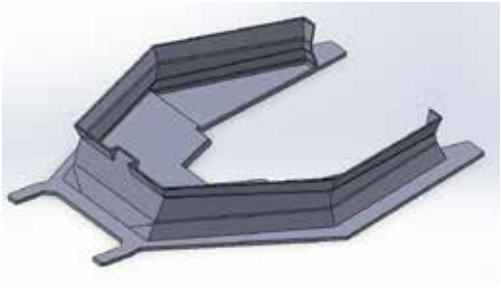
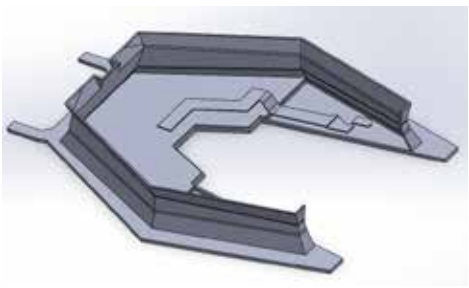
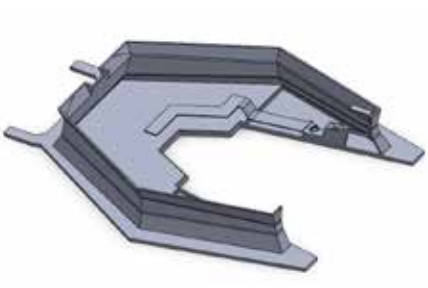
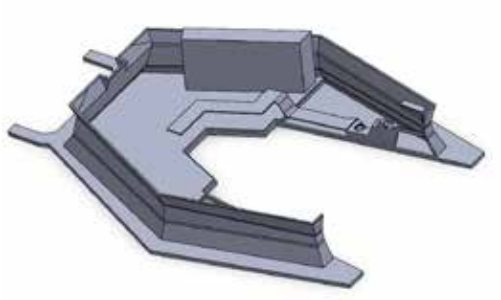
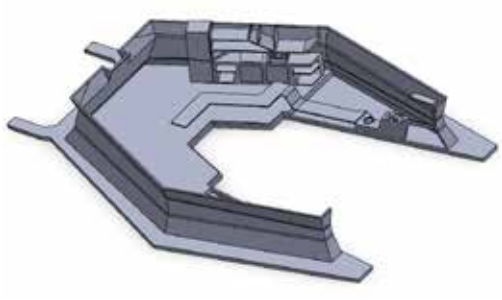
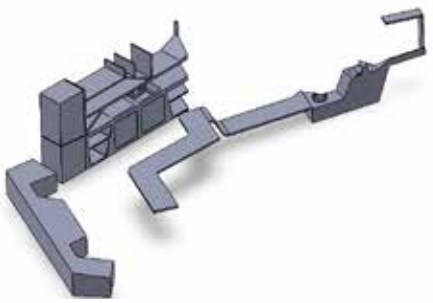
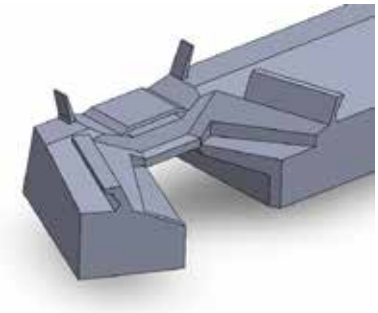
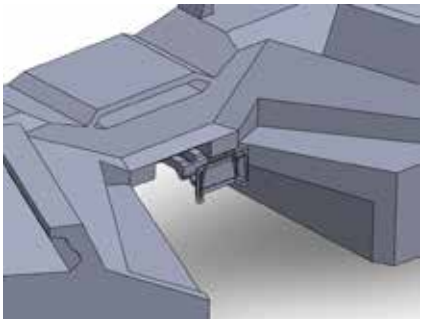
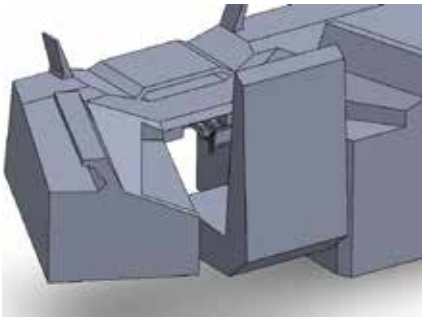
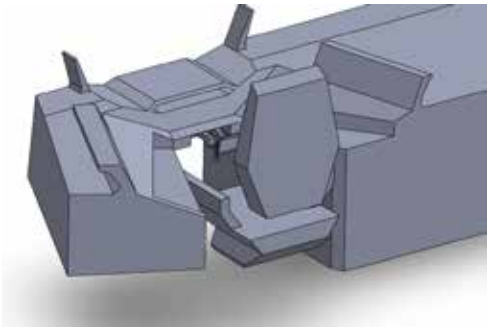
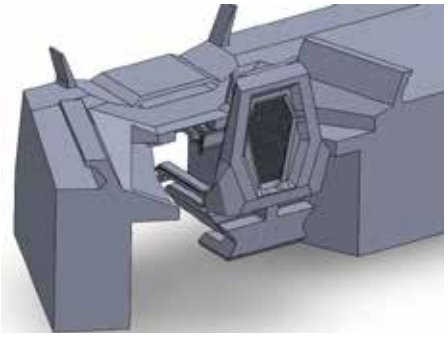
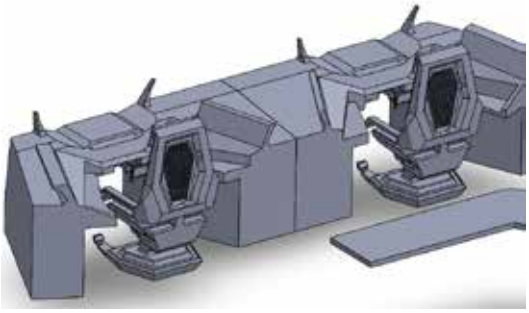
Starting from the initial sketch, the final concept of the water vessel was refined through a more detailed sketch. This final sketch was created to capture the aesthetic appearance and main purpose of the vessel, which was heavily influenced by the organic form of the Devil Sting Ray and its physical characteristics such as the cephilian fins at the front and the angular shape. The design was also meant to reflect the environment and location of use, which is in a tropical climate. Therefore, the choice of colors was carefully considered to ensure that the final product would not absorb sunlight, but instead bounce it off. Accent colors were chosen to represent the primary purpose of collecting sargassum or to match the Sting Ray's common color.

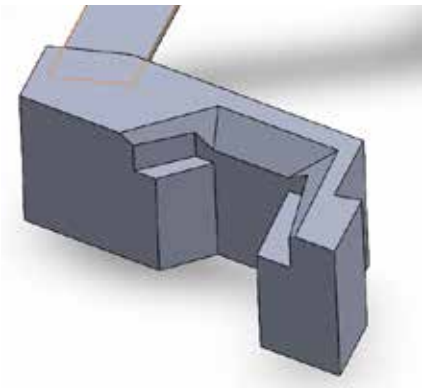
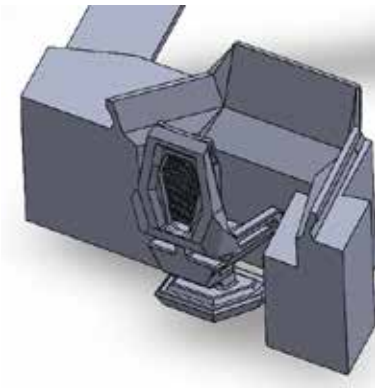
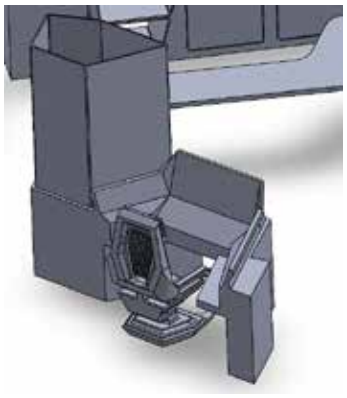
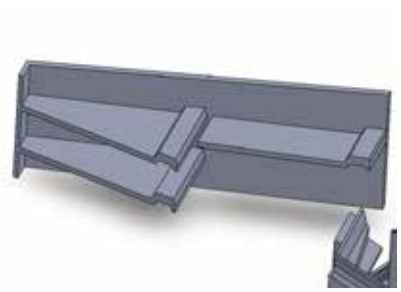
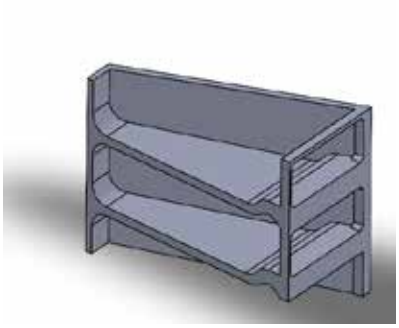
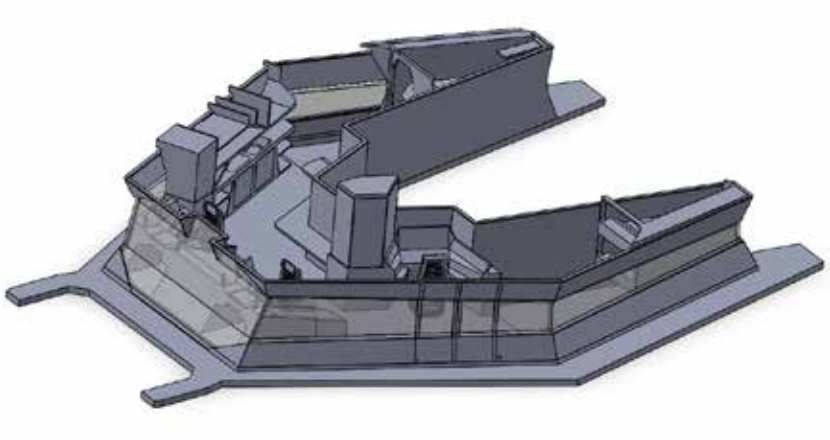
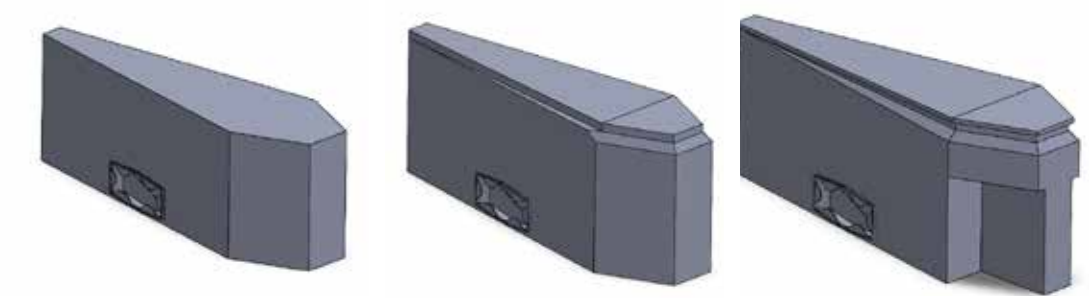
The water vessel was designed to have a glass component that surrounds most of the interior, allowing the sargassum workers to have a beautiful view of the ocean horizon and also to let natural light inside the vessel. As an additional development, there is a scoop-like design between the two robotic arms to enable the sargassum to enter the water pump collection area without getting stuck under the boat in case of accumulation. The overall design was inspired by a futuristic aesthetic to offer something new to the market.

