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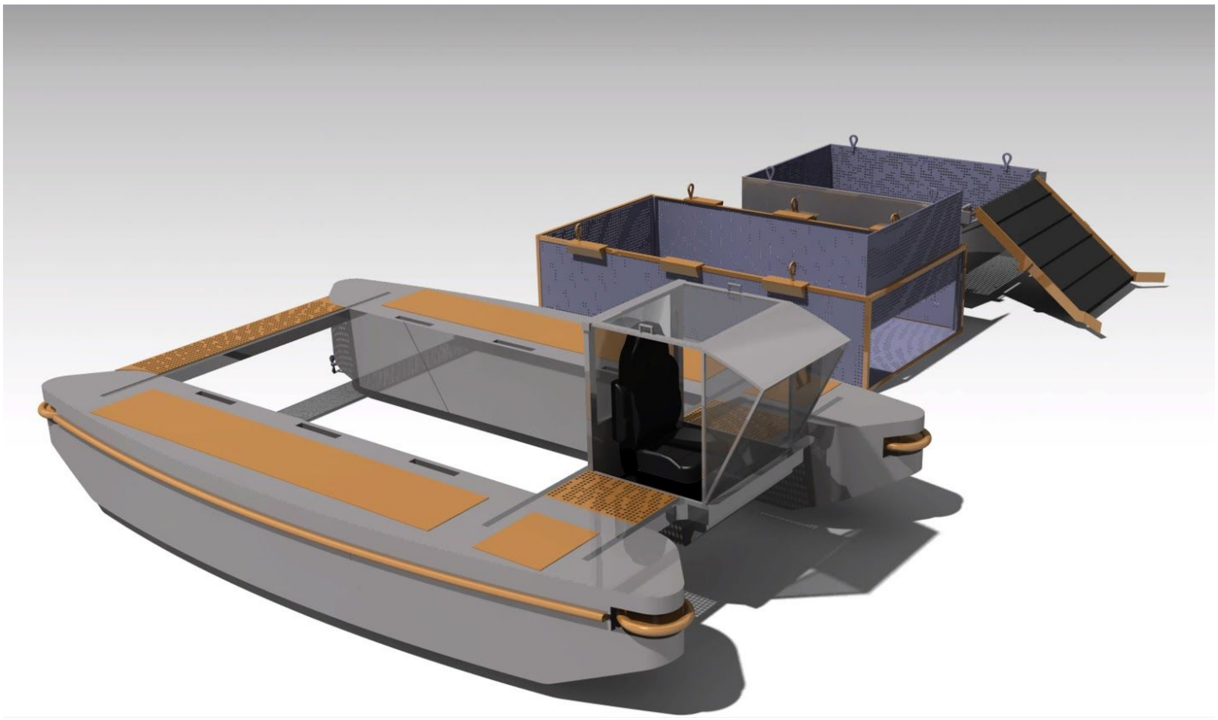

# Concept development and modularization of a cleaning vessel

Bachelor's thesis in mechanical engineering

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CHALMERS UNIVERSITY OF TECHNOLOGY
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Gothenburg, Sweden, 2017-06-01

Albin Hansson

Felix Sjöstrand

# Preface

Both of the group members Albin Hansson and Felix Sjöstrand consider the project as very fulfilling and a good chance to further develop skills in executing product development projects. We think that the thesis was particularly fun for the lack of constraints we were initially given. We had to independently figure out how and where to gather the information needed to proceed in the process (especially considering our prior lack of knowledge in vessel design and the importance of keeping city invironments clean). Consequently also allowing us to think creatively when generating ideas, hence the thesis project allowed us to work the parts of development that we personally find most interesting; ideation and concept development of innovative new products.

# Abstract

A product development project have been conducted for GreenStar Marine in collaboration with Altran. Due to increasing litter and garbage in inner cities, more of it is accumulated in the water canals. The goal of the project is to design and develop a new concept that solves the issue of cleaning the water surface of the canals in cities.

A feasibility study to conclude the actual needs of the product have been performed including interviews with the people that currently operate the existing solution for cleaning vessel. Based off the information different concepts were generated and evaluated before going into detail design. The result is a catamaran utility vessel as a platform with a modular interface where different tools can be attached between the hulls. Two different concepts of tools have been developed for cleaning water surfaces. The first concept filters the garbage through and metal net and the second concept picks up the garbage with a conveyor belt. This allows the driver to operate the vessel in a more smooth continuous motion, separating debris from water in the process.

## Table of content

# 1. Introduction

In this chapter, the background and main focus will be explained. The chapter also include purpose, limitations and problem statements which concludes what will be included and what will be left out.

## 1.1 Background

The inner canals of cities in Europe are in a need of an effective method of cleaning the surface of the water. There are current products on the market serving this specific purpose but are not necessarily the optimum design.

The marine industry has since long been dominated by combustion engines to propel different marine vehicles. Green star marine is currently developing electrical powertrains, a technology that will lead to new opportunities for innovation within the industry. Electrical powertrains and engines differ from their combustion counterpart which is why there is a need to find and evaluate new applications related to the new arising possibilities.

Greenstar Marine is one of the first companies to develop electric powertrains for sea vessels. Their main target group is sailing vessels although they see potential in the use of electric powertrains in utility vessels.

## 1.2 Purpose

Furthermore the purpose of this bachelor's thesis is to design and develop a new concept of a product that is able to propel itself in water canals of cities and clean off the surface of the water suffering from garbage and litter caused by bypassing citizens.

## 1.3 Limitations

This bachelor thesis will include development of the complete concept but not necessarily the detail design of all components. Some parts will be conceptually benchmarked only to find a solution better than the previous one. Based on a feasibility study on concepts of cleaning the oceans by Boyan Slat, it is assumed that vessel type solutions are the most suitable for smaller applications such as canals and rivers [1]. The project excludes the prototyping, physical testing and manufacturing phases of the product development process.

## 1.4 Problem statements

The bachelor thesis have three different problems statement. Which will be approached with focus on safety, effectiveness, complexity and how environmentally friendly the solutions are.

- The product must be able to float and propel on water.
- The product must be able to collect garbage from the surface of the water
- The product must use electricity as its source of power

# 2. Theory

In this chapter the theory behind the thesis work is presented. Mainly concluding theory revolving the product development process.

The product development process is a structured way of developing completely new products or further develop existing ones. It encompasses the whole chain from identifying market needs, generating concept all the way to preparing manufacturing. The structure and approach can vary in different product development processes [2][3][4] . The project is an iterative process, meaning that stepping back and repeat a phase can be necessary for best results. [2][3][4]

The first phase in the product development process is **feasibility study** which includes reviewing the background material such as design and engineering of the current product see figure 1. [2] This phase also includes interviews with people that haves a connection to the product to find underlying needs. In the second phase, **product specification**, the goal is to specify different needs and boundaries. Which leads to next phase, the **concept development** phase where all needs and boundaries are translated into different concepts [2]. While generating concepts, it is important to leave out criticism of all ideas in order to not exclude anything possibly groundbreaking too early in the process. After the concept development comes the **concept evaluation** phase, this is where concepts that are not realizable are eliminated. This part includes different evaluation matrices used to find the concept that fulfills all set requirements and needs the best [2]. After the concept evaluation phase a **detailed design** of the winning concept is made [2]. The last two steps are prototyping and manufacturing. Prototyping allows for physical testing as a last form of validation before preparing for final manufacturing. [2]

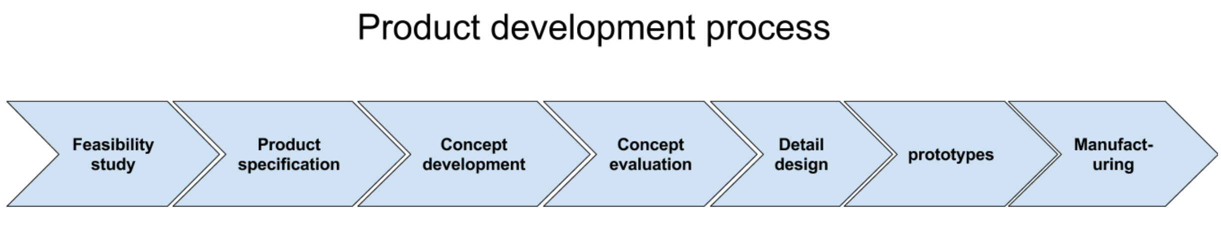



*Figure 1 shows the product development process adopted from Produktutveckling: effektiva metoder för design och konstruktion. [2]*

## 2.2 Feasibility study

Feasibility study is the first phase of the product development process where the aim is to identify what the boundaries of the products system is. The output of the feasibility study is the adequate information needed to understand what needs the product has to fulfill before continuing into the product specification phase. Usually the feasibility study includes some form of interviews, either quantitative or qualitative. [4]

One method for collecting data to use as basis for identifying needs is interviewing customers (or other stakeholders during the product life cycle). In interviewing there are several methods with different types of results. One method is qualitative interview which includes focus groups or depth interviews. Focus groups means gathering a group of product- or project stakeholder and allowing them to freely discuss a topic related to the data that you try to collect[1]. Depth interview means interviewing a single person with either open or strict questions. The results can then be compiled in order to evaluate the answers and to find underlying product needs. [4]

One way of conducting these interviews is the so called semi-structured interview. It means that the questions are prepared before starting the interview but the interviewer also allows the interviewed to freely discuss the topics. [5]

Quantitative interviews includes letting a larger amount of people answer surveys or be interviewed with specific questions. Quantitative data can then be compiled into diagrams or analyzed using statistics but is less suitable for finding underlying needs. [2]

### Analyzing existing solution

Analyzing the set of products currently available on the market is a way of mapping what problems have already been solved and what needs to be further developed or completely re-engineered in order for the new product to be superior to the previous. [4]

## 2.3 Product specification

The second phase of product development process aims at specifying and quantifying the needs and requirements so that the future concepts can be benchmarked against these criteria. This phase uses the result of the feasibility study to conclude the final statement in a requirements list of what the product should do. [3]

### Design requirements

A design requirement list consist the requirement and desires, which the project aims to work towards. Interviews and meeting with the focus group is fundamental to get the right criterias. [3]

## 2.4 Concept development

Down below follows the theory for the methods used in order to generate new concepts to solve the problems. This is the creative phase of the product development process where the goal is to generate ideas that solve the problems while also satisfying the listed design requirements. Furthermore the goal is to maintain a out of the box thinking strategy to not exclude any new ideas too early. [3]

### Functions tree

Functional tree is a way to schematically describe the different functions needed in a product. The main function is listed in the top which follows by underlying functions which solves the main one under which even more functions solving the previous are listed.. The purpose is to describe the functions in general terms but in increasing detail in order find the list of functions which can be solved by different technical solutions. [3]

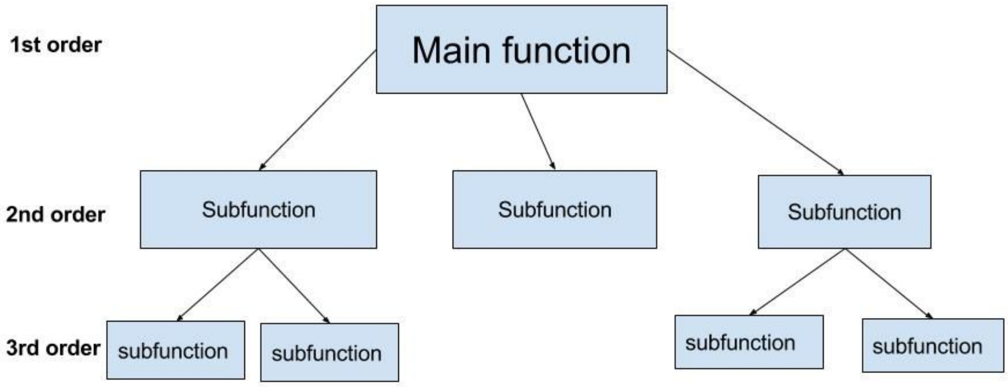



*Figure 2 shows one example of a function tree*

### Functions structure

Functional mean structure is a useful way of defining the functions in a product that includes both an input and an output. The following procedures can be divided into two steps. [2]

- Definition of the systems functions and systems boundaries.
- Decomposition of the functions into sub functions

First a black box is created, a non-defined box with the desired output and necessary input. Furthermore the functions are schematically drawn inside the black box in chronological order from the input to the output. The point is to define what needs to happen inside the product for the input to turn into the desired output. Based from the list of functions, the designer can then find technical solutions for each function to solve the product design. Furthermore the output consists of a refined form of the input as the input doesn't disappear.[2]

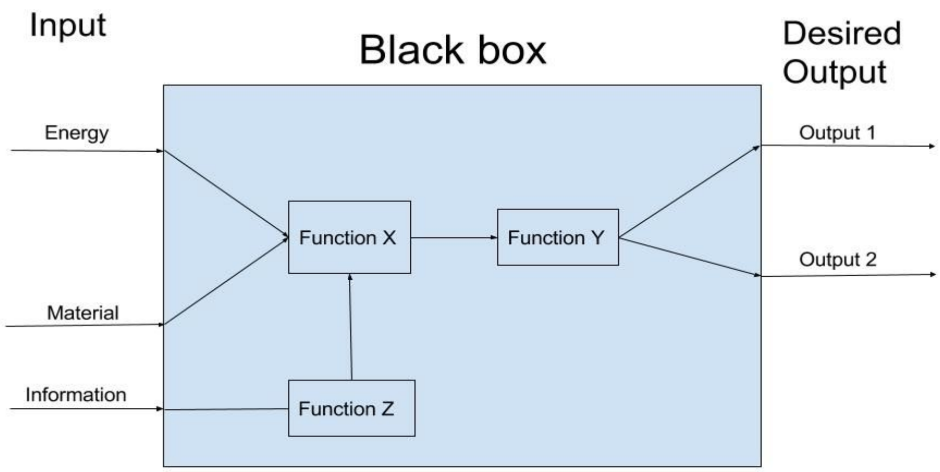



*Figure 3 displays one example of a function structure.*

**Brainstorming**
Brainstorming is used in order to identify ideas of how to solve different functions. Brainstorming is an activity advantageously performed in a group. [2] Fundamental for the brainstorm sessions is to stimulate creativity by allowing any kind of ideas to be expressed without criticizing them and by open dialogue between the group members. An ideal group consists of several members of the projects with different competence areas and should not exceed more than 60 minutes in duration. [2]