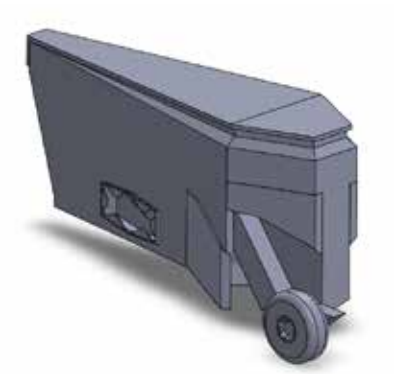
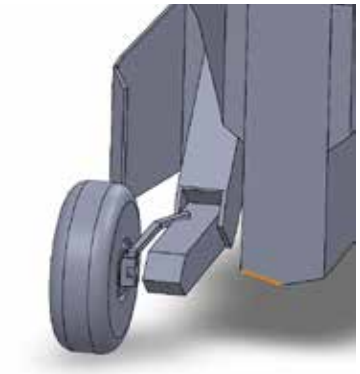
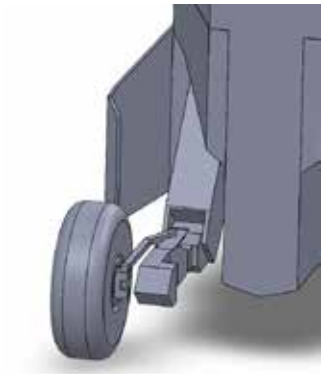
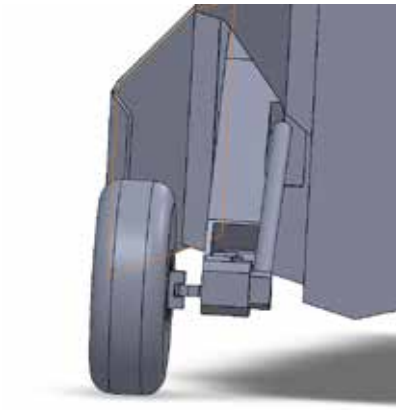
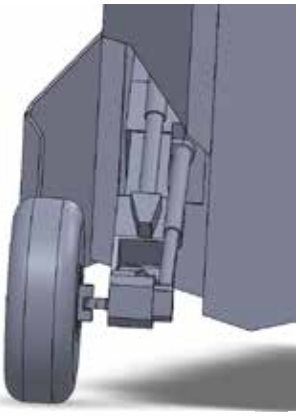
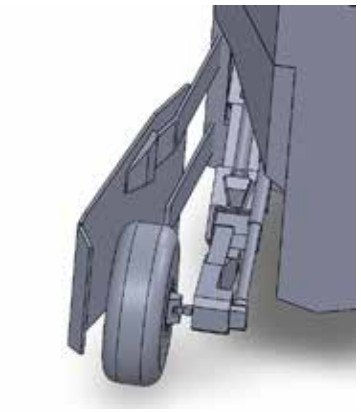
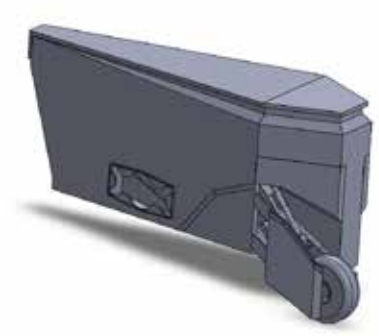
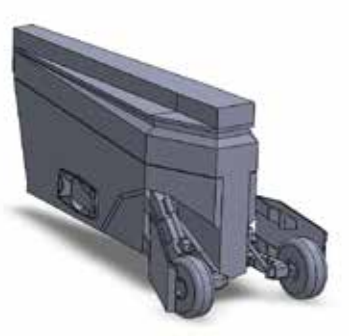
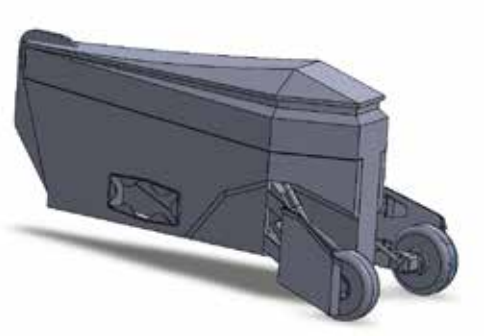
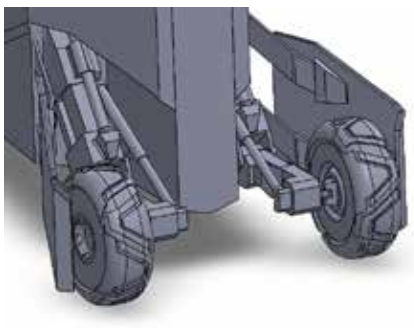
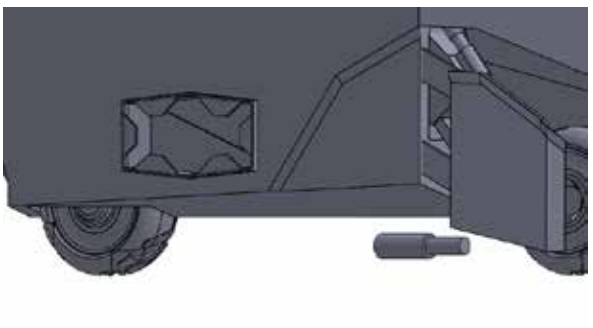
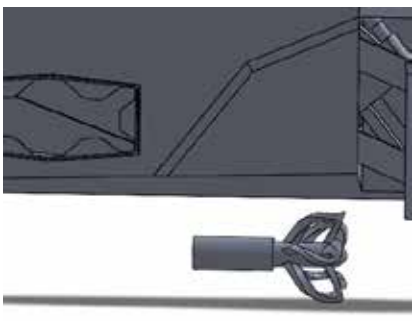
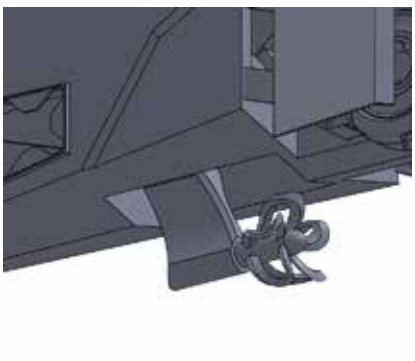
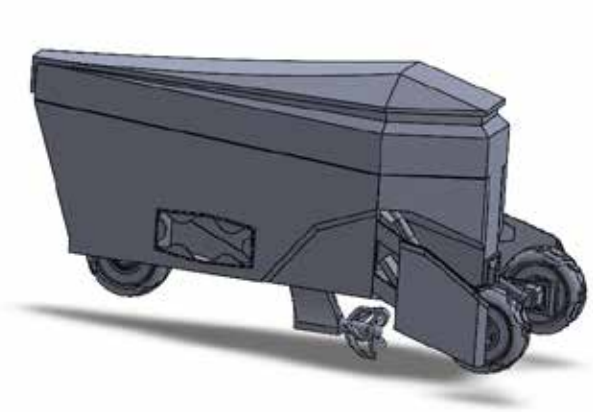


4.7 CAD Development

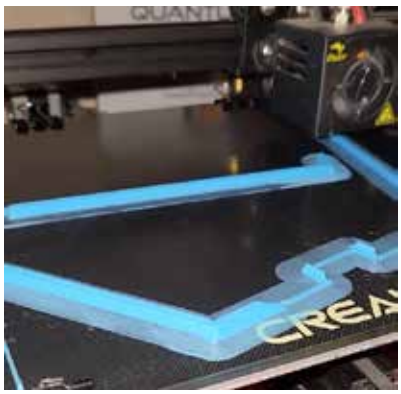


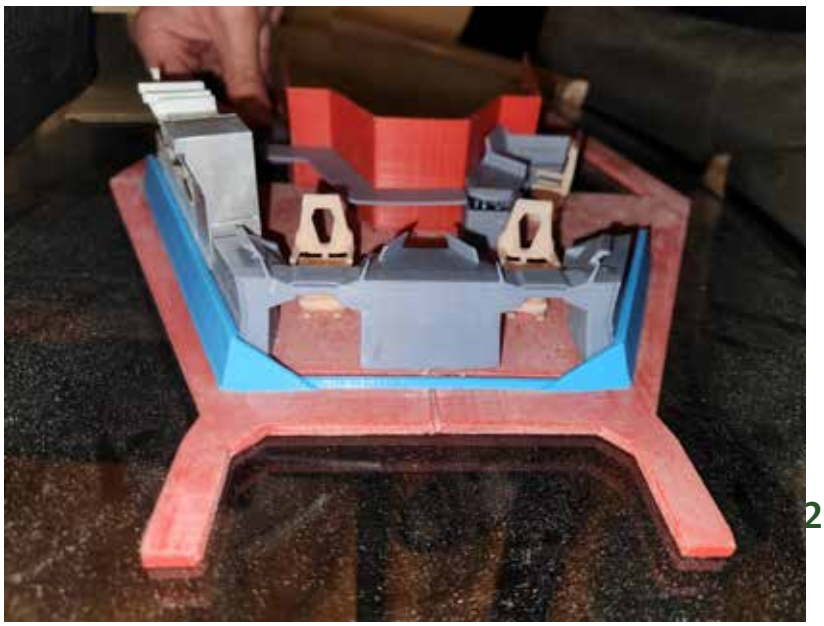



















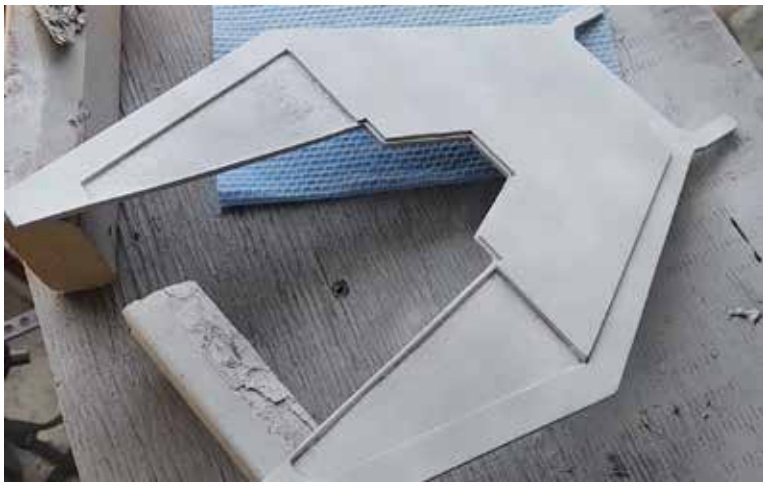








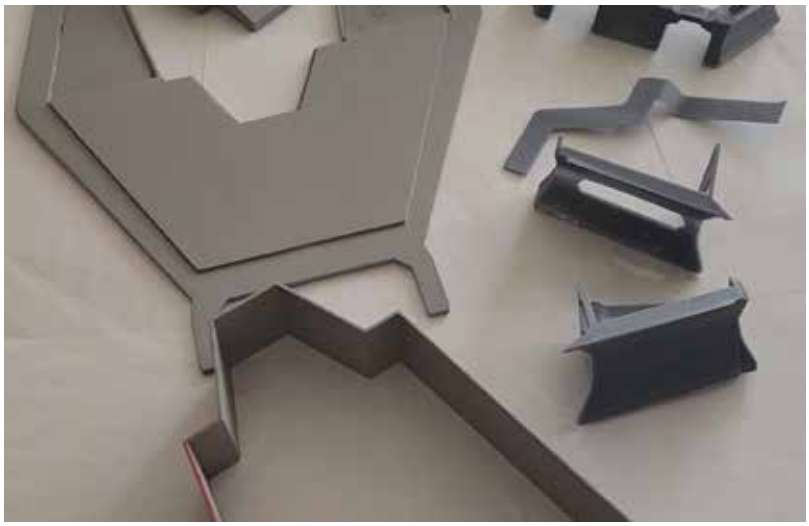
















4.8 Physical Model Fabrication









CHAPTER 5

FINAL DESIGN

5.1 Design Summary

5.1.1 Description

Mobula is a water vessel that focuses on collecting large patches of sargassum in the open ocean. These patches are found a few kilometres away from the shore. Multiple Mobula vessels covering large areas will act as gatekeepers from the Yucatan Current. This way the sargassum won't reach the shoreline or area with aquatic activities. The sargassum collected will be brought back to the shore to be converted to biofuel for the local region.

5.1.2 Explanation

The sargassum population has been increasing since 2011. More than 600 km of coastline has been invaded by sargassum in Mexico alone. Efforts to remove sargassum have been inadequate and inefficient. There are concerns about the current solutions and what harm they could bring. As of 2023, there are no proper ways of disposing of sargassum. When sargassum gets moved from the coastline to an unofficial dumping site, it releases harmful chemicals and decaying matter into the aquifer of the region. This can infiltrate and pollute the freshwater of the region. Some small businesses are reusing sargassum for consumer products. These are mostly artesian products. However, once sargassum reaches the shoreline and starts to decay, it's hard to reuse.

Mobula's efforts rely on collecting sargassum from the open ocean. This can guarantee that the sargassum is fresh and ready to be reused. The Mobula concept is aimed to be made for the year 2040. This futuristic concept requires an on-land plant to convert the collected sargassum to biofuel. As of 2023, there are biofuel plants located in different parts of Mexico using different organic matter to produce energy, so it is safe to assume that a sargassum plant could be built by then with the financial resources. The collection of sargassum in this concept will require the sargassum workers to stay in the living quarters for a few days of the week to minimize the back and forth from the land.

5.1.3 Benefits

Mobula allows the users to collect sargassum without any of the current pains and frustrations such as back pain, muscle pain, fatigue, headaches, nausea, skin irritation, or exposure to the sun and heat. Mobula has an automated water pump system that collects sargassum with ease. Sargassum workers only need to operate the vessel and control the collection system. The collected sargassum will be transported back to land using three pods. These pods are fully autonomous so there is no need for a worker to be driven back and forth. The pods are amphibious vehicles so they are able to work on water and on land.

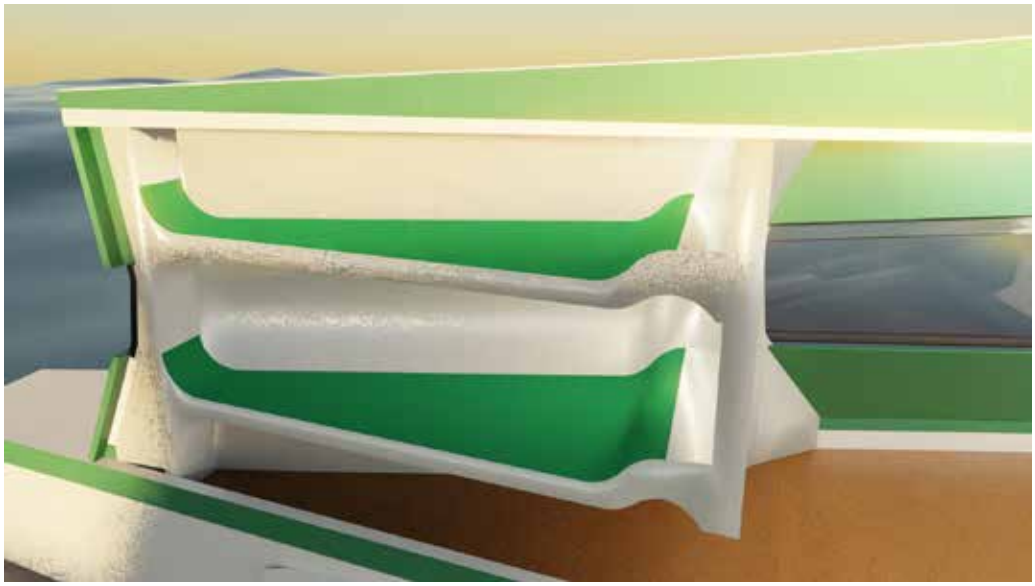
Mobula is included with drones and satellite technology that allows the vessels to communicate with other vessels and the control room on land. These communication systems allow the vessels to be synced with one other and locate large patches of sargassum. The drones are designed to identify sargassum, marine life, and litter caught inside the sargassum. The readings are shown to sargassum workers to keep track of how much marine life and litter is collected along with the sargassum.

Once the sargassum is brought back to the plant, workers are meant to separate the litter and marine life caught inside the sargassum. The sargassum will go through a pre-treatment and then to a process that will convert it to bio-energy, and that energy will power the Mobula vessel, the pods, and the local region. The green initiative will bring more businesses and tourists to the area as well as green energy.

5.2 Design Criteria Met

5.2.1 Full Bodied Interaction Design

Mobula's final design meets the criteria required for a full-bodied interaction design, human ergonomics, enhancement of human life, and sustainable design. Inside Mobula, the user is able to interact with everything in their surrounding. Within the interior, the user is able to spend a few days and nights in the open ocean collecting sargassum to minimize the back and forth from the land. In addition to the control panels for both the vessel and the drone, the interior includes a tower bed that can accommodate two people per shift. The main idea is to have at least three to four people working inside Mobula and rotate the use of the beds depending on the shift. This could allow the Mobula to be working 24 hrs efficiently.



A kitchen setup that allows the user to prepare their daily meals. This includes a sink, a stove, a fridge with a freezer, and shelves for storage and easy access. A wooden counter for eating or working also turns into a sitting bench around the corner. Lastly, a small bathroom with the essentials; a shower, sink, and toilet. The bathroom has a window that introduces natural light and the user can open or close it to see the sea horizon.

Human ergonomics was taken into consideration when designing the major component inside the interior. These major components are the equipment that the user will be interacting with the most. This includes the control panel, the chairs, and the tables. The male user percentile ranges from 5% to 99%. The measurements for each interior component were worked around these percentiles to accommodate a range of male users. The control panel has a wrap-around design to allow the user to use the controls on the front and the sides of the chair, this way all the controls are within comfortable reach and range of motion. The beds have an integrated headrest to accommodate a comfortable side sleeping position. Even though the bed shape is a triangle, there is enough space to accommodate a 99-percentile male.

The interior layout is designed within the bounds of the exterior shape. The exterior shape was inspired by the Devil Sting Ray. The main characteristics that were taken from this marine animal were the two cephalic fins in the front and the angular body shape. This influenced the exterior design and, therefore, the interior layout into angular living quarters. The living quarters are designed with the user in mind, therefore there is enough space to move around. Inside the interior there are wooden pieces that combined with the green and white colours, create a tropical and natural atmosphere that will bring calmness and peace to the workers since they will be staying on board for days at a time. The glass was designed in a way that surrounds the entire vessel to include a beautiful view of the ocean for the users and introduce natural light. It's important to design around their mental health as well.

5.2.2. Materials, Processes and Technology

As mentioned in previous sections, the materials and manufacturing processes need to be sustainable and environmentally friendly in order for Mobula to make a positive impact when collecting sargassum. In this case, there are three main areas in which to implement the sustainable practice, these areas are the water vessel built, the interior built, and each pod built. Since this is an industrial design complex manufacturing project there needs to be adequate research from an engineer's perspective in order to be accurate. However, the general outline should be enough to express the idea of the materials required for this project.

The exterior of the vessels includes the hull, the inside of the hull, the collection system, the platform, the exterior walls, and the roof. These major components should be made with weather-resistant, wear-resistant, corrosion-resistant, and anti-fouling characteristics since they are in constant contact with seawater, and the warm tropical climate of the region. These materials can be recycled carbon fibre with recyclable Elisum epoxy mentioned in previous sections. The mechanical and electromechanical components are difficult to express with the current resources; however, the general idea is to include a bio-fuel engine

that will allow Mobula to move efficiently on the water, a water pump collection system run by bio-energy produced electricity or bio-fuel, and two robotic arms at the front that control the amount of sargassum being collected will need to be made bio-energy produced electricity as well.

The interior materials include common furniture materials, as well as electronic components for the control panels. These can be made from recycled plastic, recycled synthetic fibres, natural fibres, or hybrid fibres. In order to have a functional kitchen and bathroom, all the discarded organic matter can be stored inside the vessel until they reach land to be properly discarded and cleaned out. All opportunities for recycling will be taken into account; for example, shower water and sink water can be recycled into the toilet water.

The pods are similar to the exterior in terms of the materials used; however, the interior has able to hold a lot of sargassum as well as keep it from decaying. A possible process could be to integrate a pre-treatment inside the pod so that by the time it reaches the plant it could be ready to use. The material inside the pods is still unknown. Inside the pod, there must be enough space for an electromechanical autonomous base, a propeller, a back wheel, and two robotic articulated wheels. These components retract and are stored inside the pod when they are not in use. The general idea for materials for these components is recyclable and durable metals.

5.2.3 Design Implementation

As mentioned above, Mobula is a complex design solution that integrates multiple parts and components. These parts and components are large enough to have their own subparts list. Mobula is considered a combination of an industrial litter collector machine and a small yacht. The main purpose of this concept design is not to have a luxurious environment but to have a comfortable and aesthetically pleasant interior. The main purpose is to collect and transport the sargassum from the ocean to the plant.

This means that Mobula has a sum of the components found in a yacht and an ocean litter collector machine. Finding every single component is beyond the purpose of this design thesis project, considering how complex the final solution is. The futuristic projection of Mobula means that there isn't technology required for its construction yet. However, there is an estimate based on the components that are currently in the market both from a litter machine and a yacht. The following table shows the bill of materials for Mobula:

Exterior built

Item	Quantity	Estimated Price
Hull (recycled carbon fibre with recyclable Elisium epoxy)	1pc	$10,000 - $20,000
Deck (Sandwich Steel with honeycomb interior)	1pc	$5,000 - $10,000
Mast (aluminum)	1pc	$2,500 - $5,000
Engine (bio-diesell)	2pcs	$10,000 - $20,000
Fuel tank (aluminum)	1pc	$500 - $1,000
Fuel lines and filters	-	$500 - $1,000
Electrical system	-	$2,000 - $5,000
Plumbing system	-	$2,000 - $4,000
Steering system	1pc	$1,000 - $2,000
Anchor (stainless steel)	1pc	$500 - $1,000
Chain and rope	1 set	$500 - $1,000
Safety equipment	6 pcs	$1,000 - $3,000

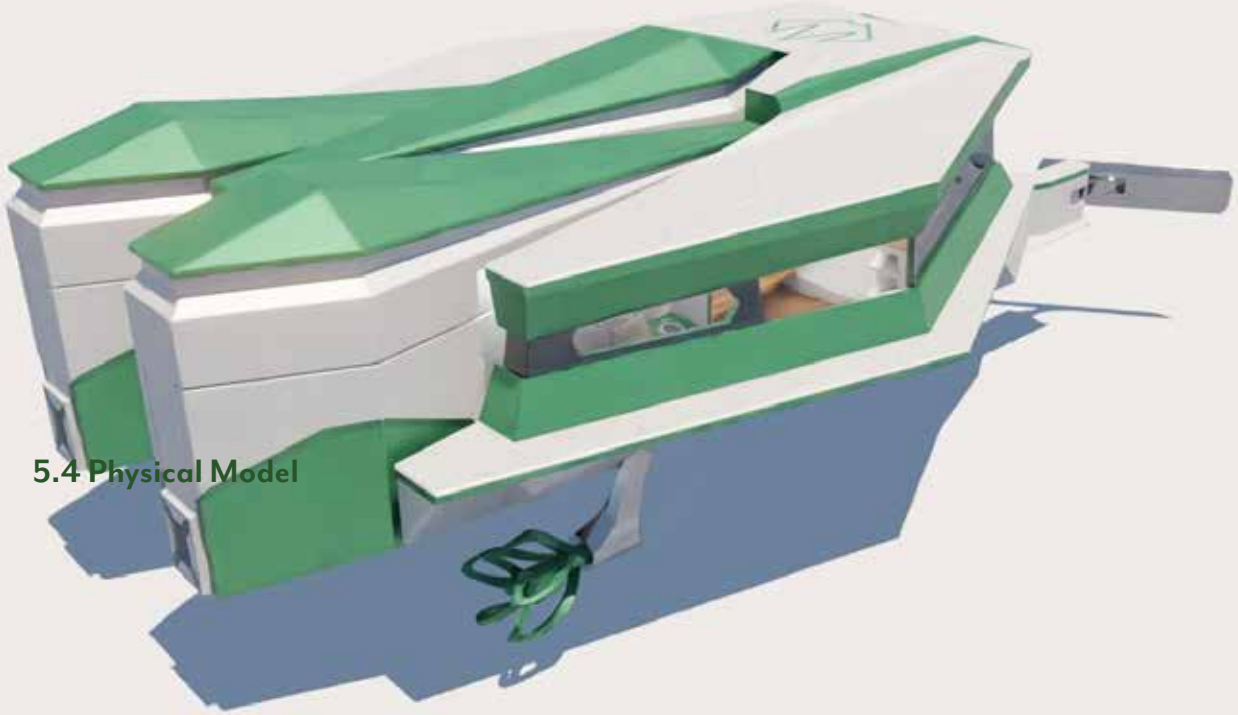
5.3 Final CAD Rendering

Interior Built

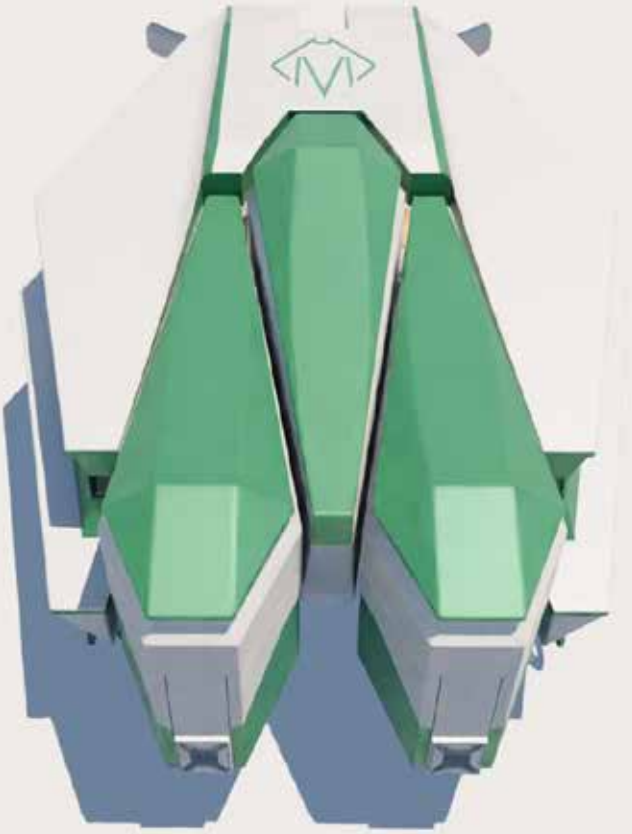
Item	Quantity	Estimated Price
Teak Wood Flooring	500 sqft	$10,000.00
Henequen Upholstery	60 sqft	$3,000.00
Walnut Countertops	30 sqft	$4,500.00
Stainless Steel Sink	1 pc	$500.00
LED Lighting	20 pcs	$1,000.00
Sound System	1 set	$1,000.00
Fridge	1 pc	$900.00
Custom Shelving	1 pc	$1,500.00
Recycled Plastic Bathroom Counter-tops	1 pc	$200.00
Bedding (Henquen and Bamboo)	2 pcs	$300.00

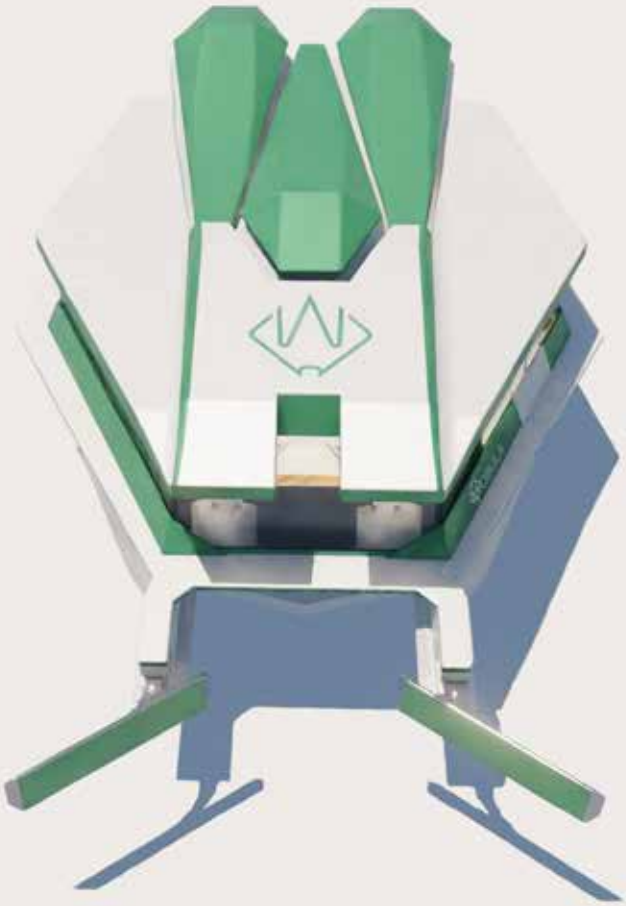
Collection System Built (Both Exterior and Interior)