**Search for existing solutions**
The search is used to find different viewpoints and solutions for the problem. In general, the problem is different in various part of the world. All the information and viewpoints are the basis for the concept generation. The search for existing solutions can also extend to other industries. Searching for solutions can be conducted in different ways, but patent search engines are commonly used. [4]

## 2.5 Concept evaluation

Concept evaluation is the part of the product development process where the prior creative phase turns into a pragmatic phase of deciding which of the ideas actually solves the problem in the best possible way. [2]

First a Pugh matrix is applied on all of the concepts. A pugh matrix is a type of matrix used for evaluating different concepts compared to a reference. The y-axis represents the different concepts while the x-axis represents the different evaluation criteria. In the intersection between the criteria and the concepts the designers put a value on how well the the concepts meet the criteria in comparison to the reference product. [3]

## 2.6 Detail design

Detail design is the net result of the whole product development project. It usually concludes the foundation of what is necessary input for manufacturing of the product. The process of detail design usually includes, but not exclusively 3D models of product, dimensioning & calculation of components & production drawings. [2][3]

### CAD (computer aided design)

CAD is a 3D modeling software for creating the geometry of a product during the development process. The foremost advantage of CAD is the quick process of getting from an idea to something testable (within the software) without have to build something physical. This relieves strain on both time and economical constraints as it is both quicker and cheaper. [2]

After a model is created is it possible to conduct FEM **(Finite Element Method)** analysis on the model to produce information of how the geometry reacts from a mechanics of materials point of view when different loads are applied. This too is both faster and cheaper compared to actually testing physical models. [2]

When the final geometry is created and tested the CAD software is able to generate **production drawings** where tolerances can be added as well as other adequate information needed for manufacturing.

## 2.7 Types of garbage in cities

Garbage in cities, rivers and ocean is a global environmental problem. The garbage endanger sensitive wildlife and ecosystem. It also has aesthetic impact and is strongly connected to a sustainable society.[6]

Gothenburg park och naturförvaltning collects 30 000 kilogram of garbage in Gothenburg canals each year. Various measuring methods have been used to evaluate what sort of garbage that lies in the inner city of Gothenburg. The diagram below, see figure 4, lists different type of fraction in the x-axis and the numbers of finds per 10 square meters on the y-axis. [7]

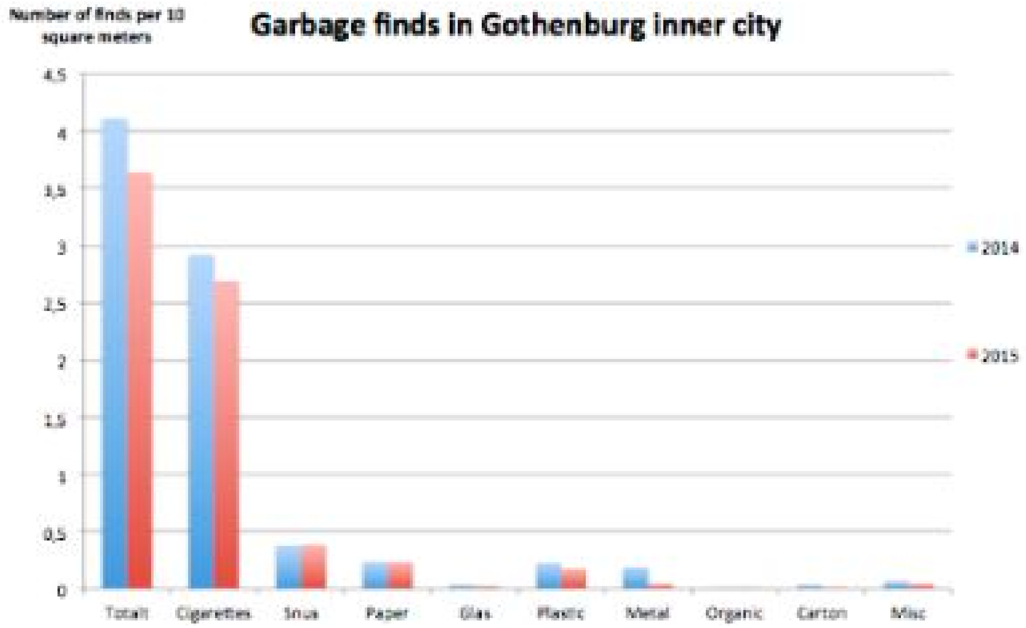



*Figure 4 displays a bar graph depicting the types of garbage on the x-axis and amount of finds per 10 square meters found in gothenburg inner city on the y-axis*

During an interview, information about vessel collecting capability range between cigarette to a tire. From about 0.2 square (0.5 centimeter radii) centimeters to 1300 (68 centimeter radii) square centimeters. The same measuring method has been used to evaluate different garbage along the shoreline. A national average has been evaluated and is presented as a bar chart, see figure 5.[8]

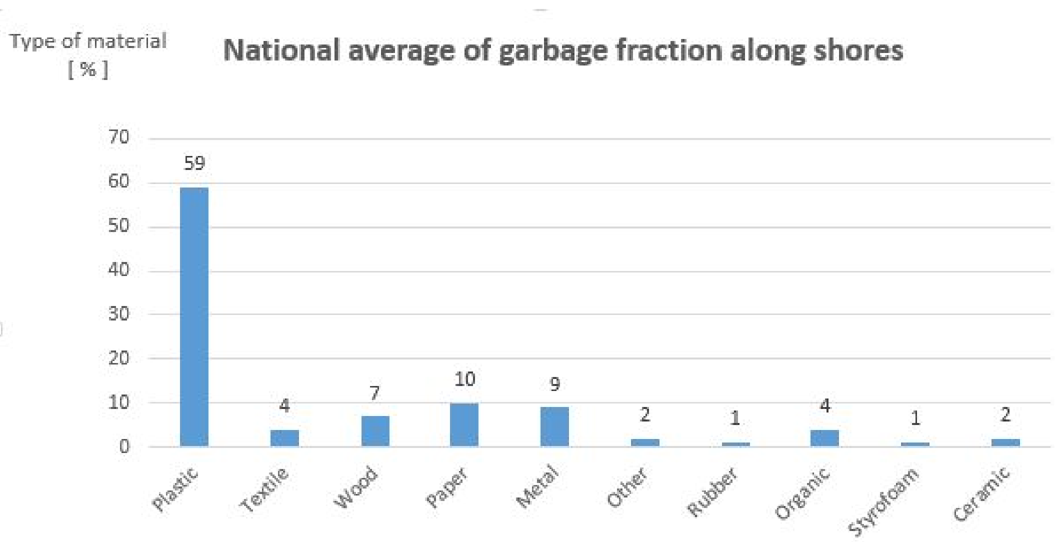



*Figure 5 displays the fraction in percentage on the y-axis and type of garbage on the x-axis based on national average finds along shores.*

## 2.8 Cleanup concepts

As presented in figure 5, the plastic pollution problem is five times higher than the second highest material type. Many possible concepts have been proposed and this section will discuss some of these concepts . In general there is three technical sections: autonomous drone systems, ship or vessel systems and ‘floating islands’.[1]

The basic idea behind **autonomous drone systems** is to release an amount of floating drones, fitted with electric engines to autonomously search a certain area of water and collecting whatever debris coming into their sight. After collecting, the drones then propel back to a common base station where they release the collected debris before heading back to search for more. The key advantage of this concept is the flexibility when deploying drones. If one area is more dense in debris the drones can rearrange accordingly to keep the optimum amount of drones at the right place.[9]

Furthermore the concept is not without potential problems. For instance, the small size of the drones would lead to a small potential in energy storage as well as less capability in collecting larger debris. To cover a large area there would have to be a very large amount of drones, or a very large amount of time considering their small reach.[9]

**Vessel systems** is the idea of taking existing ship or vessel technology and fitting them with some means of collecting debris, a fine meshed net for instance like a fishing vessel. This is so far the most common way of collecting floating garbage. The main advantage of this concept is that the technology already exists which reduces the cost of research and development, hence it is only a matter of finding the best combination of vessel and collecting method. The main downside is that it can’t cover a very large piece of ocean surface. It also leads to risk of extra emissions if the vessels themselves doesn’t run on renewable energy.[10]

Another version of this is to make boats that are not used for cleaning, able to clean. One example could be **leisure boats** around coasts with some way of collecting. This would minimize the potential for extra emission caused by vessels used specifically for cleaning, as leisure boats would go around water independent of cleaning purposes. The main conclusions is that fishing for debris from vessels is a cost efficient way of cleaning water surface on a small scale, but would not be so on a larger scale.[10]

The third concept is **floating islands**. This is the least conservative concept as it has not yet been tried at all. The idea is that you can recycle plastic debris and use it to construct floating islands. The islands can then themselves start collecting more plastic with fishing nets and continue expanding the size of the island. However no technical details exist so it is impossible to determine the feasibility of this concept.[11]

The **conclusion** is that existing concepts are not without problems when applied in a large-scale ocean cleanup strategy. Therefore there is a need to develop a new type cleaning technology which has a cheaper price per effective area. However the vessel concept and drone concept are probably more commercially and technically suitable for smaller applications, such as cleaning rivers or coastal areas. [11]

## 2.9 Modularization

Due to higher demands on lower price per performance, more competition and increasing strain on financial resources in research and development, it is of increasing value to maximize the potential of the existing resources. Businesses strive to beat this strain by increasing their market shares by developing a more varied and high quality set of products while also decreasing R&D and manufacturing costs per unit.[12]

One solution for this is by reusing resources and products to individualize each product by putting together different components into a complete product. This increases value for the customer as the product is adapted to their individual needs while also decreasing cost as you can create a lot of different products by combining a few different component variations. Thus reusing the same components over and over again but with different results.[12] The key element to modularization is to create a common interface between the components. In that way the components are all interchangeable. Furthermore if the interface is determined before the development of the components the developers can work parallel to each other and consequently decrease the time span of the development project significantly.[12]

By modularization strategies, that is to build products using interchangeable modules with predefined interfaces, could lead to the following improvements:

- Shorter time span in product development.
- Faster product changes.
- Lesser risk when developing new products.
- Faster lead time in manufacturing.
- Increased quality in manufacturing.
- Fewer parts to handle and administer.

# 3. Methods

The following part summarizes the methods were applied during the project and how the group executed them.

## 3.1 Feasibility study

The feasibility study's main focus is to locate different requirements and desires. To get a good picture of the product and the problems both interviews and a deeper analyses of the current product has been made.

### Interview

The main goal of collecting data through interviews is to find the underlying unidentified needs. Therefore the methods chosen to implement are depth interview with the person who operate the current product, as well as a focus group including stakeholders like the operator, Green star marines technical manager and the manager from Gothenburg city’s park- och naturförvaltning (department of park and nature management).

The depth interview lets the operators step by step go through his workday of operating the current product. The workday is transcribed immediately while interviewing. Furthermore the information is analyzed to see if there are any underlying needs not yet satisfied.

The focus group let's stakeholders of the project discuss what they think are the needs as well as contributing with previous experience. What geometrical constraints are there, what functions does the product need to have and are there any current ideas of improvements that could be implemented in the new product. Before the meeting with the group a selection of questions related to product requirements was compiled which can be found in the results section (page 21). The answers are immediately transcribed so that it can be analyzed in the following phase.

### Description of functions of existing product

As a reference product, the current one used in Gothenburg, called Renström is analyzed. All the functions of Renström that contributes to solving the problem is described. Furthermore, the problem statements of the thesis have been compared to the actual solutions used today to identify what needs to be exceeded in terms of functionality.

## 3.2 Design requirements

A list specifying requirements and desires is compiled based on the interviews and focus groups. In the list, different functions are defined as well as their target values. Values strive to be quantified, but in some cases it is impossible. Desires have been valued on a scale from 1-5.

## 3.4 Concept generation

The following subjects describe how the methods for generating concept were performed. First off, the system is defined in a **functions tree and functions structur**e then the **brainstorming** takes place to generate ideas after which a **search for existing technical solutions** can take place. After the methods have been executed they can be turned into a number of different concepts that are then evaluated in the next phase.

- **Functions tree & functions structure**

A workshop designing a functions tree using a whiteboard and discussing what all the necessary functions would be for all the outspoken and underlying needs to be satisfied. The needs are based off the results of the interviews and the compiled list of design requirements.

Just like the functional tree, the functional structure was made during a workshop with the project group based on the same needs.

- **Search for existing solutions**

The search is divided in two different stages. First the project group looks at each function and how the function has been solved. At the second stage the project group looks at complete solutions.

- **Brainstorming**

A list of functions based on the functional structure and functional tree methods were compiled. The functions are then the basis for the brainstorming sessions consisting of the two project members allowing any ideas to solve the functions to be written down. The ideas are then sketched for a visual interpretation of the solutions.

## 3.5 Concept evaluation

This part describes how the methods of evaluation concepts were performed in order to decide which is the most suitable concept bring into the detail design phase.

### Pugh matrix

For the pugh evaluation a list of criteria that are considered essential for the end product was compiled. The criterias were developed in collaboration with stakeholders from Green star marine. The scale chosen for the concept evaluation were -1, 0 & 1 for worse, the same or better than the reference product. In this case Renström was chosen as the reference. See figure 6 for an example.

| Criterias | Scale | Reference | Concept #1 | Concept #2 | Concept #3 | Concept #4 | Concept #5 | Concept #6 | Concept #7 |
|---|---|---|---|---|---|---|---|---|---|
| Criterias#1 | -1,0,1 | x | 1 | 0 | 1 | -1 | -1 | 0 | 1 |
| Criterias#2 | -1,0,1 | x | 1 | 1 | 1 | 1 | 0 | 0 | 1 |
| Criterias#3 | -1,0,1 | x | 1 | 1 | 1 | 1 | 1 | 0 | 1 |
| Totals | | | 3 | 2 | 3 | 1 | 0 | 0 | 3 |

*Figure 6. An example of a pugh matrix*

## 3.6 Detail design

Based off the ideas sketched during brainstorming, the actual defining of the products geometry takes place during the detail design process. The project includes system level detail on the 3D geometry, assembly drawings as well as a rough cost estimation. Each of which are described below.

### Computer Aided Design (CAD)

In order to develop the geometry of the product and create visual 3D-models for presentation a CAD software is used. In this project the design has been developed in Catia v5. Due to lack of time, the final 3D model does not encompass the complete detail design of all components, but serves as a rough understanding of what the product looks like and how it works on a system level including all critical components as well as Green Star Marines electric driveline and engines.

### Cost estimation

To roughly estimate the cost of production an excel sheet is created. In the sheet the cost of each component that is bought is listed. Some parts is benchmarked from a supplier and some parts are calculated on the basis of material cost and labor cost.

# 4. Results

The following part summarizes the end results of the methods that were applied during the project. Initially, interviews are conducted in order to identify needs for improvements as well as collecting any existing background information. Furthermore the current solution is analyzed to concretize what solutions already exists and which of the existing needs to be further developed or replaced. Based on this data a design requirements list is compiled. Continuing with the requirements into the concept generation phase. During concept generation several methods are applied including function trees & structure to identify what needs to happen inside the boundaries of the product, as well as analyzing existing solutions on the market before brainstorming new solutions. Based off the generated concepts from brainstorming, an evaluation phase to find the best idea is concluded before heading into the development of detail design. Henceforth the actual mechanical design development process is taking place within CAD (computer aided design) software.

## 4.1 Interviews

Down below follows the results of the two different interview techniques. First are the answers from the focus group with stakeholder. The second part is the transcribed text of the interview with the operator.

### Focus group

The focus group consisted of the two project members, Green star Marines technical manager and CEO, Göteborg park- och naturförvaltnings manager as well as an Altran Engineering manager. The questions listed below were prepared before the focus group session. In accordance with the theory of semi-structured interviews, the attendants were allowed to freely discuss the topics after answering the questions. The questions asked were aimed at quantifying needs that are already known from the stakeholders.

- **Weight of current product?**
- 4000-5000 kg
- **Height from water level to the edge of the lowest bridge in the canals of - Gothenburg?**
- 1.5 meters
- **Size of garbage container of current product and its weight when fully loaded?**
- 1-1.5 cube meters and about 1000kg.
- **Amount of time needed for the container to be filled once?**
- At least one full day of work
- **How much is the current product used?**
- 4 days a week until the canals freeze
- **How is the container emptied?**

- Lifted by a crane from land

- **Cost to build the current product?**
- 1.5 million [SEK]
- **How deep is the canal?**
- 1 meter
- **What is the energy storage capacity of the current products batteries?**
- 8 lithium ion batteries with a capacity of 17kWh in total

### Depth interview

After the focus group another interview was performed with the operators of the current product Renström. They were asked to go thoroughly describe their whole workday from arriving to the office into finishing off their days. Down below follows the transcription of the interview.

The operator starts the description of a workday from leaving the office. He first goes off by car around the canal to detect the different parts where garbage has been collected the most. After this he drives to where the vessel is docked. When starting he immediately go for the places where the most garbage was seen. When approaching floating garbage he lowers the scoop and drives into it while lifting it again and dropping the collected material into the garbage container.

Another operator stand on the sides of the vessel and collects garbage passing by on the sides with a hand net. If enough material is in front of the vessel so that one scoop cannot contain it, the operator must reverse the direction of the vessel in the middle of the operation causing all the garbage left in front to drift away. Which is described as a problem. In general the method of driving is based on driving back and forth in order to catch all the material, instead of driving smoothly which the operator expresses as a possibly more effective method, although not possible with the scoop solution.

The operator continues cleaning the canals in a non structured manner, choosing pathway loosely based on the observations earlier. He continues until the canal is finished or the workday is over. The container is only emptied once full, once or twice a week.

Furthermore problems related to ergonomics and user perspective is described. For instance, the view and operability of the vessel is severely limited while sitting inside the cabin during bad weather. The operator describes the vessel as only really drivable while in a standing position rather than a sitting position. Also if noticing any larger objects in the water, like a bicycle, the operators manually catches on to it using a stick with a hook. Henceforth he pulls it towards the front of the vessel where he then uses scoop to pick it up from the water. This process is described as very non-ergonomic.

## 4.2 Description of existing product (Renström)

The current product used in Gothenburg City is called Renström. Renström was built by Wester mekaniska to suit the cleaning demands in Gothenburg's canals. Renstöm is entirely made by sheet  aluminium and beams that has been welded into position. Down below follows the solutions for the main functions of the product.

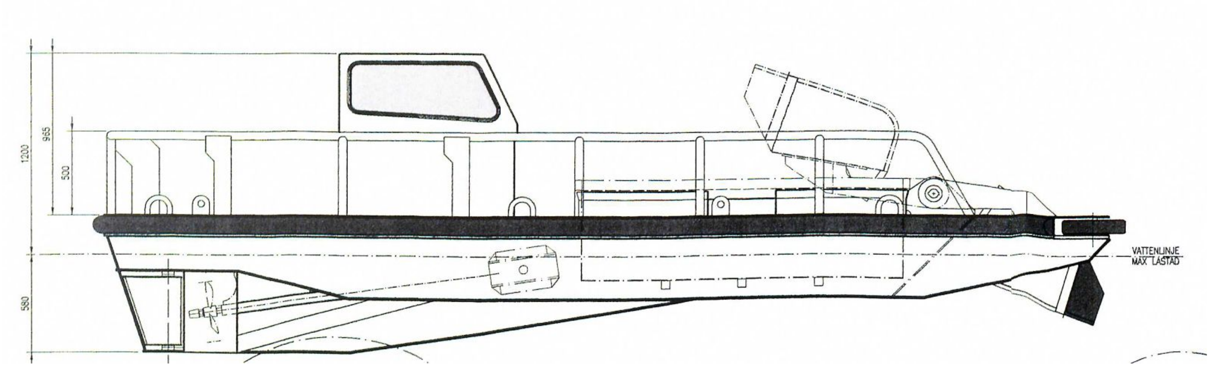



*Figure 7. Renström side view.*

**Solutions:**

- **Propel:**

Renström utilizes two electric motors and powertrains powered by lithium ion batteries in order to propel above the water.

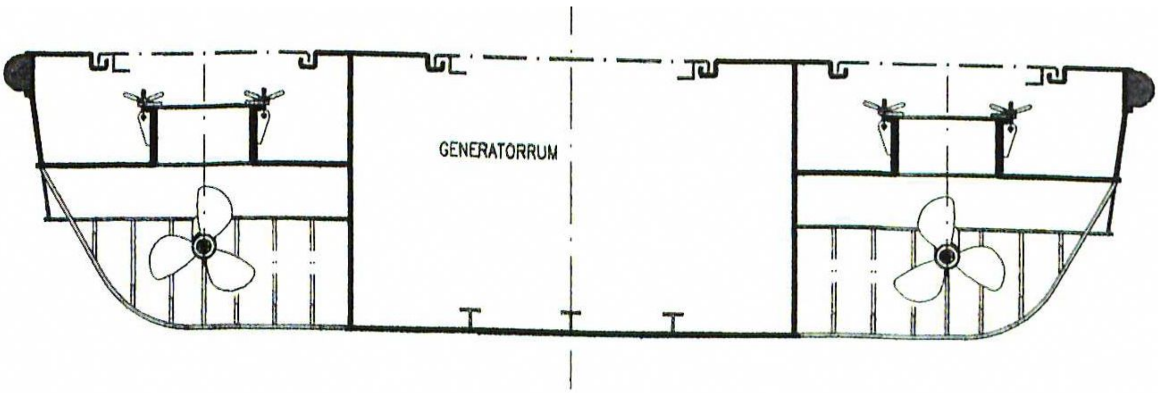



*Figure 8. Renström back view*

- **Float:**

Under the structures lies pontoons that lets Renström float on top of the water

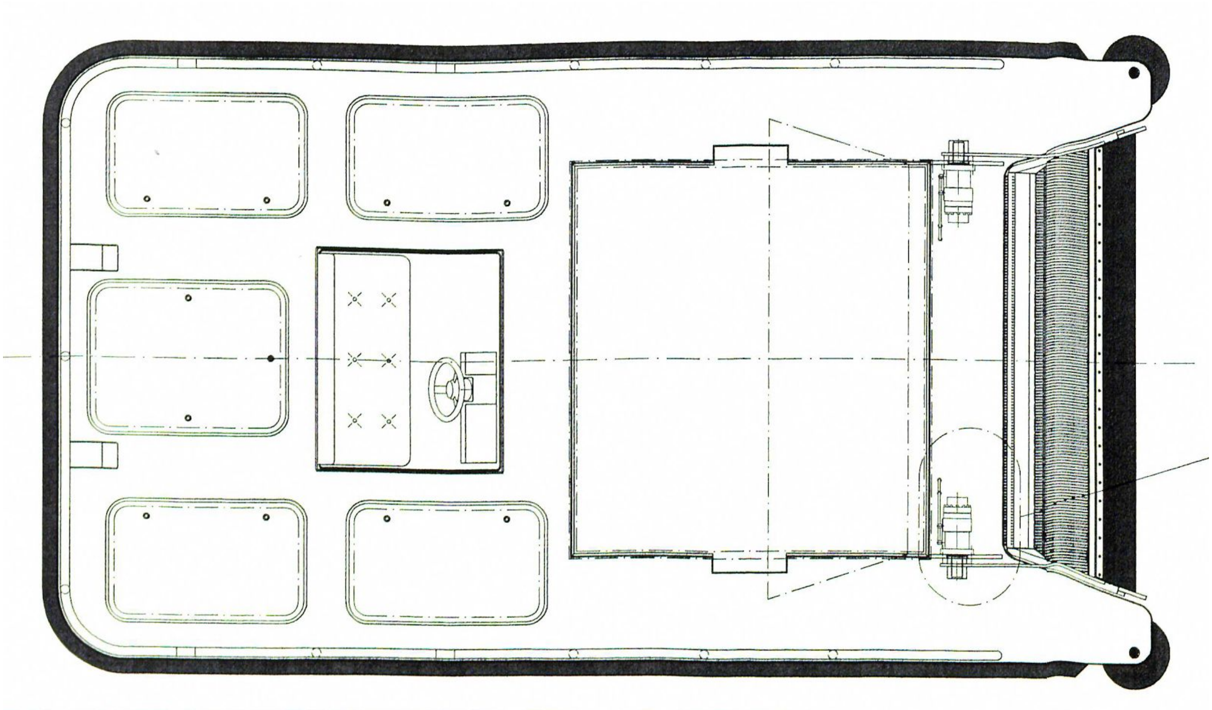


*Figure 8. Renström top view*

- **Collect garbage:**

On the front of Renström is an excavator type scoop attached that via the operator is controlled to be either lowered down or lifted up. While Renström propels forward and the scoop is lowered down, it collects all of the garbaged in front of it. When the scoop is lifted up it drops the garbage inside into the garbage containment.