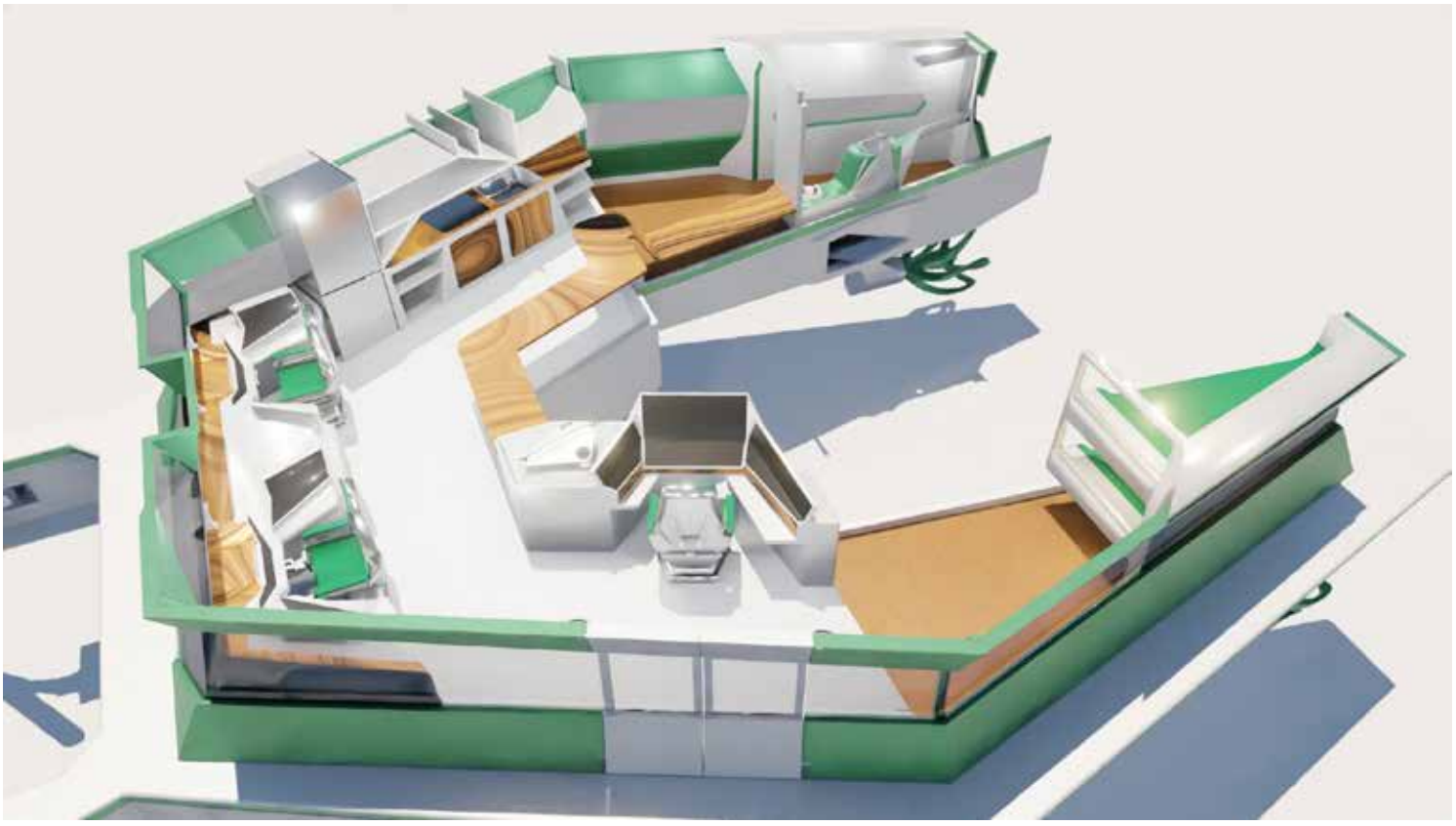
Item	Quantity	Estimated Price
Stainless Steel Frame	3pcs	$6,000.00
Submersible Large Industrial Water Pumps	3pcs	$10,000.00 - $50,000.00
Bio-Energy and Battery	1pc	$6,000.00
Control and Monitoring System	1pc	$3,000.00
Robotic Arms	2pcs	$10,000.00
Drone	2pcs	$10,000.00