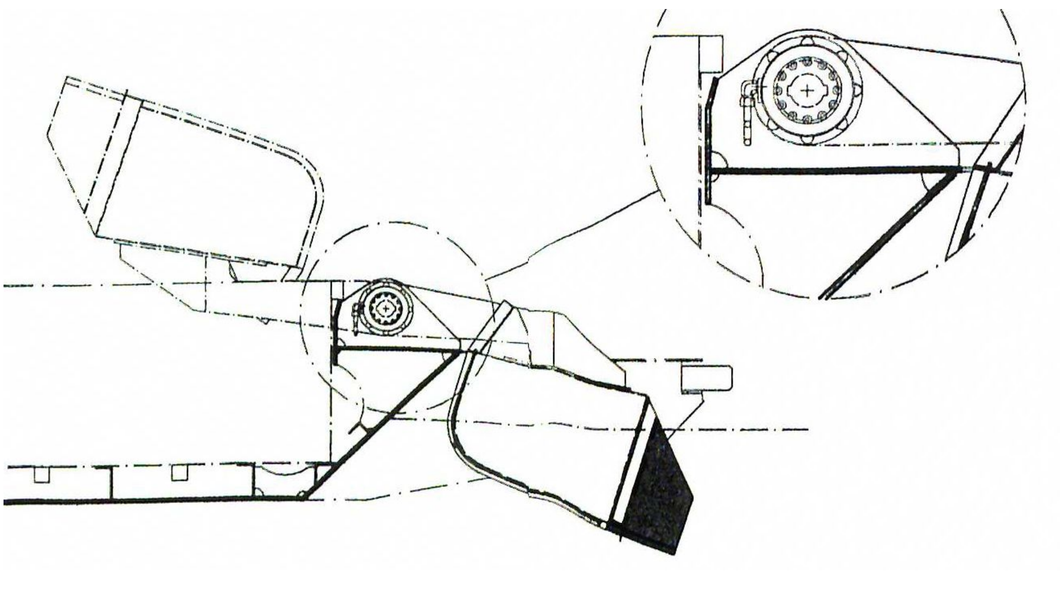


*Figure 9. Close up on the scoop garbage collector*

- **Contain garbage:**

Between the operator and the scoop is a cube formed container lowered down into the product structure. Henceforth the container can be emptied by lifting it with a crane once it is docked.

- **Steering:**

Renström uses regular boat steering to let the operator control the direction of the vessel. Because Renströn uses two engines some of the boat steering can be done by reversing one engine and drive one forward.

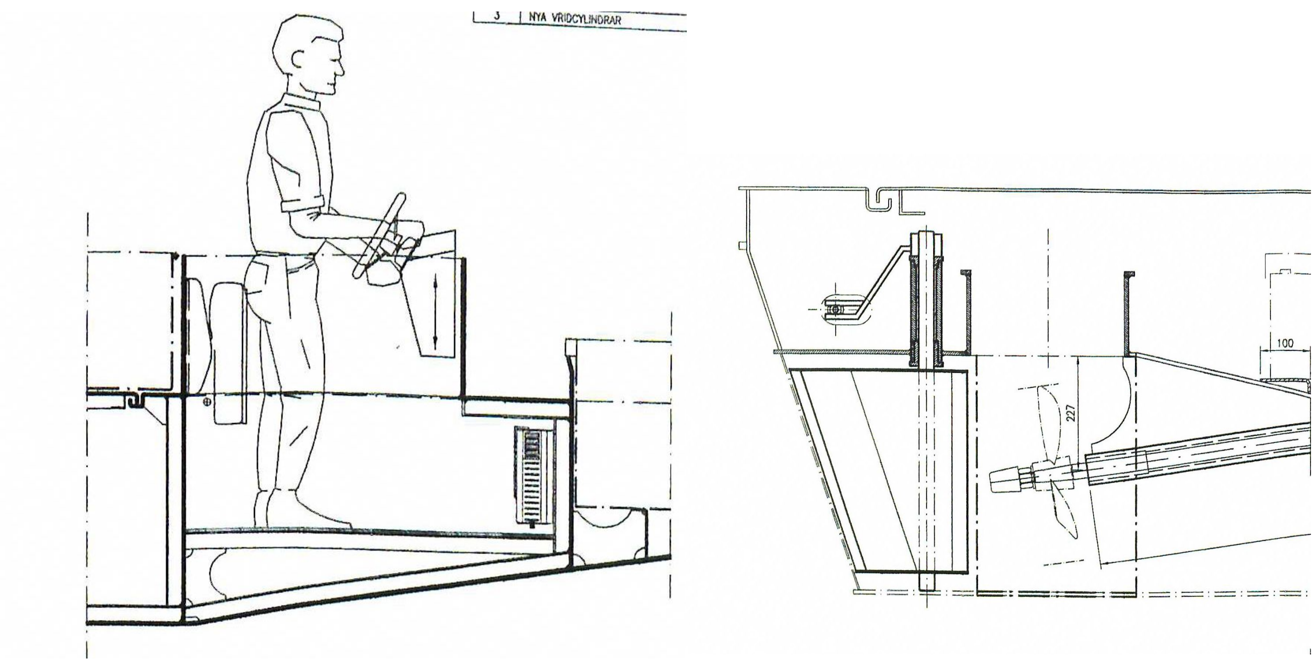



*Figure 10. Close up on the drivers cabin (left) and the propellers in the back end (right)*

## 4.3 Design requirements

The desires and requirements have been compiled in a table below, see figure 11. Each function has been ranked as Desired or Requirement and the desired has also an importance scale ranked from 1-5.

| | | | | | | |
|---|---|---|---|---|---|---|
| | Chalmers | | | | | |
| | | *Project* | Project<br>Worlds best cleaning vessel | **R=Requirement** | | |
| *Created by: Albin & Felix* | | | *Created: 2017-02-01* | D=Desired | | |
| | | | | | | |
| | *Criteria* | *Function* | *Target* | *R/D* | *Importance (1-5)* | *Verification* |
| | 1 | Collect garbage | From the front | R | - | Test |
| | 2 | Collect garbage | From the sides | D | 5 | Test |
| | 3 | Steering | turn left and right and rotate | R | - | Test |
| | 4 | Detect objects under water | > 5 m in depth | D | 2 | Benchmark |
| | 5 | Drain excess water | | R | - | CAD |
| | 6 | Access to clean the propellers | | R | - | CAD |
| | 7 | Lift objects from under water | <50kg | D | 4 | Benchmark |
| | 8 | Float | 2 passangers, its own weight, 1000 kg garbage | R | - | Calculation |
| **1.** | **Performance** | | | | | |
| | 1.1 | Contain garbage | Capacity of 1.5 cubic metres of garbage | R | - | CAD |
| | 1.2 | Tolerance towards bumps | 5 knots of impact towards stationary object | R | - | FEM |
| | 1.3 | Propel | 5 knots | R | - | Calculation |
| | 1.4. | Energy source | Electricity | R | - | Benchmark |
| | 1.5 | Rate of collecting garbage | 1,5 m^3 in 6 hours | R | - | Calculation |
| | 1.6 | Autonomous | Completely self driving | D | 2 | Benchmark |
| | 1.7 | Remote controlled | >300m distance | D | 3 | Benchmark |
| **2.** | **Environment** | | | | | |
| | 2.1 | Non toxic materials | In water | R | - | CES |
| **3.** | **Life span** | | | | | |
| | 3.1 | Total product life span | >30 | R | - | CES |
| | 3.2 | Total product life span | >50 | D | 3 | CES |
| **4.** | **Cost of production** | | | | | |
| | 4.1 | Total cost | <1,500,000 SEK if 1 product is produced | R | - | Calculation |
| | 4.2 | Total cost | <1,000,000 SEK if 1 product is produced | D | 3 | Calculation |
| **5.** | **Weight** | | | | | |
| | 5.1 | Max weight | Less than 3500 kg | D | 3 | CAD |
| | 5.2 | Max weight | Less than 4500 kg | R | - | CAD |
| **6.** | **Dimensions** | | | | | |
| | 6.1 | Length | <6 metres | R | - | CAD |
| | 6.2 | Height above water | <1.5 metres | R | - | CAD |
| | 6.3 | Depth in water | <1 meter | R | - | CAD |
| **7.** | **Aesthetics** | | | | | |
| | 7.1 | Pleasing aesthetics | Fit in to the invironmental "feel" | D | 2 | Consulting |
| | 7.2 | Advertising space | Equal amount of advertising space as Renström | D | 4 | CAD |
| **8.** | **Material** | | | | | |
| | 8.1 | Corrosion resistance | | R | - | CES |
| | 8.2 | Degration resistance | | D | 3 | CES |
| **9.** | **Regulatory requirements** | | | | | |
| | 9.1 | Operable without class VIII | <6 metres in length | R | - | CAD |
| | 9.2 | Undulation | < 0.6 m i height | R | - | Test |
| **10** | **Ergonomics** | | | | | |
| | 10.1 | Operable while sitting | | R | - | CAD |
| | 10.2 | Operable while standing | | R | - | CAD |
| | 10.3 | Protect operator from weather | | R | - | CAD |
| **11** | **Safety** | | | | | |
| | 11.1 | If operated manually it must have a ladder | | R | - | CAD |
| | 11.2 | Mooring system | | D | 4 | Test |
| | 11.3 | If operated manually it must accept 2 people | | R | - | Calculation |

* Benchmark = select a already existing product/function and implement the solution on our concept.

*Figure 11 shows the complete list of design requirements*

## 4.4 Concept development

The product consists of several subsystem. In order to develop the subsystems, you need to understand how the subsystem interact with each other. In order to understand this a functional structure and a functional tree have been made.

### Functions tree

The functional tree (see figure 12) includes both active functions as well as the passive functions that are not included in the function mean structure. To solve the main function of the vessel, to clean the canal, the group decided that there were three different minimally required underlying functions. Namely to handle garbage, move itself and to moor the vessel. Furthermore the minimum amount of functions were listed again that is needed to solve the previous.

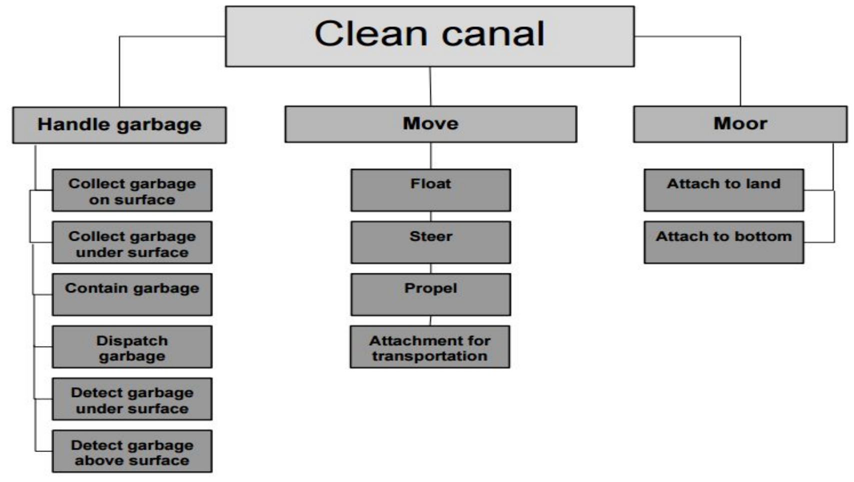



*Figure 12. The result of the functions tree workshop*

### Functions structure

While schematically drawing the functional structure, the group listed the necessary input to be water, garbage and energy which would lead to an output of water, garbage and kinetic energy, see figure 13.

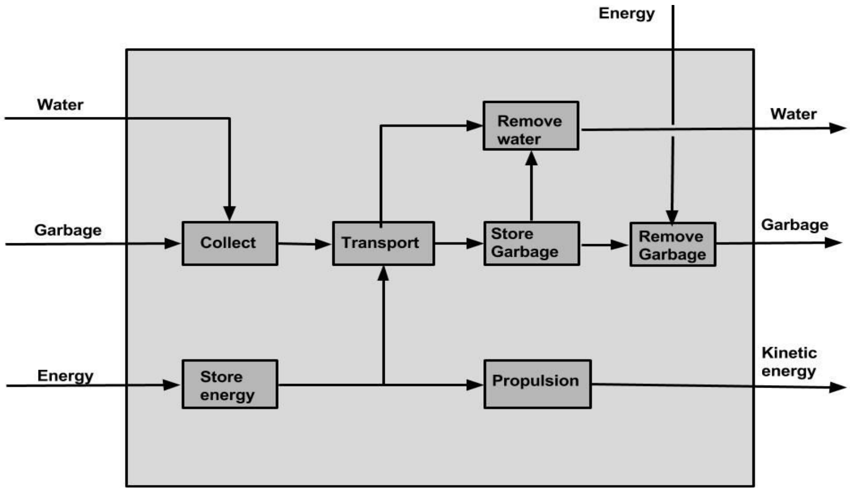



*Figure 13. The result of the functions structure workshop.*

### Search for existing products

The search is divided in two different stages. First the project group looks at each function and how the function has been solved. The functions is then put into the second stage where a complete solutions with this specific function is found. Of the different patents found the results shown below concludes the 5 most differentiable solutions with different main functions.

One of the found solution is a **"Floating debris harvesting system"** see figure 14. The floating structure  reminds of Renström in its design of a pontoon structure but with a combine harvester instead of a scoop that collects the garbage in front of it. The garbage then float in and gets collected in a container at the back of the vessel.[13]

The combine harvester is a more effective way of collecting debris compared to the scoop thanks to its constant movement although the size of the vessel is too big for cleaning in city canals.

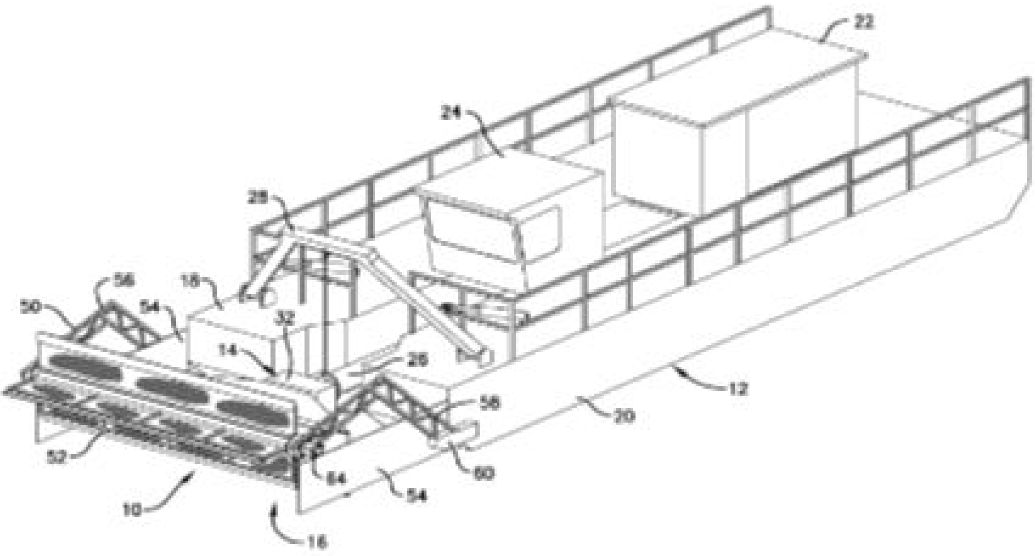


*Figure 14 shows one of the images from the patent of "floating debris harvesting system"*

"**Device for collecting flotsam**" is a product using two separate smaller boats, to drive a smaller floating garbage container. The garbage itself is collected via nets that joins the vessels together, see figure 15.[14]

The nets allow for a great width for collecting the debris and the idea of just letting the garbage float into the container is also an energy efficient method. However the size of the whole system is more suitable for ocean cleaning rather than city canals.

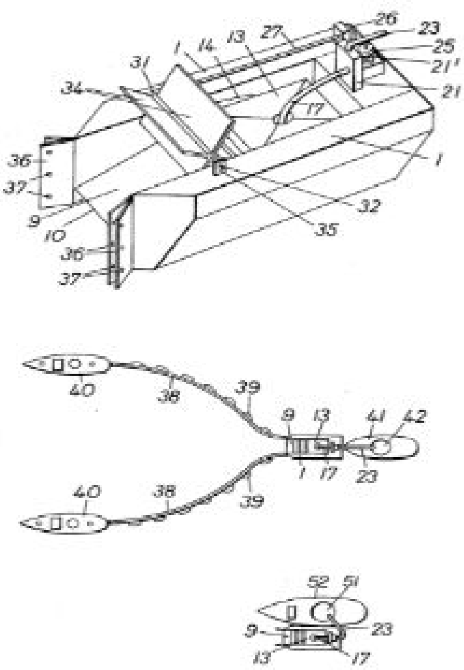


*Figure 15 shows one of the images from the patent "device for collecting flotsam"*

**“Apparatus of collecting buoyant foreign matter”,** see figure 16, is a product that drivers over the floating debri to collect it. Underneath the driving seat between the pontoons is a combine harvester that pulls the garbage into the vessel.[15]

The main pro of this concept is once again the ability to drive straight through the debris without having to stop and lower or lift a scoop. Another smart thing in this concept is the removal of the water. Because the water is running all the way through the vessel it doesn't need a specific function to remove the water in the garbage container.

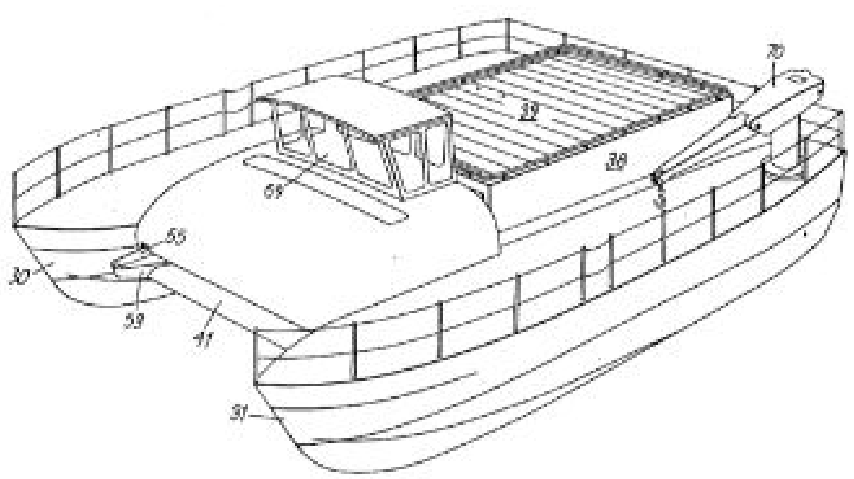


*Figure 16 shows one of the images from the patent “apparatus for collecting buoyant foreign matter”*

**“System for removing floating oil from water”** see figure 17, is a product that lies in the water using a water pump to pump the debris, in this case oil, through a tube unto land and then through a filter to separate debris from water. The product is stationary in itself but moveable. [16]

However a solution that can attract debris without moving could be a good solution. The downside is that the pump most likely consumes a considerate amount of energy. Even if the boat is being able to store that much energy, will it then be maneuverable in the canal?

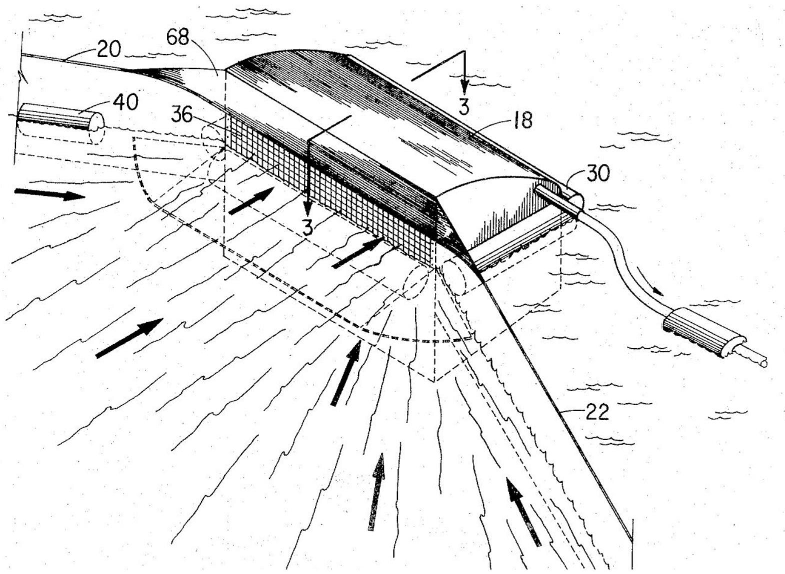



*Figure 17 shows one image from the patent “system for removing floating oil from water”*

**“Device for collecting substances floating in a liquid surface”** is a vessel for collecting substances floating in water. The concept using an endless, rotating conveyor band to collect the garbage, see figure 18. The main pro of this concept is once again the ability to drive straight through the debris without having to stop and lower or lift a scoop.[17]

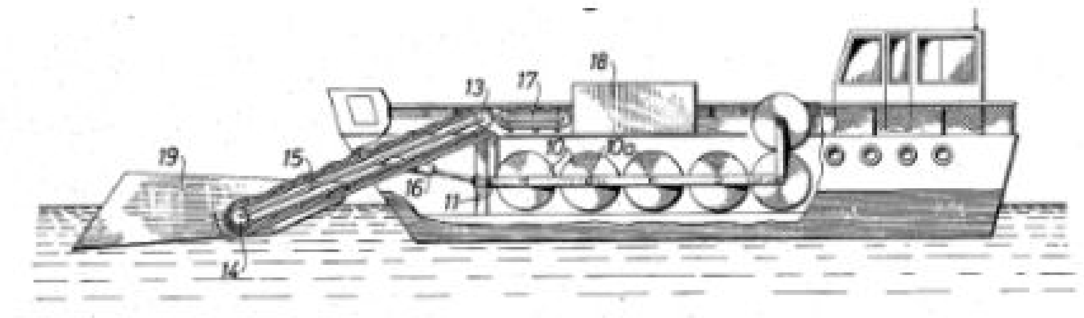


*Figure 18 shows one image from the patent “device for collecting substances floating in a liquid surface”*

## Generated concepts

Using the information from the feasibility study, creating structures for functions as well as the search for existing solutions the sketching of ideas took place. 14 ideas were generated and sketched but after the obvious non realizable concepts and ideas were eliminated, eight different concepts remained. Each concept has three main questions that needs a specific solution:

- How to collect garbage
- How to contain garbage
- How the hull & structure should look

**Concept #1**. The idea is a catamaran like pontoon structure as floatation. Instead of an active technology of collecting the garbage the front and back is just open to let the debris float into the container while the water floats through it to the other side as the container is made out of a metal net. The driver (placed on the side) or the autonomous drive could then drive both back and forth in order to collect the debris. Subsequently the container is enclosed by two doors on each side that opens up into whichever direction the vessel is heading. The other two sketches are of the same concept but with autonomous drive and a roof of solar panels.

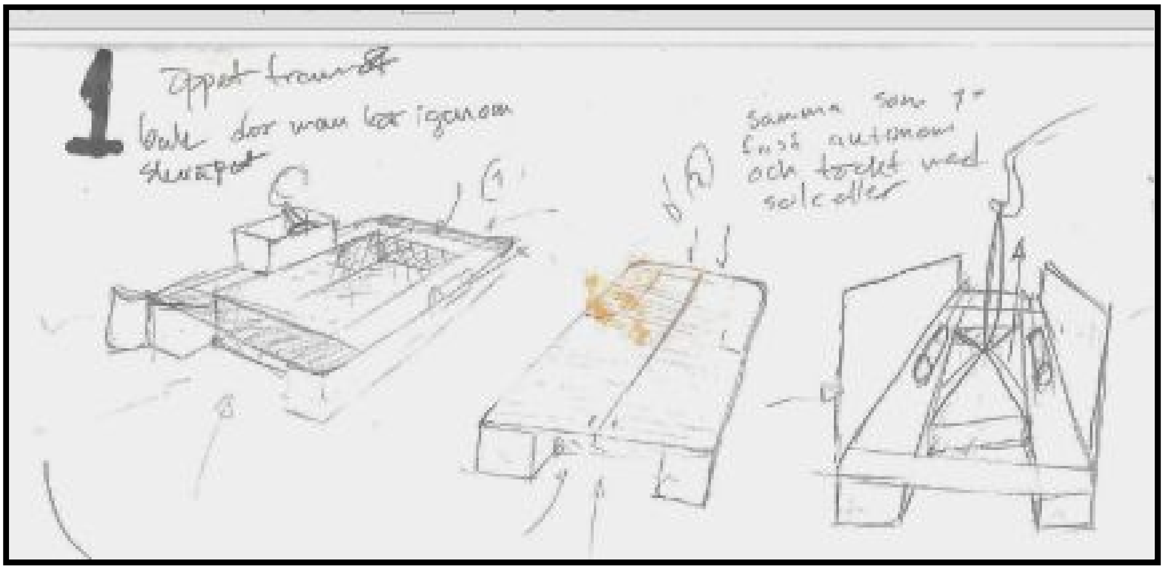


*Figure 19 displays the sketch generated for concept #1*

**Concept #2**. This concepts uses the same type of hull structure as renström but rather than a scoop lifting the debris into the container, there is a conveyor belt pulling it into the container. The container itself is made out of metal net to allow the water to drip through instead of collecting in the container. The steering is of the same type of Renström, that is a regular boat steering.

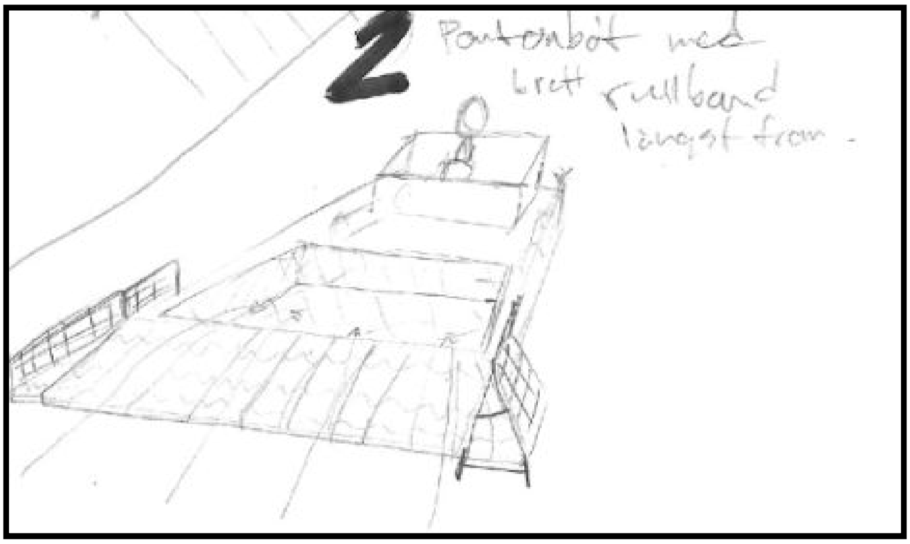



*Figure 20 displays the sketch generated for concept #2*

**Concept #3**. The hull structure is of a catamaran type pontoon. the front is open to let the debris float into the metal net container. The structure allows the water to flow through the product and then through the back, leaving the garbage in the container. The front is supposed to be able to be closed to allow the vessel to drive backwards. The driver sits at the back of the vessel steering with conventional boat steering.