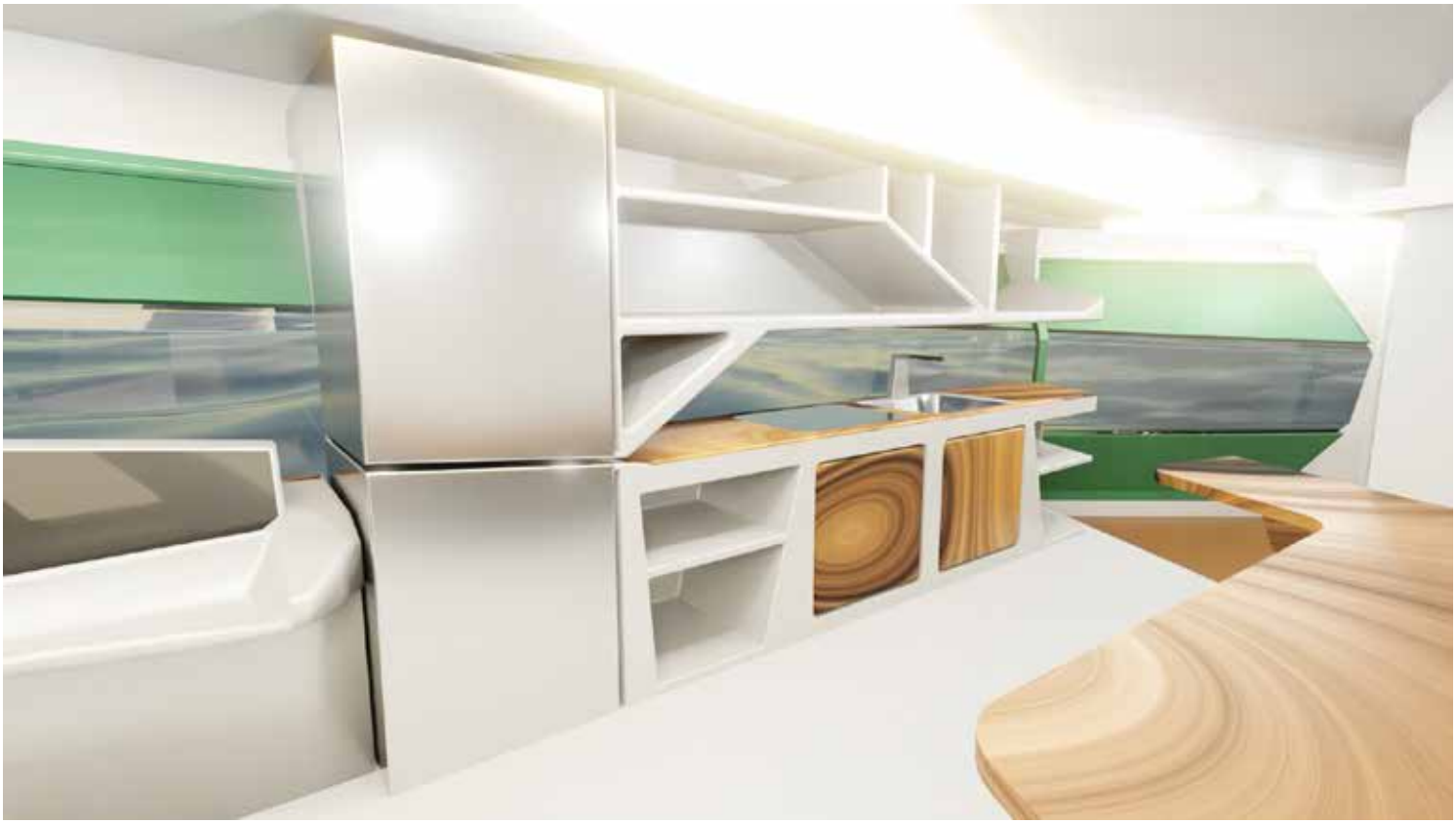


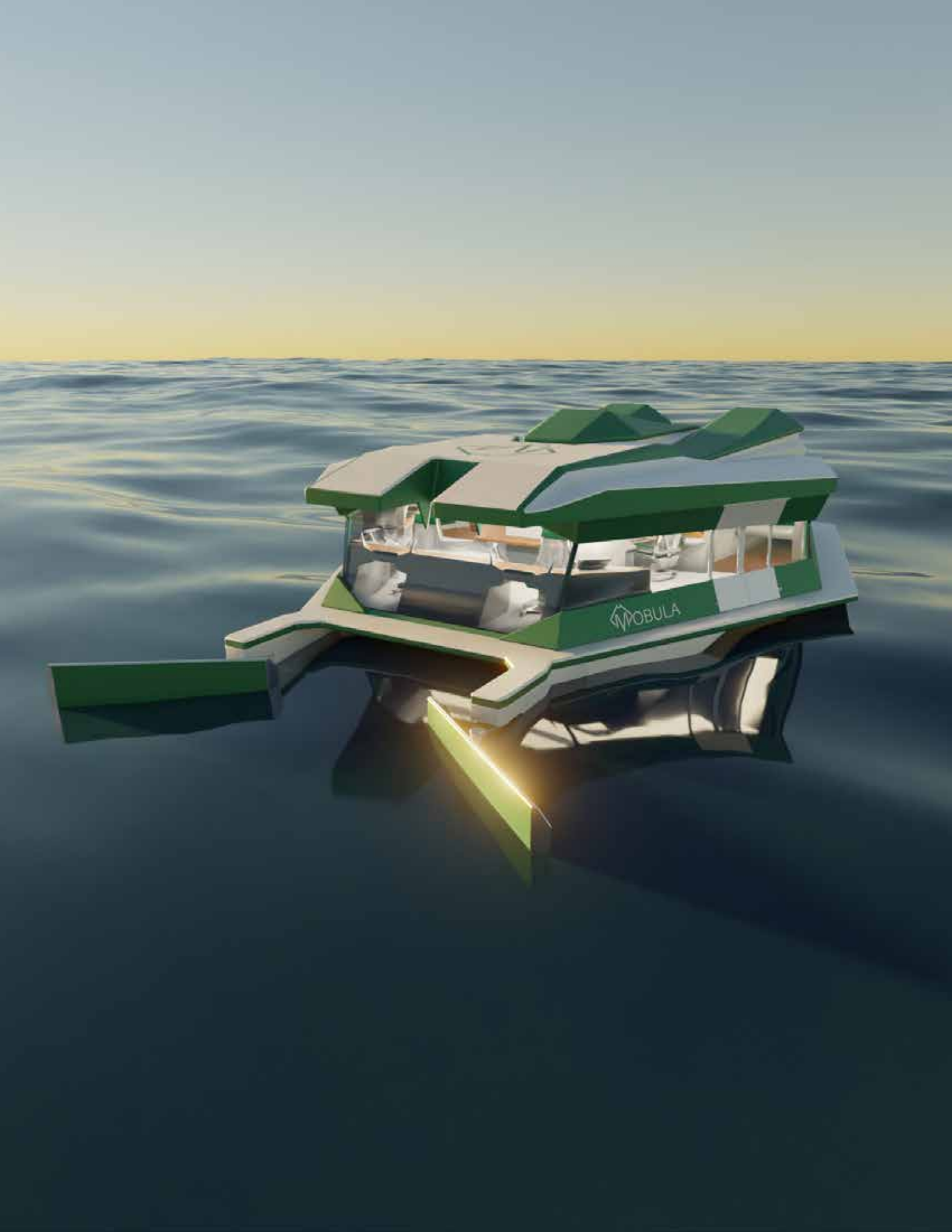
5.4 Physical Model

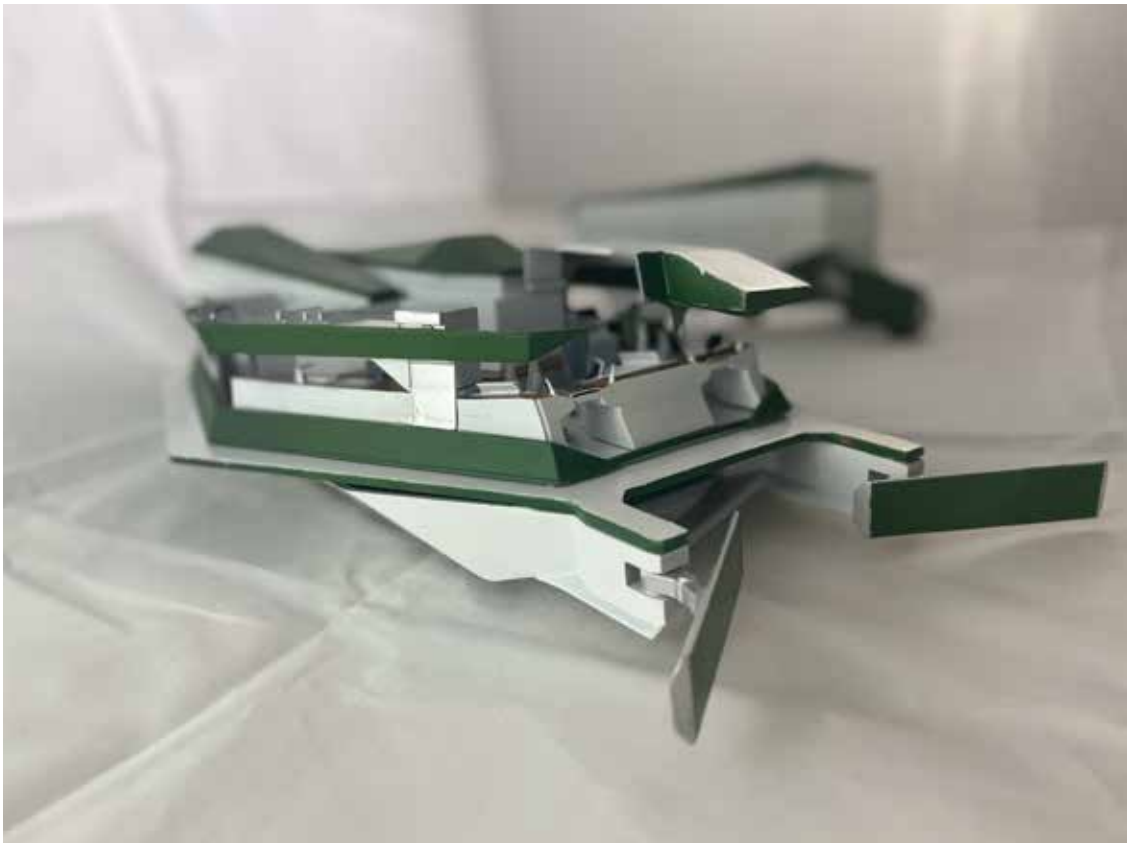


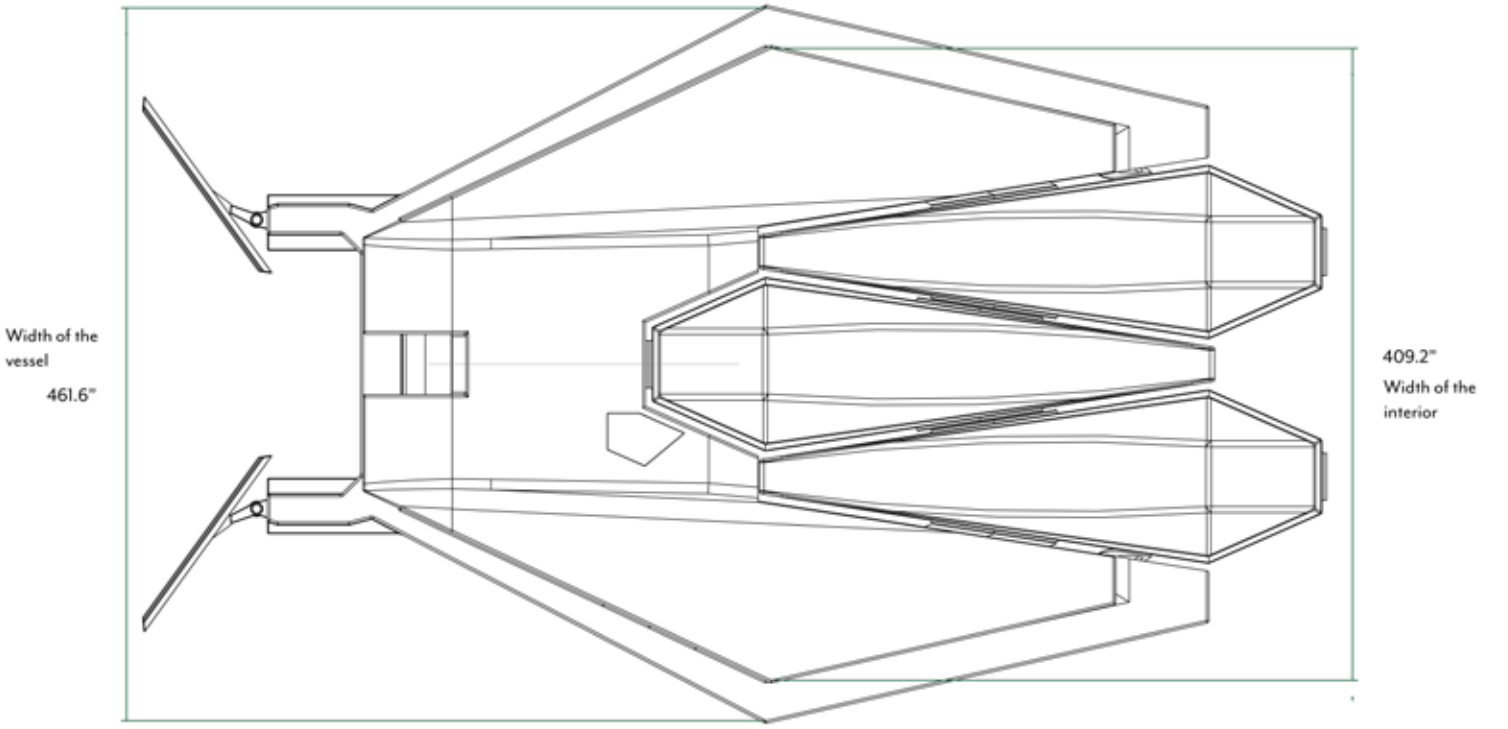


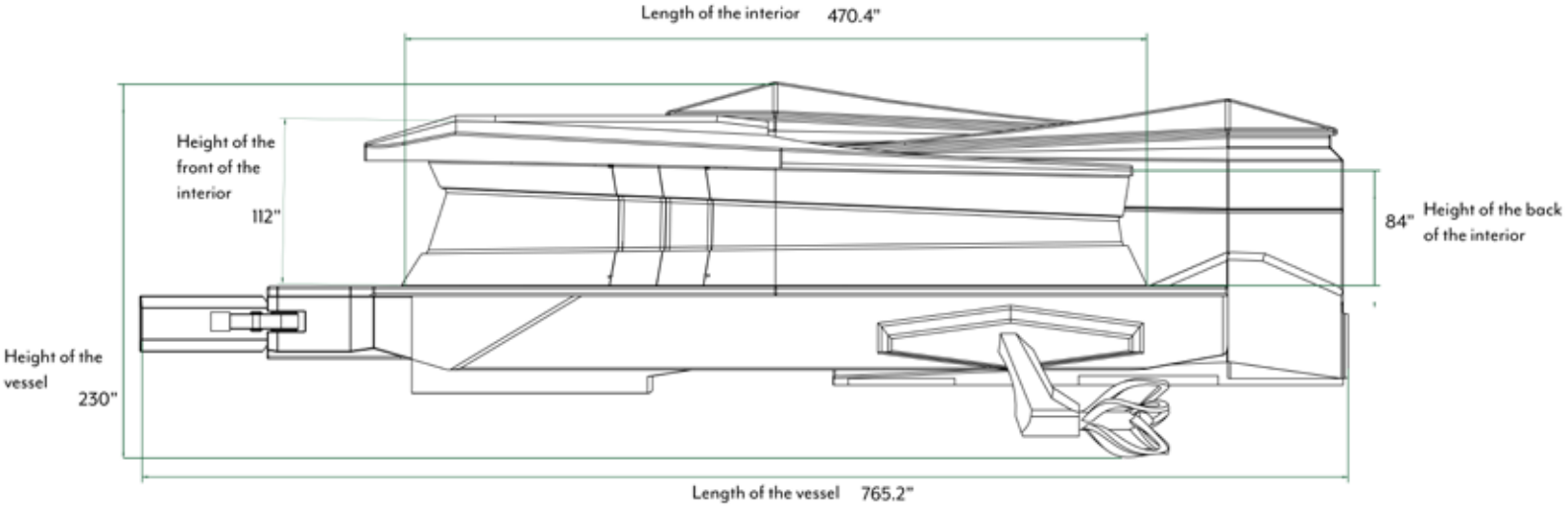


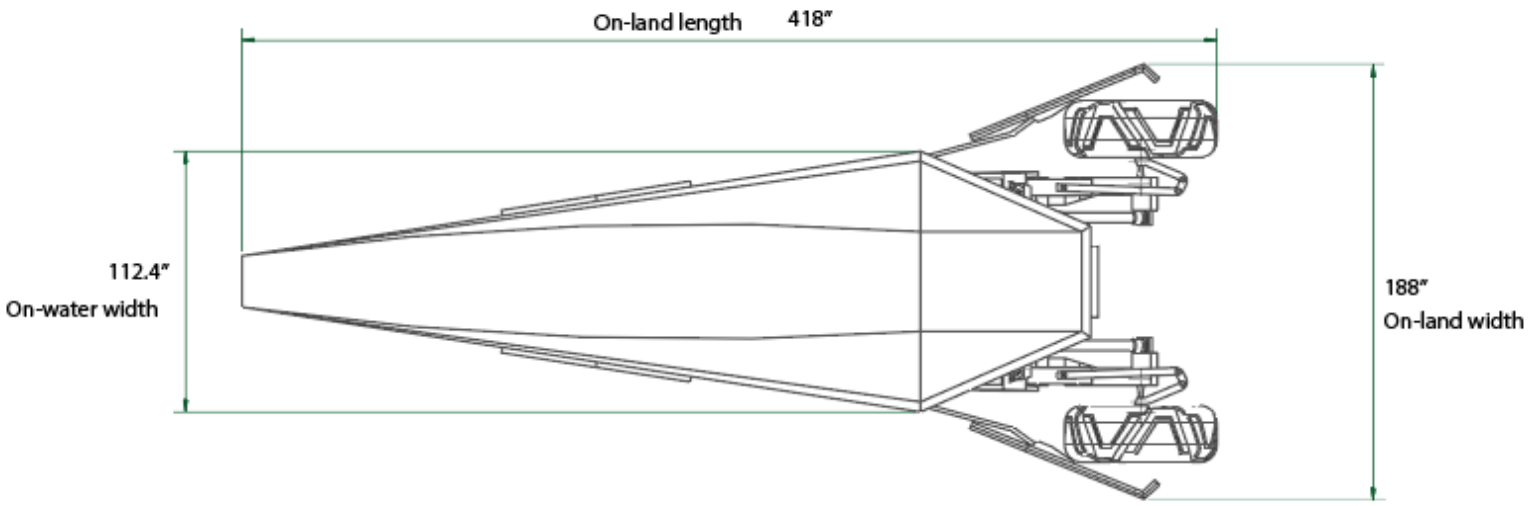


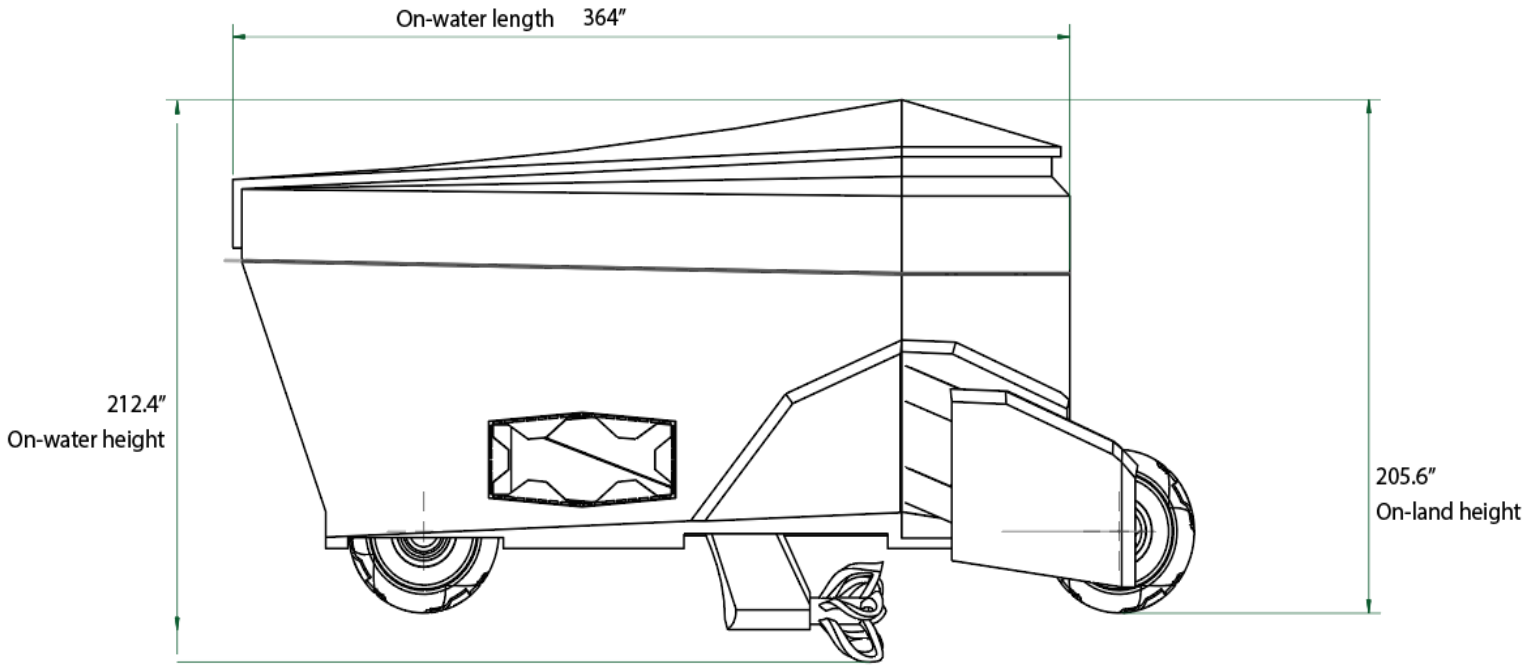

MOBULA




Width of the vessel
461.6"
409.2"
Width of the interior


Length of the interior 470.4"
Height of the front of the interior
112"
84"
Height of the back of the interior
Height of the vessel
230"
Length of the vessel 765.2"


On-land length 418"
112.4"
On-water width
188"
On-land width


On-water length 364"
212.4"
On-water height
205.6"
On-land height

5.6 Sustaintability

Proposed Sustainability Statement For Thesis Project

The main objective of this thesis project is to restore the ecosystem and tourism industry on the Mexican Caribbean coast. Dr. Legena Henry and her team from the University of the West Indies (UWI) presented the possibility of sargassum being transformed into biofuel "using sugarcane waste – a by-product of rum production" and power vehicles in Barbados. (Giovanni, 2022). Giovanni (2022) summarized the presentation that Dr. Henry gave at the SDSN's inaugural Global Solutions Forum (GSF) in September 2019 in New York, she stated the following:

"At present, the goal is to determine how much biofuel can be reasonably produced and sold at refuelling stations throughout the island. From the experimental results, it was calculated and projected that one year of transportation in Barbados requires 685,304,000 litres of rum distillery waste and 105,759 tons of fresh sargassum. If implemented successfully, this alternative combustion method can avoid as much as 1 million metric tons of CO2 emissions every year in the country."

"Bio-methane can cheaply and easily power electric grids and vehicles."

Figure 23 illustrates the possibility of a biofuel station to power vehicles. Source: https://rumandsargassum.com/story/

"A regular internal combustion engine gasoline-powered vehicle can be upgraded with a CNG kit in 4 hours and drive fully on biomethane." (Giovanni, 2022).

Figure 24 illustrates the possibility of a biofuel station to power vehicles. Source: https://rumandsargassum.com/story/

With further research and advancement of technology, the “Mobula” vessel can be 100% powered by sargassum as biofuel. This includes the water vessel as well as the amphibian pods. Using engines that consume biogas, it will allow the pods to transport the collected sargassum to the Sargassum Biogas Plants where it can provide renewable energy for the local region.