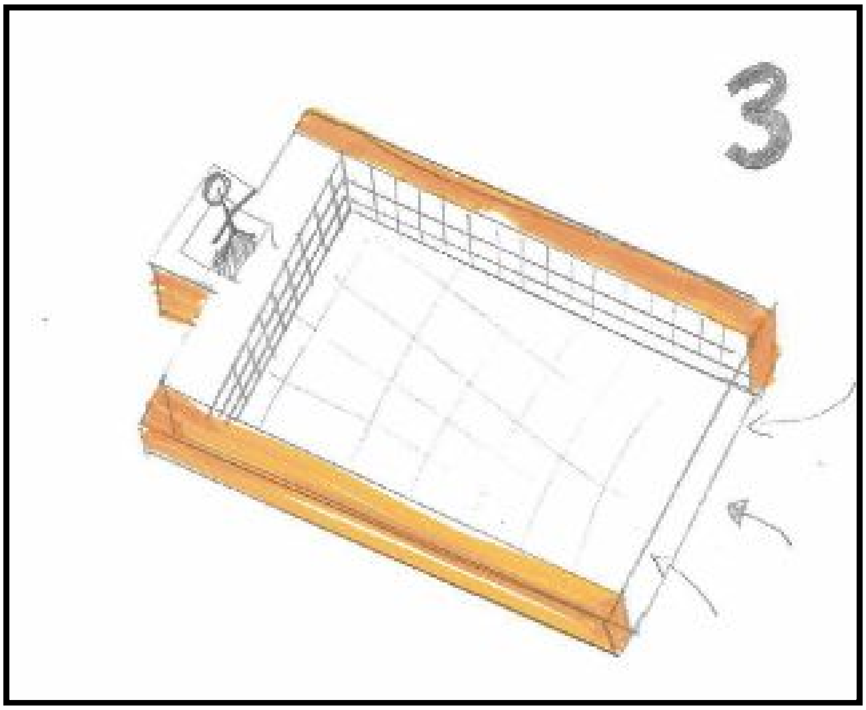



*Figure 21 displays the sketch generated for concept #3*

**Concept #4**. This concept is a catamaran like pontoon structure as floatation. The garbage is pumped from three intakes, one in the front and two on the side. back is just open to let the debris float into the container while the water floats through it to the other side as the container is made out of a metal net.

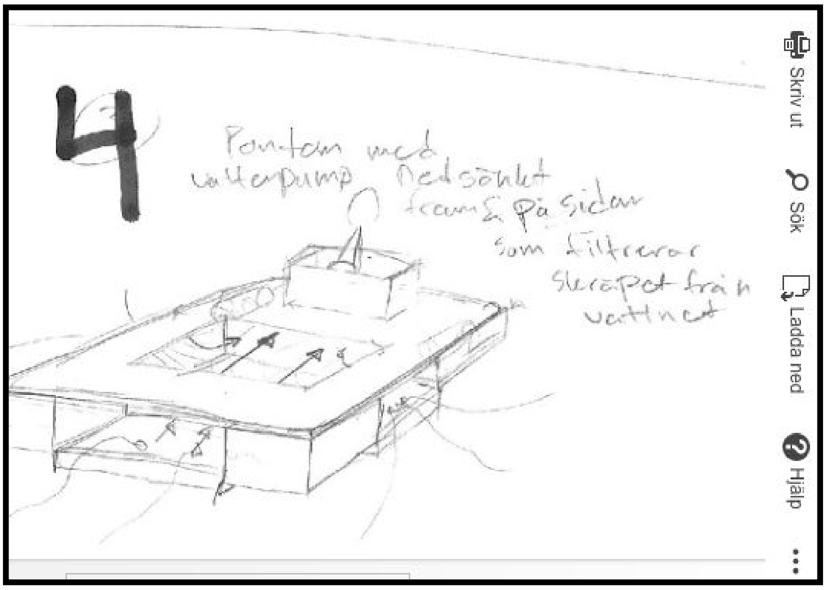



*Figure 22 displays the sketch generated for concept #4*

**Concept #5** has the consists of the same basic hull and structure as that of Renström. However instead of a scoop, it utilizes a combine harvester to collect the debris from the water into the container. The container itself is made out of a net so that the water easily can run through it.

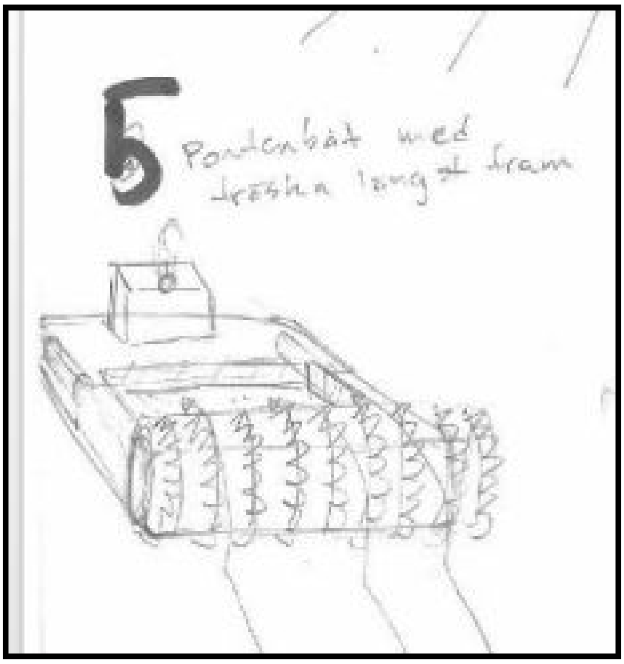



*Figure 23 displays the sketch generated for concept #5*

**Concept #6** is also based on the hull of Renström. To collect the debris there is a flat metal surface on which the garbage gets pushed upon when driven on it. The surface can then be flip back and forth in order to drop it into the container. The container is made out of a net.

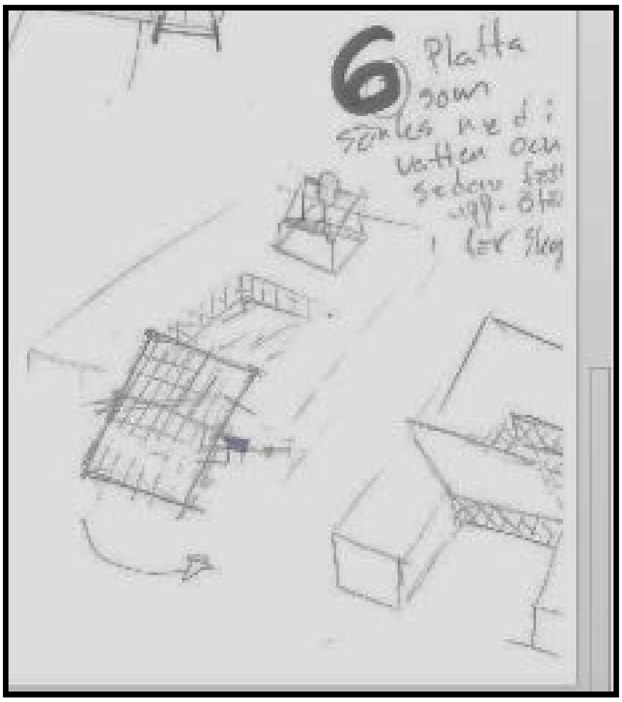



*Figure 24 displays the sketch generated for concept #6*

**Concept#7** is base on the pontoon structure and has a curved front. It collects debris by opening the front and driving straight through it. The driver sits in the back and the water flows through the back via the sides of the driver. The container is made out of a net so that the water runs through.

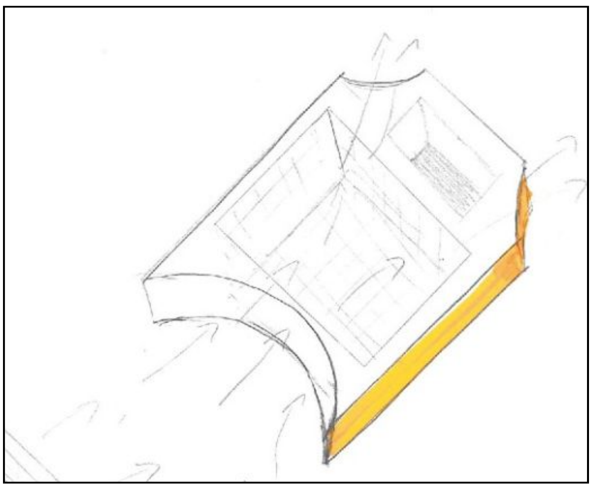


*Figure 25 displays the sketch generated for concept #7*

**Concept #8** Also utilizes the method of letting the water run through the whole vessel and collect the debris at the end of the net container. Compared to #1 and #7 this concept opens the front via doors that turn around the vertical axis.

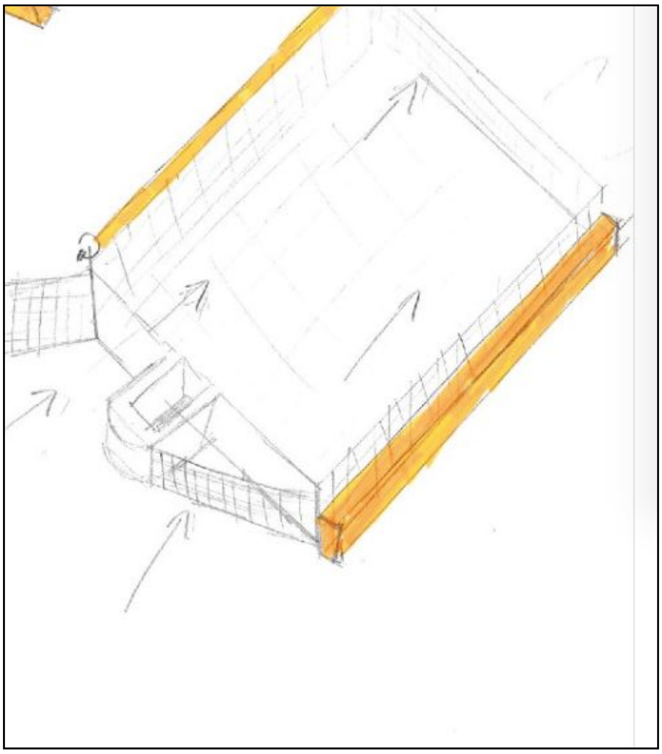


*Figure 26 displays the sketch generated for concept #8*

## 4.5 Pugh matrix

The pugh matrix shown below leads to concept 1, 2, 3 & 7 as winners. Due to the concept 1, 3 and 7 being almost non distinguishable they have been decided to be merged into one single concept. The two winner moves on to next phase where both concepts are evaluated and discussed further.

| Criterias | Scale | Renström (reference) | Concept #1 | Concept #2 | Concept #3 | Concept #4 | Concept #5 | Concept #6 | Concept #7 | Concept #8 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Collect garbage** | | | | | | | | | | |
| Energy efficiency | -1,0,1 | x | 1 | 0 | 1 | -1 | -1 | 0 | 1 | 1 |
| Collecting width | -1,0,1 | x | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 |
| Small debris collectability | -1,0,1 | x | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 |
| Large debris collectability | -1,0,1 | x | 0 | 0 | -1 | -1 | -1 | -1 | -1 | -1 |
| Garbage per time unit | -1,0,1 | x | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 |
| Minimal height | -1,0,1 | x | 0 | -1 | 0 | 0 | 0 | -1 | 0 | 0 |
| Production cost | -1,0,1 | x | 1 | 0 | 1 | -1 | -1 | 0 | 1 | 0 |
| Complexity | -1,0,1 | x | 1 | 0 | 1 | -1 | -1 | 0 | 1 | 0 |
| **Contain garbage** | | | | | | | | | | |
| Potential size | -1,0,1 | x | 1 | 0 | 0 | -1 | 0 | 0 | 0 | 0 |
| Ease of removal | -1,0,1 | x | 0 | 0 | 0 | -1 | 0 | 0 | 0 | 0 |
| Difficulty for water to stay | -1,0,1 | x | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Safety against debris leakage | -1,0,1 | x | -1 | 0 | -1 | 1 | 1 | 0 | -1 | 0 |
| Good distribution in container | -1,0,1 | x | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 |
| Production cost | -1,0,1 | x | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Complexity | -1,0,1 | x | -1 | 0 | -1 | -1 | 0 | 0 | -1 | 0 |
| **Hull & structure** | | | | | | | | | | |
| Room for internal parts | -1,0,1 | x | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Room for extra storage | -1,0,1 | x | -1 | 0 | -1 | 0 | 0 | 0 | 0 | -1 |
| Movability of driver | -1,0,1 | x | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -1 |
| Maneuverability in water | -1,0,1 | x | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Visibility of driver | -1,0,1 | x | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Potential autonomy | -1,0,1 | x | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Hydrodynamics | -1,0,1 | x | 0 | -1 | 0 | 0 | 0 | -1 | 0 | 0 |
| Production cost | -1,0,1 | x | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Complexity | -1,0,1 | x | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Totals | 0 | x | 7 | 5 | 5 | 0 | 2 | -1 | 6 | 3 |

*Figure 27 displays criteria on the y-axis, concepts on the x-axis and the points given in the intersection. The results are seen in the bottom row called "Totals"*

### Modularization & chosen concepts

Since all concepts consist of the same solution for how to float on water, it has been decided that the pontoons and its structure should make up the basis for a module platform and that the driving seat should be in the front. Furthermore different solutions for collecting and containing the garbage can be placed and locked upon the platform via a mutual interface. In this way the buyer of the product can freely choose between solutions to find the optimum combination that suits their individual needs. This allows for the potential of the product to be used in other fields other than collecting garbage on water, as well as further development of separate modules without having to redesign the whole product.

The modules decided to be further detail designed in this project are concept #1 and a reiterated version of concept #2, see figure 28

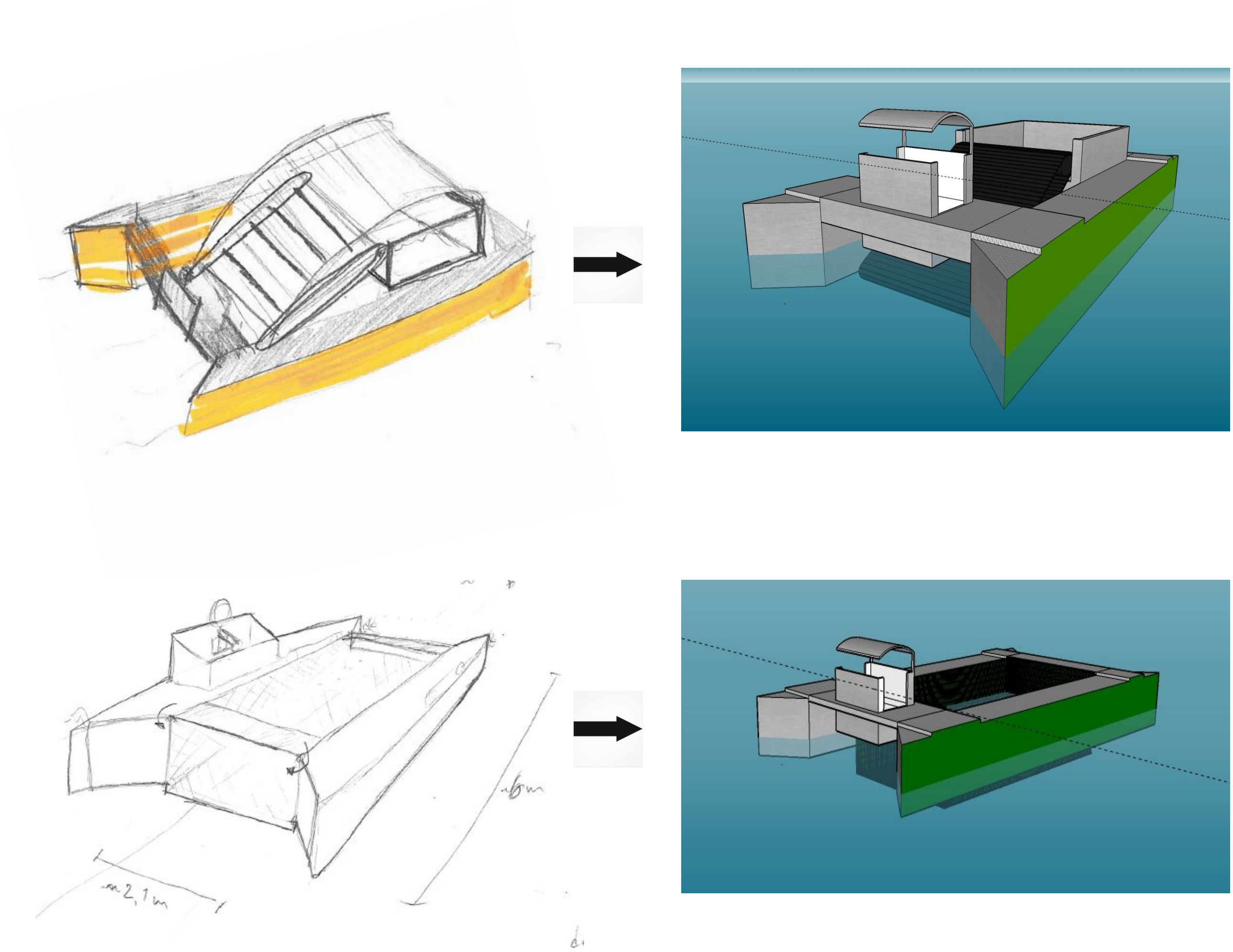


*Figure 28 shows the concept #2 (top) and concept #1(bottom) including sketches (left) and rough 3D visualizations (right side).*

## 4.6 Detail design

The basis for the detail design was the sketches from the concept development. Based off of these and the geometrical constraints from the feasibility study 3D geometry was created in Catia v5 for the three modules Eco Marine, Collector (concept #1) and Harvester (concept #2). Suppliers for components were contacted for prices and technical detail information parallel to the 3D modeling of the in house components. The following topics will describe the details of the total concept as well as all the modules.

### Total concept

The end result of the whole product development process is a modularized utility vessel mainly consisting of a platform (called Eco Marine platform described down below) that via a standardized interface can lock unto a number of different tools (e.g for cleaning the surface of canals) for various application. Together with the platform two different tools for cleaning in the canal has been developed, Harvester and Collector. The buyer of the product can then choose to buy the platform and one of the tools or both and switch between them as needs vary for different situations. The idea [10] is that further resources can be put into developing other types of tools for completely different scenarios but utilizing the same platform, thus decreasing a significant amount of expenditure in research and development.

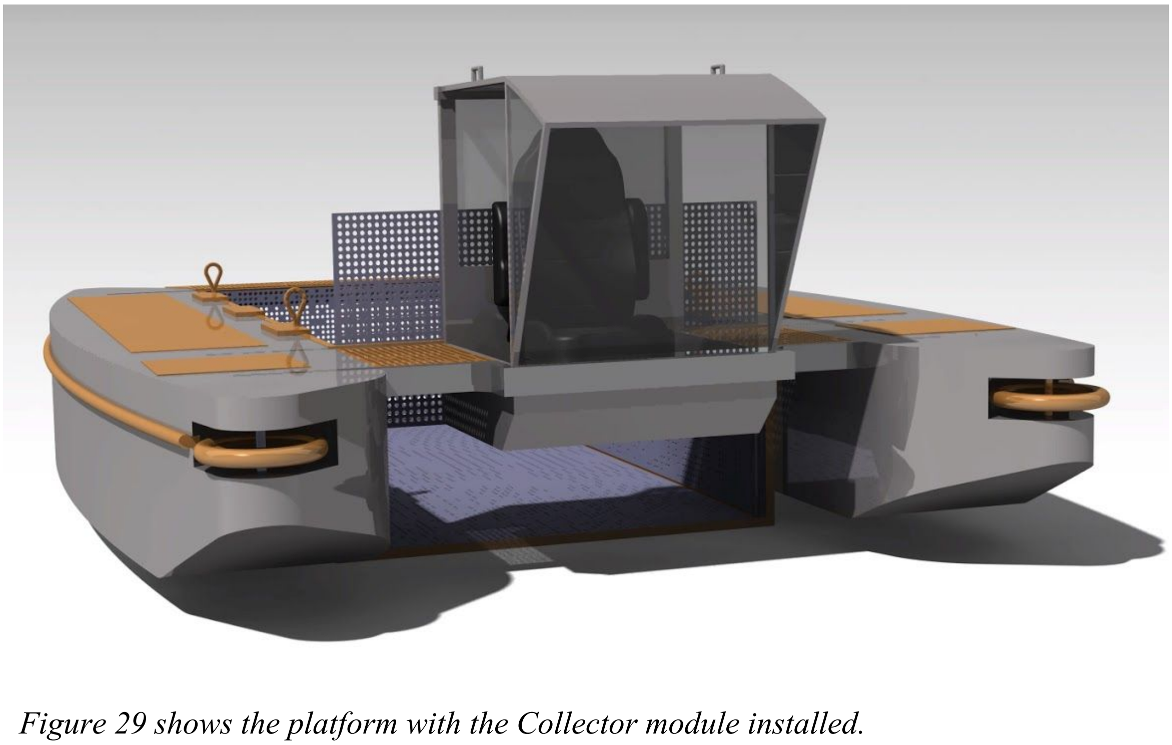


*Figure 29 shows the platform with the Collector module installed.*

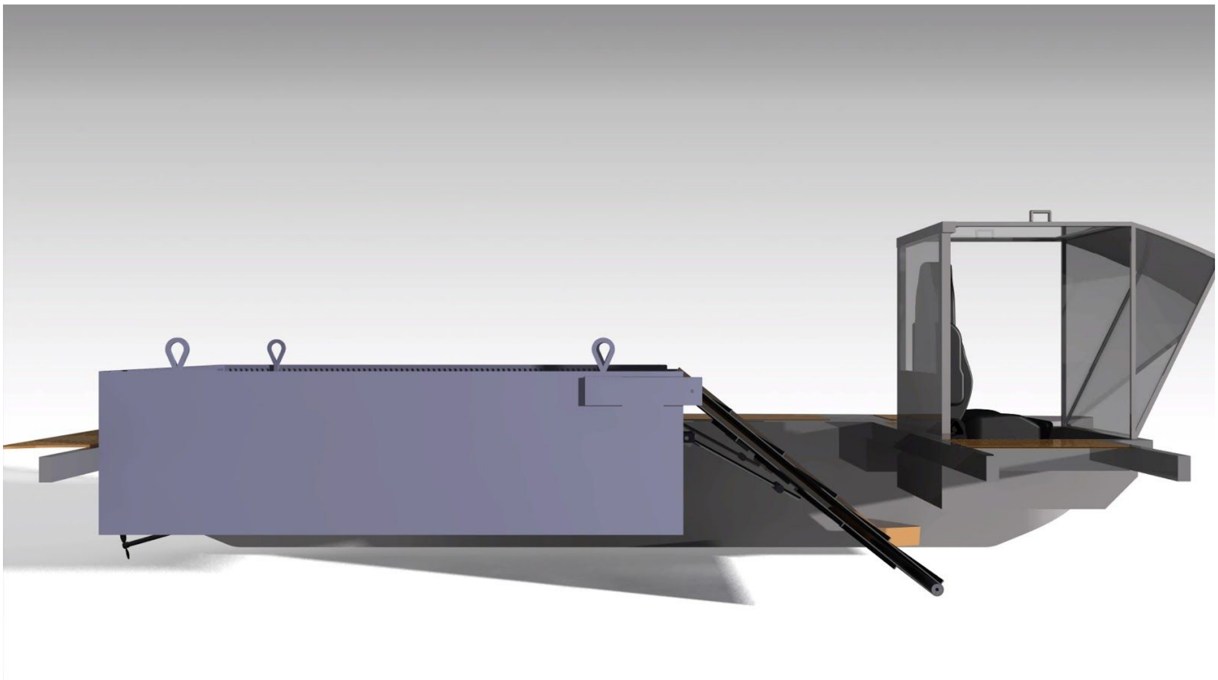


*Figure 30  shows a section view of the platform with the Harvester module installed.*

The interface between the modules consists of three female pockets in each pontoon. On the tools there are a corresponding male that fits into the pockets, see figure 31. Due to the weight of the tools they are likely to stay in place without further attachments (which would be the whole process of installing the tools), even though it should be tested in a prototype before manufacturing.

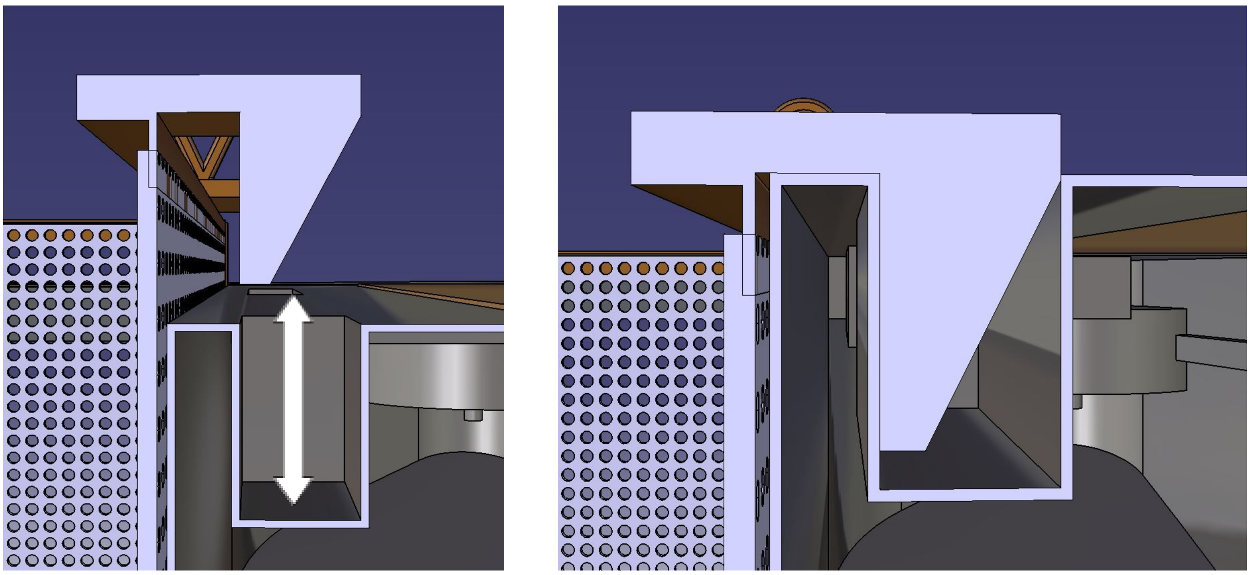


*Figure 31. The images above shows a section view of the interface in the process of being lifted into place (left) and after it have been lifted into place (right).*

**Eco Marine platform**

The platform utilizes a **catamaran type hull**, (see appendix 1 for an assembly drawing) consisting of two separate aluminum pontoons with a capacity of lifting roughly 7 tons of weight. three beams hold the pontoons together. The catamaran style reduces unnecessary area contact with water and thus reduces the drag. Furthermore the design itself allows for water to flow through the vessel compared to the more regular single hull type which pushes the water in front of the vessel. In this case it is advantageous to let the water run through as it allows the vessel to separate debris without actively picking it up, which reduces energy consumption.