In addition, in order to reduce the carbon footprint, both the water vessel and the pods need to be made from sustainable materials. The intent is to have body panels made from recycled carbon fibre and Elisium resin technology that allows the panels to be recycled once it reaches their end-of-life. Vacuum bagging the carbon fibre with the moulds is the most suited method to create the panels. The plastic used for vacuum bagging will need to be recyclable and reusable in order to be a sustainable practice. Steel, aluminum or wooden materials will be used as support structures. Normally, the choice of these materials depends on the purpose and intent of the vessel. In some cases, lighter materials are preferred if the vessel is intended to go fast or aims to reduce energy consumption.

The fitting of the mechanical components, such as the water pumps, will need to be stainless steel with a coating of protection against corrosion, wear, and anti-fouling. The interior will be using natural fibre,

as it is 100% biodegradable, in areas where there won't be too much mechanical stress on the material. This can be shelves, bedding, chairs, control panels, handles, insulation, etc. Henequen is a plant that is naturally grown in Yucatan, Mexico and their fibres are known to be used in different consumer by-products such as ropes, hats, rugs, handbags, shoes, the upholstery of furniture, room dividers, etc.

This section explored the different types of materials used in the boatbuilding industry and sustainable materials used by a few companies. The boatbuilding industry is in need to develop more sustainable solutions for materials to reduce the environmental impact. Based on the research, proposed materials and methods were explored to be applied to this thesis project. Lastly, in addition to the material proposed for the exterior and interior, the business model is 100% sustainable by using the sargassum collected as biofuel to power the water vessel, collection pods, and the affected local regions.

CHAPTER 6

CONCLUSION

6.1 Conclusion

To conclude, the sargassum influx along the Mexican Caribbean coastlines has become a significant issue since 2011. The continuous human intervention to the environment has caused an increase in sargassum that collects in large quantities and affects the marine life. It is important to have a resilient solution to this problem since sargassum is not going away. The potential use of sargassum as ingredients for consumer products can provide an opportunity for local business owners to repurpose it and turn a problem into an opportunity. However, proper disposal or pre-treatment is necessary to make it safe for consumer products and the environment. The current cleaning efforts have not been sufficient, and urgent measures of prevention and mitigation are needed to avoid harm to the coastal ecosystem and tourism-based economy. This solution also promotes environmental awareness and focuses on an environmental-friendly approach to energy, carbon footprint, materials, and manufacturing methods while improving the human lifestyle and supporting local businesses.

In addition, the accumulation of data through user interviews has revealed the current methods of removing and disposing sargassum. While there are different proposals and solutions to tackle the issue, most of them lack the necessary financial investment for mass production. On-land and on-water sargassum

collection are the two main methods, but they both dispose of it similarly, causing environmental harm. The lack of initiatives to repurpose sargassum into energy in Mexico is also concerning, as it continues to pile up on beaches and negatively impact marine flora and fauna. The physical labor required by workers to clean up the beaches is too much, causing health problems and unpleasantness. Therefore, it is essential to find ways to reduce physical stress and environmental damage to effectively address the problem of sargassum.

The final solution is Mobula, a water vessel concept that aims to collect sargassum from the open ocean and prevent it from reaching the shoreline and causing harm to the marine life, tourism industry, and the region's freshwater. The collected sargassum will be brought back to the on-land plant, where it will be converted into biofuel for the local region. This concept offers many benefits as it eliminates the pain and frustration involved in manual sargassum collection, enhances human life, and is designed sustainably. The design meets the criteria for full-bodied interaction design and human ergonomics. Lastly, the potential of sargassum as a renewable energy source has been extensively studied and shows promising results. The conversion of sargassum into biofuel can significantly reduce carbon emissions and benefit the environment. The use of sustainable materials in the production of the Mobula vessel and its pods is essential to further reduce the carbon footprint. The integration of natural fiber in the interior of the vessel is also an excellent sustainable option. The implementation of this technology in the Mexican Caribbean coast can not only benefit the environment but also help to restore the ecosystem and tourism industry in the region. With further research and technological advancement, sargassum can become a significant player in the renewable energy sector in the years to come.

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APPENDIX

PANEL ON RESEARCH ETHICS

Navigating the ethics of human research

TCPS 2: CORE 2022

Certificate of Completion

This document certifies that

Maximiliano Garcia Sosa

successfully completed the Course on Research Ethics based on the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (TCPS 2: CORE 2022)

Certificate # 0000864251

4 October, 2022

IDSN 4002
SENIOR LEVEL THESIS ONE

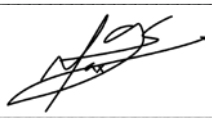
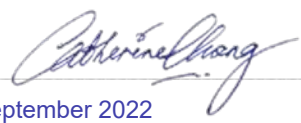
Humber ITAL / Faculty of Applied Sciences & Technology
Bachelor of Industrial Design / FALL 2022
Catherine Chong / Frederic Matovu

THESIS TOPIC APPROVAL:

Student Name:	Maximiliano Garcia
Topic Title:	How May We Sustainably remove the sargassum from the coastlines of the Yucantan Peninsula?

TOPIC DESCRIPTIVE SUMMARY (PRELIMINARY ABSTRACT)

Due to the increase of deforestation, fertilizers, and chemical runoffs in different countries, it has been creating a nutrient-rich environment for the sargassum to bloom and increase in population drastically in the Atlantic ocean. Sargassum in regular quantities is healthy for marine life, but can be harmful in large quantities. Since 2011, there has been an increase of sargassum in the Mexican Caribbean coastlines affecting the local marine life and tourism of the region. As the sargassum accumulates on the shorelines, it decomposes and releases harmful compounds into the environment, this affects the marine flora and fauna. It also releases a sulfuric-like smell causing nausea, headaches, and drowsiness for tourists and beach-goers. There has been efforts in removing the sargassum from the beach, but are fruitless as sargassum accumulates faster than is collected. Furthermore, when sargassum is collected, it is not properly disposed as it's placed in an unused natural area causing the heavy metals inside the sargassum to inflitrate the fresh water of the region. This thesis proposal aims to understand how sargassum affects the environment and the people of the region, and sustainably remove it from the shoreline to re-purpose it into consumer end-products. This will benefit local business owners to develop environmental-friendly products and hotels to remove sargassum from their shorelines. This water or land vehicle/device will be operated by trained personnel to remove the sargassum and pre-treat it so it can be re-purposed into consumer products. This will involve full-bodied human interaction and human ergonomics study to mitigate working conditions in both physical labor and the climate of the region. Finally, the final product will mitigate the new normal conditions of sargassum on the Mexican Caribbean shorelines to bring back business to the tourism industry, and create opportunities for local business.

Student Signature(s):		**Instructor Signature(s):**	
Date:	27/09/2022	**Date:**	29 September 2022

HUMBER
Faculty of Applied Sciences & Technology
Bachelor of Industrial Design / FALL 2022 &

IDSN 4002 /4502
SENIOR LEVEL THESIS ONE & THESIS TWO

INFORMATION LETTER

Research Study Topic: How may we sustainably remove sargassum from the Mexican Caribbean Coastlines?

Investigator: Maximiliano Garcia / (647)8858425 / garciamaxisosa@hotmail.com »

Sponsor: Humber ITAL, Faculty of Applied Sciences & Technology (IDSN 4002 & IDSN 4502)

Introduction

My name is Maximiliano Garcia, I am an industrial design student at Humber ITAL, and I am inviting your participation in a research study on various problems that regards the sustainable removal and repurposing of sargassum on the Mexican Caribbean coastlines. The results will be contributed to my Senior Level Thesis project.

Purpose of the Study

This study is being conducted as an aid in designing a product that can safely remove sargassum with minimal environmental damage and repurpose it for the production of consumer products made from sargassum. This study is primarily based on understanding ergonomics, human interaction design activities, and user experience aspects of the research area.

Procedures

If you volunteer to participate in this study, your answers from the questionnaire will be observed and documented. Your answers will be documented by means of note-taking or a voice recorder. You will also be asked questions pertaining to sargassum and how it relates to your area of expertise. For example, previous academic work you have done regarding sargassum.

Confidentiality

Every effort will be made to ensure confidentiality of any identifying information that is obtained during the study. In the case of being recorded visually, your face will be masked /blurred or hidden. The information and documentations (photographs) gathered are all subject to being used in the final presentation of the study.

Participation and Withdrawal

Your participation in this study is completely voluntary and you may interrupt or end the study and the session at any time without giving a reason or fear of being penalized.

If at any point during the session, you feel uncomfortable and wish to end your participation, please let the moderator know and they will end your participation immediately.

Humber Research Ethics Board

This research project /course has been approved by the Humber Research Ethics Board. If you have any questions about your rights as a research participant, please contact Dr. Lydia Boyko, REB Chair, 416-675-6622 ext. 79322, **Lydia.Boyko@humber.ca**

IDSN 4002 /4502
SENIOR LEVEL THESIS ONE & THESIS TWO

HUMBER
Faculty of Applied Sciences & Technology
Bachelor of Industrial Design / FALL 2022 &

INFORMATION LETTER

Conditions of Participation

- ✓ I understand that I am free to withdraw from the study at any time without any consequences.
- ✓ I understand that my participation in this study is confidential. (i.e. the researcher will know but will not disclose my identity)
- ✓ My identity will be masked.
- ✓ I understand that the data from this study may be published.

☑ **I have read the information presented above and I understand this agreement. I voluntarily agree to take part in this study.**

the Zdeněk Ordelt		2022-09-30
Participant's Name	Participant's Signature	Date

Project Information

Thank you very much for your time and help in making this study possible. If you have any queries or wish to know more about this Senior Level Thesis project, please contact me at the followings:

Phone: (647)8858425

Email: garciamaxisosa@hotmail.com

My supervisor is:

Prof. Catherine Chong, **catherine.chong@humber.ca**

2

HUMBER
Faculty of Applied Sciences & Technology
Bachelor of Industrial Design / FALL 2022 &

IDSN 4002 /4502
SENIOR LEVEL THESIS ONE & THESIS TWO

PARTICIPANT INFORMED CONSENT FORM

Research Study Topic: How may we sustainably remove sargassum from the Mexican Caribbean Coastlines?
Investigator: Maximiliano Garcia / (647)8858425 / garciamaxisosa@hotmail.com
Courses: IDSN 4002 & IDSN 4502 Senior Level Thesis One & Two

I, Zdeněk Ordelt, have carefully read the Information Letter for the project of sustainable removal of sargassum, led by Maximiliano Garcia. A member of the research team has explained the project to me and has answered all of my questions about it. I understand that if I have additional questions about the project, I can contact Maximiliano Garcia at any time during the project.

I understand that my participation is voluntary and give my consent freely in voice recording, photography and/or videotaping; with the proviso that my identity will be blurred in reports and publications.

Consent for Publication: Add a (X) mark in one of the columns for each activity

ACTIVITY		YES	NO
Publication	I give consent for publication in the Humber Library Digital Repository which is an open access portal available to the public	✓	☐
Review	I give consent for review by the Professor	✓	☐

Privacy
All data gathered is stored anonymously and kept confidential. Only the principle investigator /researcher, Maximiliano Garcia and Prof. Catherine Chong or Prof. Frederick Matovu may access and analyze the data. All published data will be coded, so that visual data is not identifiable. Pseudonyms will be used to quote a participant (subject) and data would be aggregated.

I also understand that I may decline or withdraw from participation at any time, without negative consequences.

I understand that I can verify the ethical approval of this study, or raise any concerns I may have by contacting the Humber Research Ethics Board, Dr. Lydia Boyko, REB Chair, 416-675-6622 ext. 79322, **Lydia.Boyko@humber.ca** or Maximiliano Garcia / (647)8858425 / garciamaxisosa@hotmail.com.

Verification of having read the Informed Consent Form:

✓ I have read the Informed Consent Form.

My signature below verifies that I have read this document and give consent to the use of the data from questionnaires and interviews in research report, publications (if any) and presentations with the proviso that my identity will not be disclosed. I have received a copy of the Information Letter, and that I agree to participate in the research project as it has been described in the Information Letter.

Click or tap here to enter text.
Zdeněk Ordelt

2022-09-30

3

IDSN 4502

SENIOR LEVEL THESIS TWO

Humber ITAL / Faculty of Applied Sciences & Technology
Bachelor of Industrial Design / WINTER 2023
Catherine Chong / Fredric Matovu

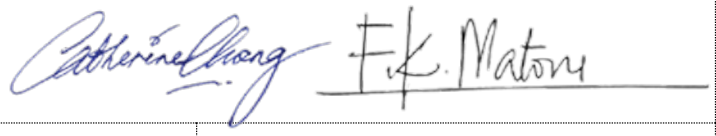
CRITICAL MILESTONES: APPROVAL FOR CAD DEVELOPMENT & MODEL FABRICATION

Student Name:	Maximiliano Garcia
Approved Thesis Title:	Sustainable Sargassum Removal

THESIS PROJECT – DESIGN APPROVAL FORM

Design is reviewed and approved to proceed for the following:	X	**CAD Design and Development Phase**
Comment:	Continue design refinement in CAD development, need to iron out detailing and product's features, pay attention to surfacing, components and assembly methods for design feasibility. Viable holistic design thinking in conjunction with considerations into sustainability aspects. CAD development must be at least 75% complete for review before approval for fabrication.	

Design is reviewed and approved to proceed for the following:	X	**Model Fabrication Including Rapid Prototyping / 3D Printing and Model Building Phase**
Comment:	Waiting for CAD development review (as of Feb-21). Good progress with CAD, design completed, continue detail refinement, once refined, fabrication of model can begin.	

Instructor Signature(s):	
Date:	07 March 2023

User Research: User Profile REPORT

Objective:

1) To identify the primary, secondary and tertiary users of the product.
2) To determine the demographics of primary user of this product
3) To determine user behavior with this product
4) To create a persona that represents a typical user

Deliverables: Information Gathering
User Profile Report

Due Date: Mon. Nov 14, 2022

Primary, Secondary and Tertiary Users

What are primary, secondary and tertiary users of a product?

Typically we think of the person using the product to accomplish a task as the 'user'. However, other people are also affected by the use of the product. For example, those involved in the sale of the product are affected, as well as those involved in servicing the product. Sometimes the product is a tool to provide a service to others (e.g. medical devices used by nursing personnel in hospitals on patients).

"Eason (1987) identified three types of users: primary, secondary, and tertiary.
Primary users are those persons who actually use the artifact.
Secondary users are those who will occasionally use the artifact or those who use it through an intermediary. Tertiary users are persons who will be affected by the use of the artifact or make decisions about its purchase. " http://www.e-learning.co.il/home/pdf/4.pdf

Taking into account these other stakeholders will enhance success of the design in the marketplace.

For this thesis, the primary, secondary and tertiary users are identified as follows.

Primary User	Sargassum Workers
Secondary User	Tourists, Hotel Staff
Tertiary User	Marine Biologists

DEMOGRAPHICS: Raw Information Search

Keywords used:

Sargassum workers + demographics

Sargassum workers + market research

Sargassum workers + blogs

Age & Gender

The majority of the workers who are hired to clean up the sargassum are young male (about 90%) . Typically from 18 to 40 years old. These are the years where their body can take heavy loads of physical labor. Female worker are needed most when there is a lack of male workers available.

Sargassum workers in Mexico

Gender: M 90% F 10%

% of overall population: M: 0.5 % F: N/A

Sargassum Workers (Work > 320 days / yr):

Demographic Data (Mexico)	
Gender	M 80 F 15
Age Average	25 (bi-modal)
Ethnicity: Mexican	100%
Income: $100,000 MXN / year	55
Educat'n: HS or less	49
* 75% compares with 75% overall population	

Ethnicity / Culture

Since this is a problem affecting the Mexican Coastlines, the majority of workers who are cleaning the sargassum in the ocean are Mexican born. There could be some outliers such as immigrants from other Latin American countries working either legally or illegally. There is no exact way to determine the ethnicity of those outliers. The Mexican culture heavily impacts work efficiency as sargassum workers tend to be high school educated; therefore, it determines their eagerness to work and make a living. “Mexicans have a strong work ethic. According to data from the OECD, Mexico has the longest average working weeks (41.2 hours). This work ethic is largely driven by necessity, but does not always translate into high productivity.” (Evason, 2018)

Education and Income

1) Low Income ($50,000 MXN)

Summary of Demographics

Age	25-44 <20
Gender	Mostly male (~90%)
Culture / Ethnicity	Mexican
Income	<20 : low income 21-40: $100 000 MXN
Educational Background	High School

Overall, Sargassum Mexican Workers tend to be younger, and male with low levels of income.

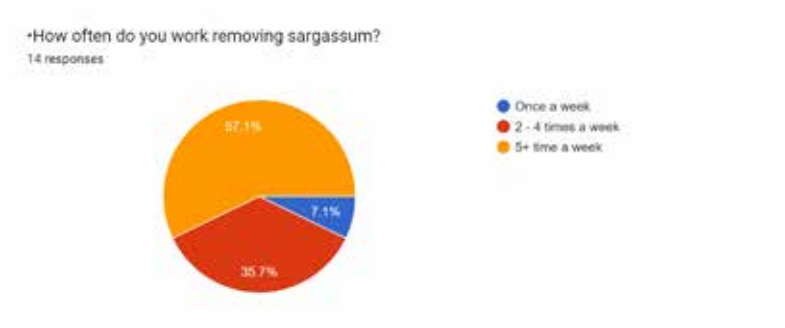
Age: Majority < 40 18

Income: around $50, 000 MXN

Education: High School graduates

USER BEHAVIOR: Information Search

Frequency



Days working/ week	%
1	7.1
2 - 4	35.7
5 +	57.1

Use Behavior	
Frequency: 2-4 x's/ week	35.7 %
Average hours of work per day	10 hrs
Group work	100%
Group Size	20 people

Frequency Summary

They work mostly 5 or more days per week and approximately 10 hours per day.

Group

Sargassum clean up require a team effort, and the crew or team is usually form by groups of 20 people depending on the hotel staff or company's staff and their availability.

Motivation and Lifestyle

Sargassum workers tend to be motivated by the pay because that's their source of income. In addition, some of the workers live closer to the shore for easier transport so they may also enjoy going to the beach and open ocean. So cleaning the ocean from sargassum is also a motivation to work. Their lifestyle to have a good time with friends and family after a day's work and enjoy coworkers or friends company.

Ch 2.1. USER PROFILE

The User Profile documents the demographics and behaviors of the user, allowing the focus of design to be on the user needs rather than a refinement of a current product.

A demographics profile was determined by a google search (Mountain bicycle + Demographics), as well as drawing on user surveys, user interviews and user observations.

Primary, Secondary, Tertiary Users Primary User: Sargassum Worker

Secondary User: tourists, hotel Staff

Tertiary User: Marine Biologists

User Profile of Primary User

Demographics Table

Demographics		Use Behavior		Personality (optional)		Cognitive aspect (optional)	
Age	18-40 <18	Frequency of work	5 + days / week	'locus of control'		Technical Skill	
Gender	Mostly male (~90%)	Duration	10 hrs /day	Self-efficacy		Pre-req. content knowledge	
Culture / Ethnicity	Mexican	Group/ Solitary	20 + people	Changeability			

Income	<18 : low income 22-40: $100 000 +	Motivation/ Lifestyle	Competitive / Active	Uncertainty Avoidance	---	
Educational Bkgd	High School	Income Level/ Purchasing Power				
		Level of Focus	High			
		Location	Yucatan Peninsula			

Persona

Empathy Map

Who are they empathizing with?
Sargassum Cleaner workers.
Hotel employees
Beach cleaners
Environmentally concern individuals and scientists

What do they need to do?
Clean the beach
Have a job
Remove and dispose sargassum
Use removal equipment

What do they see?
Ocean
Sun
Boats
Removal Equipment
Sand
Sargassum
Other Workers
Hotels
Tourists

Persona - Luis
35 years old
Single Male
Working Full Time
Live in Apartment near the beach
Has two children

What do they say?
"its so hot today?"
"Smells awful"
"I'm getting sea sick"
"I'm hungry"
"It's too heavy"
"There is a lot of sargassum"

Pain
Too sunny and hot weather
Exahausting labor
Sea sick
Heaches from the smell
Muscle pain

Gain
Get paid
Have a cleaner beach
They spend their days on the beach
Satisfaction of helping the environment

What do they do?
They clean the beach
They work on the ocean
They drive the boat
They use the equipment for heavy duty removal
They work all day under the sun and heat
They use sun block and sun protective wear

What do they hear?
"I can't wait to fo home"
"I'm tired, man"
"Are you almost done?"
"Did you finish that?"
"How are you doing today?"
"How is the boat mantiance?"

Thought and feeling:
They wish there was a heat preventive method when working all day
They would want an automatic process for easier removal
They dont want to smell the sulfuric smell
Reduce the headaches

Information Interview

By Maximiliano Garcia

Topic area currently being considered: **Sustainable removal of sargassum**

Name of Interviewee:

Background of interviewee (relevant to this topic):

"I am currently in the discovery phase of selecting an area of interest.

This area is .....

Top 3 challenges

- What do you believe are the top 3 challenges or major issues regarding the influx of sargassum today?
- What do hotels or companies do with the sargassum when they pick it up from the shore?
- How does sargassum pollute fresh water in the region?
-

Top 3 trends in the past 5 years

- What are the devices or proposals that people have try to create to remove sargassum from the coastlines in recent years?
- What are some of the local businesses that are repurposing the collected sargassum? Do you know the company names?
- What consumer end-product is the most promising when using sargassum?
- Out of all the consumer products made from sargassum which one is the most promising or easier to produce?

Top 3 opportunities

- What would you consider the top three opportunities with sargassum collection?
- Why is it important to pre-treat sargassum before repurposing it?
- What's the best time to harvest sargassum for re-purposing?

4 Impact of new technologies

- Can you identify possible new technologies that can be implemented in the collection of sargassum, disposal, or reuse?
- What are the technological requirements needed to pre-treat sargassum?
- Is there any limitation on technology that prevents the production of certain products made from sargassum?

Finishing the Interview

- Is there a question that I should have asked?
- Is there someone who would be good to follow up with?

Thank you for your time.

Sustainability Report

By Maximiliano Garcia

Humber College Institute of Technology & Advanced Learning

Senior Level Thesis Project 2 - IDSN-4502-0NA

Catherine Chong

Fredric Matovu

Introduction

This thesis aims to collect and repurpose sargassum in an environmentally-friendly way. In recent years, sargassum has reached the shorelines of Mexico and other countries and has caused environmental damage as well as the tourism industry to decline. With more research and investigation sargassum has the potential to become a renewable source of energy for the affected regions. This report analyzes the common types of materials used in boatbuilding, explores the sustainable materials currently used by companies, and explains the sustainable aspects of the final design for this thesis project.

Benchmarking – Materials and Manufacturing of Existing Products

Steel

Steel has been a commonly used material for boatbuilding since the industrial revolution. The mass manufacturing processes allowed for boatbuilding to have a faster production rate. Steel is produced by a combination of iron and carbon among other metals with low concentrations. Usually, the steel used for the hull construction is “mild steel containing 0.15 to 0.23% carbon, and a reasonably high manganese content.” while sulphur and phosphorus are kept at 0.05% or lower. When producing steel panels, and structural supports manufacturers perform different heat treatment methods to change the mechanical properties and modify the steel’s structure. The following list shows the different heat treatments for steel in the shipbuilding industry:

Annealing.

Normalizing.

Quenching (or hardening).

Tempering

Stress relieving

These methods are used depending on the water vessel, its functionality, and stress conditions. (Molland, 2008)

High-tensile Steel

For large tankers, container ships and bulk carriers high tensile steel is preferably used in their highly stressed regions. This practice can lead to less thickness of various parts of the vessel. However, the nature of high-tensile steel is that is susceptible to deflection. Due to the reduction of thickness in the material effects of corrosion may require more careful maintenance. (Molland, 2008).

Another use of steel is the steel sandwich panels. They have gained popularity because of their lightweight construction method. There are different types of steel sandwich panels with different combinations of materials. For example, steel cores in form of honeycomb, which are spotted or laser welded to the steel panels, add reinforced strength and lightweight to the material. The proprietary technology of steel sandwich plate system (SPS) developed a core made of elastomer material. This material can tolerate high mechanical stress levels and recovers from deformation. This makes it suitable for marine applications. (Molland, 2008).

Aluminum

Aluminum is another material used in shipbuilding mainly because of its characteristics and lightweight compared to steel. The use of aluminum can save up to 60% of the weight of steel structures. In addition, aluminum has a naturally high resistance to corrosion and better non-magnetic properties. Unfortunately, because pure metal has low tensile strength it needs to be alloyed with small percentages from other materials in order to be used in the shipbuilding industry. Moreover, aluminum production has a high initial fabrication cost. (Molland, 2008).

Benchmarking – Sustainability of Existing Products

In recent years there has been an increase in the use of composite materials. The most common has been glass-fibre reinforced polymer (GRP) and fibre-reinforced plastics (FRP). This is due to low operating (maintenance) cost, good fatigue resistance, high specific strength, good corrosion resistance, good thermal resistance, and reduced parts count. “The use of composites enables a 30–40% reduction in overall weight in contrast to aluminum or steel, leading to a number of benefits like lower operating costs, higher fuel consumption efficiency and so reduced greenhouse gas emission (Dokos, 2013).” (Frej et al., 2021). It also allows the possibility to design and produce complex and organic shapes without compromising the strength of the materials due to the freedom of fibre orientation.

“The matrix plays a critical role in determining off-axis strength, damage tolerance, corrosion resistance, and thermal stability.” However, the use of resins and synthetic fibre increases the overall carbon footprint in energy production and the lack of biodegradability properties.

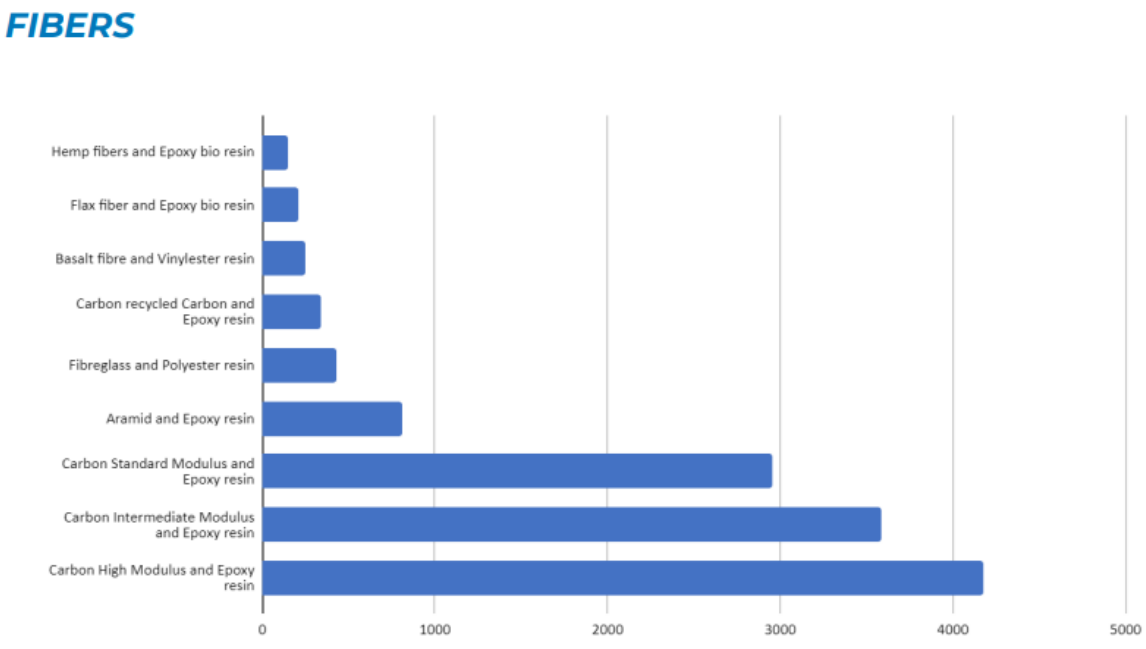


Figure: Comparing relative greenhouse gas impacts of different fibers
Source Michel Marie
Calculated with MarineShift360 beta software on October 14, 2021

Figure 2.2.5.1 Compares GHG of different fibers. Source: 11TH HOUR RACING TEAM SUSTAINABLE DESIGN AND BUILD REPORT (2021) pg. 60

In the figure above, various fibres were compared to assess the environmental impacts of each one. Natural fibre offers the least environmental damage compared to carbon fibre and epoxy resin.

Frej et al. (1993) investigated the feasibility of recovering carbon fibre and reinforcing the matrix with the reusable thermoplastic Elium composite. There is a growing interest in recycling and repurposing carbon fibre due to its economic and environmental aspects. “recycled carbon fibres (rCF) from ELG Carbon Fibre’s cost is around 40% less than industrial virgin carbon fibre. Some other industrial suppliers announced that their rCF is from 20% to 40% less expensive than virgin carbon fibre (vCF).” (Frej et al., 2021).

Currently, various applications using carbon fibre-reinforced polymers (CFRP) will reach their end-of-life (EoL) stage and will be considered harmful to the environment. Finding alternatives and sustainable materials is an important research area.

Arkema has developed a reactive methacrylate thermoplastic resin called Elium as an alternative thermoplastic resin material. “The micro-molecular structure… facilitates the recycling of large-scale composite parts by recovering and reusing initially used raw

Materials (Cousins et al., 2017).” (Frej et al., 2021). This investigation concluded that recycled carbon fibre (rCF) with Elium resin only had 3% less tensile modulus and 4% tensile strength than virgin carbon fibre (vCF). This showed promising mechanical behaviour similarities between vCF and rCF for marine applications. (Frej et al., 2021).

Sargassum to Bio-fuel

Due to the harmful impact on the environment from non-renewable energy such as fossil fuel, there has been an increased interest in renewable energy such as solar, wind and bioenergy. This thesis aims to design a transportation unit that harvests the accumulation of harmful quantities of sargassum from the Mexcian Caribbean coastlines and repurposes it through biorefinery to produce biogas. Sargassum is a macroalga naturally found in the Atlantic Ocean,

due to climate change there has been a bloom of large quantities that affect the marine life and the tourism industry in Mexico. Macro algae have been an interest in the scientific community as a sustainable energy source. This means that pelagic sargassum has the potential of becoming bio-fuel in the coming years. (Alvalo-Betancourt et al., 2021). Alvalo-Betancourt et al. (2021) concluded in their research that “the high influx beaching of these algae in the Mexican Caribbean coast in recent years has made it possible to estimate that its removal of only one month from 600 km of coastline that can theoretically supply the annual bioenergetic needs of residential heat of 79,163 inhabitants in said region. Its viability as a solid biofuel, considering a comparative analysis with other bioenergetic fuels, is shown through potential benefits in terms of costs and emission generation, because it is a marine residue with an imperative need for removal. With proper transformation management, Sargassum spp. Could be converted into densified materials such as briquettes or pellets, generating a new market in the bioenergy industry.”

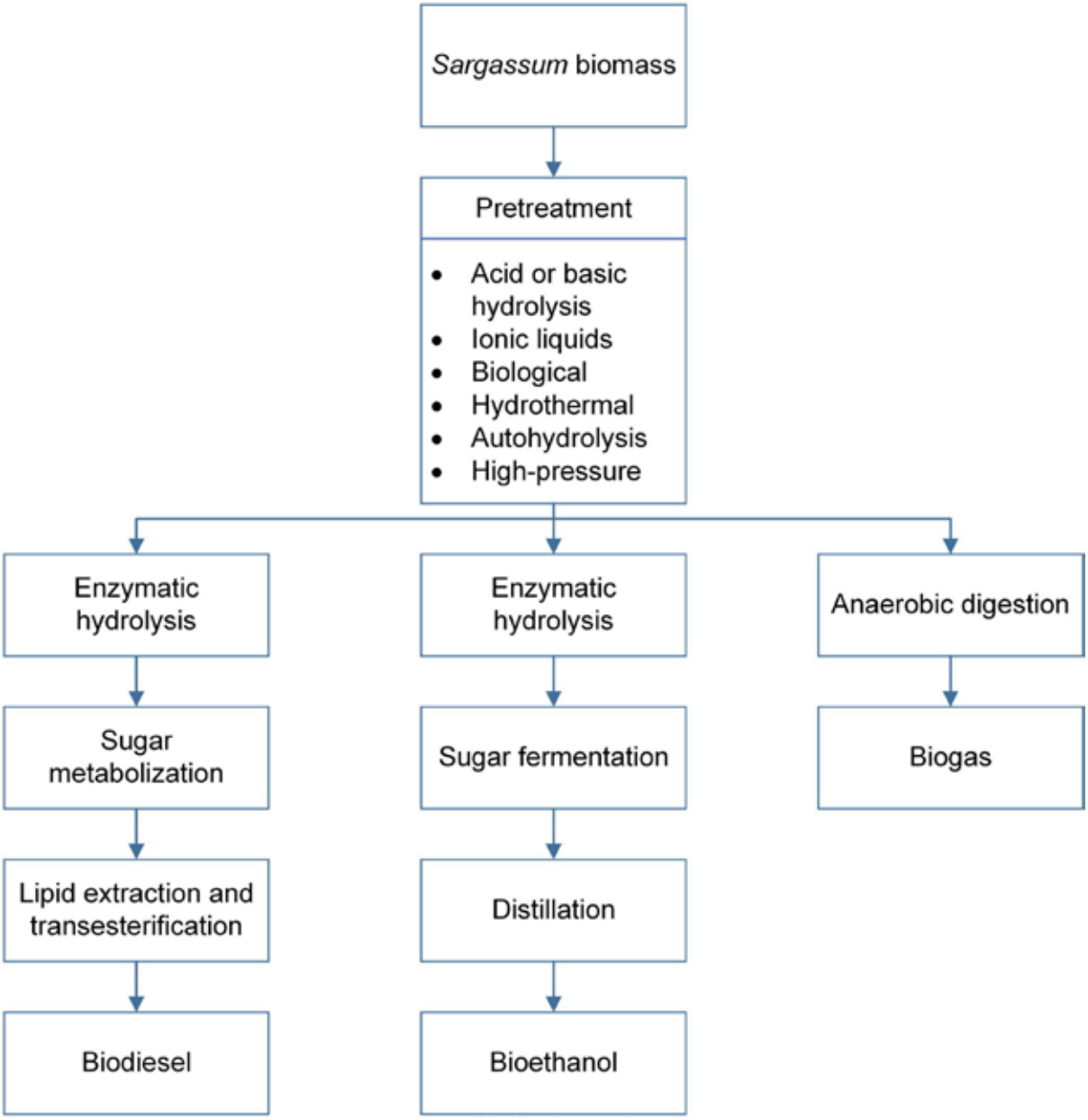


Figure 3.5.1 shows the different process to create biodiesel, bioethanol, and biogas using sargassum. Image taken from: Orozco-González, J. G., Amador-Castro, F., Gordillo-Sierra, A. R., García-Cayuela, T., Alper, H. S., & Carrillo-Nieves, D. (2022). Opportunities Surrounding the Use of Sargassum Biomass as Precursor of Biogas, Bioethanol, and Biodiesel Production. Frontiers in Marine Science. https://doi.org/10.3389/fmars.2021.791054

Orozco-González, et al. (2022) reported in their research the following.

“Thompson et al. (2021) adjudged that pelagic Sargassum from the Caribbean can be used for optimized biogas production when using hydrothermal pretreatment coupled with anaerobic co-digestion with food waste. Food waste was mainly composed of noodles, bread and rice, vegetables, meat, coffee, tea, fruits (24.8%), and eggshells in the study. The composition of the biogas obtained will diverge depending on the pretreatment applied prior to digestion. Hydrothermal pretreatment on Sargassum biomass reduced the presence of hydrogen sulfide (H2S) in biogas from 3 to 1%, relative to the untreated biomass (Thompson et al., 2020a)”

Orozco-González, et al. (2022) concluded that there are different factors regarding the success of sargassum in biofuel. Economic restraints can affect the feasibility of creating a sargassum-based biorefinery, factors such as local transportation, biomass availability, and initial investment. Moreover, to create environmentally-friendly bioenergy, there needs to be most if not all usage of all sub-products and residues from biorefineries. Lastly, further research regarding sargassum as a biofuel needs to be conducted to develop viable processing methodologies.

Safety and Health of the User

There has been little to no research on the overall health of sargassum workers. However, there is anecdotal research in which people have been interviewed in terms of their personal experience working with sargassum. Sargassum starts to deteriorate once it reaches the shoreline creating a hazard zone because of its sulfuric smell. This can cause people close to the shore to have headaches and feel nauseous. On the contrary, sargassum workers are known to remove the sargassum by hand using a rake and a wheelbarrow. They work in direct contact with the sargassum. Sargassum is known to carry toxic contaminants in addition to seawater and metal such as Arsenic (As). There hasn’t been any research regarding long-term exposure to sargassum, specifically for workers.

Mochizuki (2019) mentioned, in his research, that there need to be more studies on the effect of Arsenic (As) metal exposure because there has been evidence pointing at neurotoxicity. He stated the following:

"Several studies have shown that As exposure induces peripheral neuropathy or neuritis [4,58–60]. The type of neuropathy caused by such extremely long exposure to low As concentrations in water has gradually become clear over the last decade. For neurological impairments, it has been suggested that mild peripheral neuropathy may occur by drinking As-contaminated water at the level of 10 ppb [6]. On the other hand, there is no study showing that CNS impairments occur due to drinking As-contaminated groundwater in adults [4,6,61] except the DPAA exposure of the Kamisu city incident [24]."

Sargassum is known to carry a variety of heavy metals as it travels across the Atlantic ocean. During their travel, sargassum patches absorb contaminants from industrial sites near the shore. The contaminants can include heavy metals such as As and other chemicals that can be harmful to humans and the environment. When working with sargassum, it's important to clean out the toxic material from sargassum in order to repurpose it. (Orozco-González et al., 2022).

Proposed Sustainability For Thesis Project

The main objective of this thesis project is to restore the ecosystem and tourism industry on the Mexican Caribbean coast. Dr. Legena Henry and her team from the University of the West Indies (UWI) presented the possibility of sargassum being transformed into biofuel "using sugarcane waste – a by-product of rum production" and power vehicles in Barbados. (Giovanni, 2022). Giovanni (2022) summarized the presentation that Dr. Henry gave at the SDSN's inaugural Global Solutions Forum (GSF) in September 2019 in New York, she stated the following:

"At present, the goal is to determine how much biofuel can be reasonably produced and sold at refuelling stations throughout the island. From the experimental results, it was calculated and projected that one year of transportation in Barbados requires 685,304,000 litres of rum distillery waste and 105,759 tons of fresh sargassum. If implemented successfully, this alternative combustion method can avoid as much as 1 million metric tons of CO2 emissions every year in the country."

"Bio-methane can cheaply and easily power electric grids and vehicles."

Figure 5.6.1 illustrates the possibility of a biofuel station to power vehicles. Source: https://rumandsargassum.com/story/

“A regular internal combustion engine gasoline-powered vehicle can be upgraded with a CNG kit in 4 hours and drive fully on biomethane.” (Giovanni, 2022).

Figure 5.6.2 illustrates the possibility of a biofuel station to power vehicles. Source: https://rumandsargassum.com/story/

With further research and advancement of technology, the “Mobula” vessel can be 100% powered by sargassum as biofuel. This includes the water vessel as well as the amphibian pods. Using engines that consume biogas, it will allow the pods to transport the collected sargassum to the Sargassum Biogas Plants where it can provide renewable energy for the local region.

In addition, in order to reduce the carbon footprint, both the water vessel and the pods need to be made from sustainable materials. The intent is to have body panels made from recycled carbon fibre and Elisium resin technology that allows the panels to be recycled once it reaches their end-of-life. Vacuum bagging the carbon fibre with the moulds is the most suited method to create the panels. The plastic used for vacuum bagging will need to be recyclable and reusable in order to be a sustainable practice. Steel, aluminum or wooden materials will be used as support structures. Normally, the choice of these materials depends on the purpose and intent of the vessel. In some cases, lighter materials are preferred if the vessel is intended to go fast or aims to reduce energy consumption.

The fitting of the mechanical components, such as the water pumps, will need to be stainless steel with a coating of protection against corrosion, wear, and anti-fouling. The interior will be using natural fibre, as it is 100% biodegradable, in areas where there won't be too much mechanical stress on the material. This can be shelves, bedding, chairs, control panels, handles, insulation, etc. Henequen is a plant that is naturally grown in Yucatan, Mexico and their fibres are known to be used in different consumer by-products such as ropes, hats, rugs, handbags, shoes, the upholstery of furniture, room dividers, etc.

Conclusion

This report explored the different types of materials used in the boatbuilding industry and sustainable materials used by a few companies. The boatbuilding industry is in need to develop more sustainable solutions for materials to reduce the environmental impact. Based on the research, proposed materials and methods were explored to be applied to this thesis project. Lastly, in addition to the material proposed for the exterior and interior, the business model is 100% sustainable by using the sargassum collected as biofuel to power the water vessel, collection pods, and the affected local regions.

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