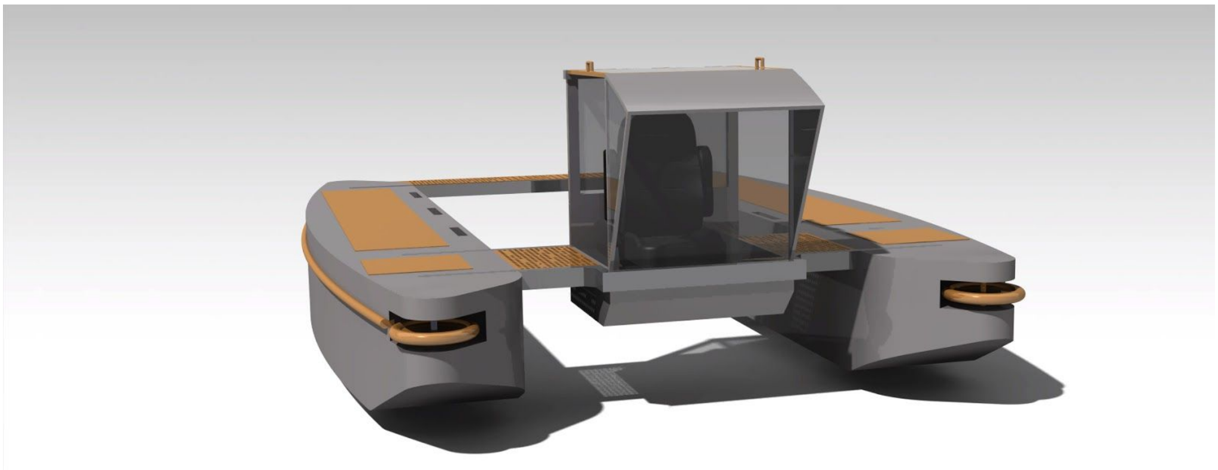


*Figure 32 shows the platform from front/right view.*

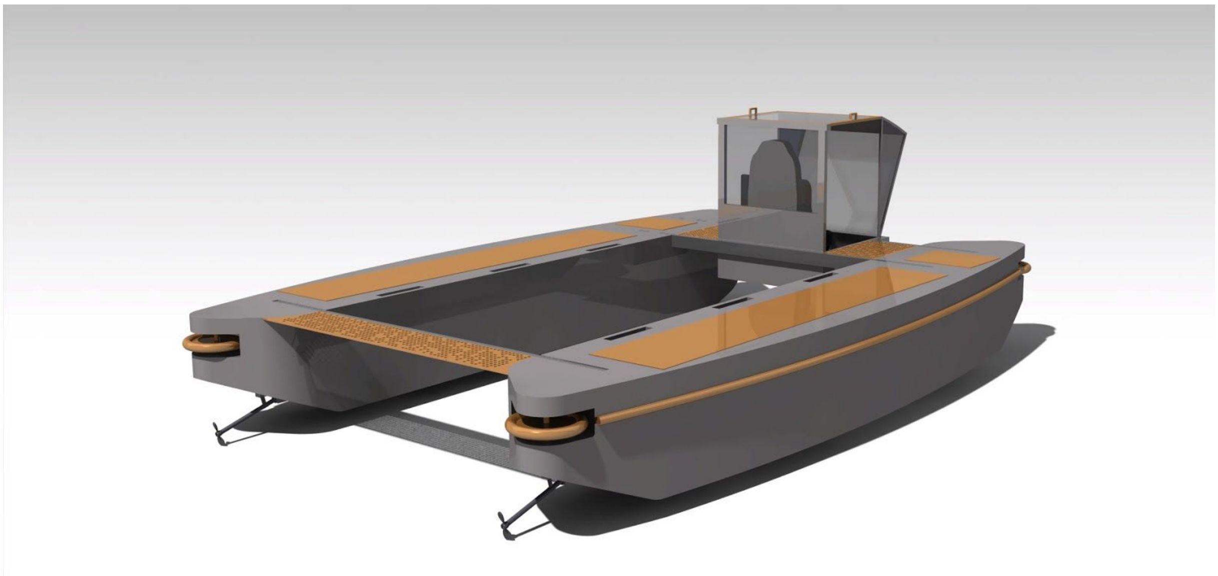


*Figure 33 shows the platform from the back/right view*

To propel the vessel one **electric motor and driveline from Green star marine** (Greenstar 36D) are attached in each pontoon.[18] These are paired with 4 lithium ion batteries per pontoon with a total of 8 batteries with a capacity of 17kWh of energy storage.

The **driver's** cabin is placed in the front of the vessel to increase sight of the operator and make it easier to spot floating debris, subsequently the back of the cabin is also covered in transparent plexiglas so that the driver can spot any in the container that is not desirable. The top of the cabin is possible to open so that the operator can choose whether to stand and drive or sit comfortably. Between the pontoons are net floor so that the operator can walk around the vessel if necessary. In the front and back of the pontoons there are wheels attached. These wheels lets the operator drive close to walls where debris usually concentrates. The orange rubber strip will decrease material strain if the vessel bumps into other objects

Throughout the development process it has been assumed that **aluminum** is the best material choice for the hull of the platform based off interviews with stakeholders and operators. In order to verify this, a material selection analysis have been made in CES (Cambridge engineering selector). To sort out materials, the constraint “acceptable to salt water” was added. Subsequently a plot was created showing all metal materials with the y-axis representing the cost per weight and x-axis show all metals accepting salt water. In the plot (see appendix 4) one can tell that the cheapest range of metals that accept the requirement are all aluminum except for some cast iron metals which are excluded due to their high density.

**Harvester module**

The harvester module (see appendix 2 for a rough assembly drawing) consists of a outer floorless welded aluminum box with brackets to connect into the platform interface. Inside the box is another separate box made of metal net. The net box is separable to make it possible to empty the container without having to remove the whole module, see figure 34.

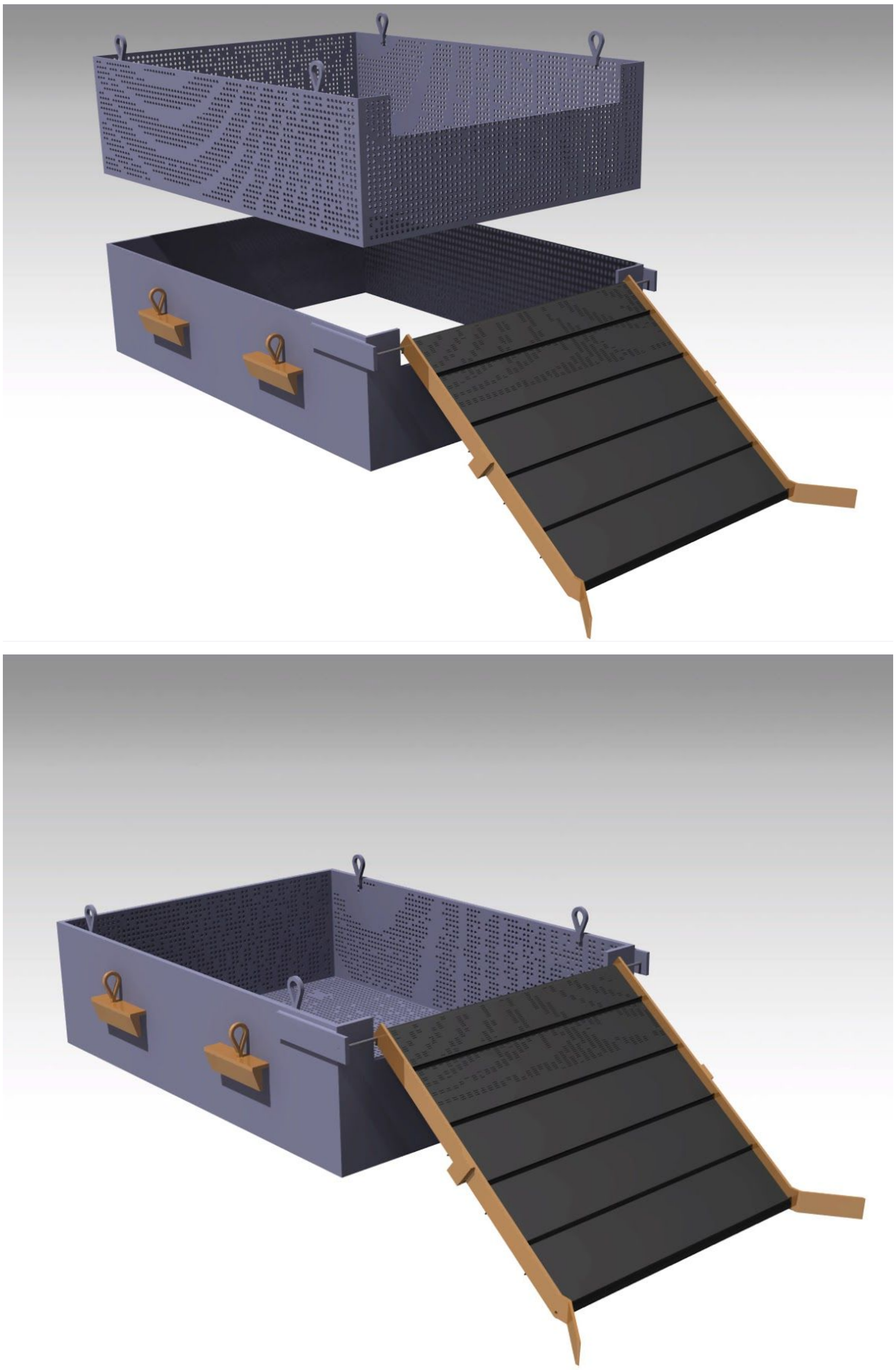


*Figure 34 shows the garbage containing net box being lifted into place.*

Furthermore there is a 1500x1500 millimeter **conveyor belt transporter** attached to the outer box facing the front of the platform. The front part of the belt is slightly suspended into water, see figure 35. This acts as the collector of the garbage debris. The transportation speed is adjustable between 0.5 - 60 meters per minute and it is made entirely out of stainless steel accept from the belt itself which is made from polypropylene links which is a waterproof plastic. The transporter costs approximately 70000 [SEK]. The electric motor is tested and classified as IP67 which means that it is waterproof enough to be suspended into water 1 meter deep for 30 minutes.[19] Which is adequate for this products needs as the motor itself won't actually be suspended into water.

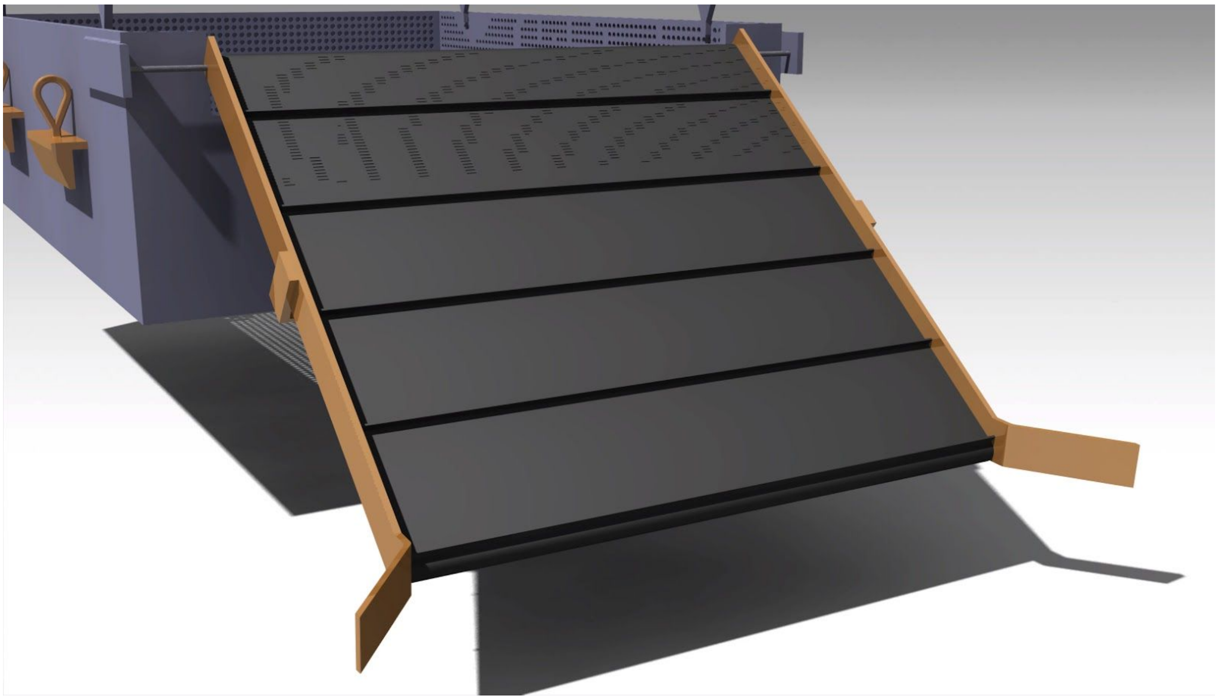


*Figure 35 shows a depiction of what the transporter conceptually looks like.*

Between the transporter and the outer box is a concept of a mechanical design solution for how to **change the angle of the conveyor belt**. A motorized threaded shaft holds the two components together. In the outer box end an electric motor is attached to another shaft so that it can rotate around its axis, see figure 36 or appendix 2. In the other end the shaft goes through another threaded hole of a bracket attached to the transporter. In conclusion the concept should let the shaft rotate around an axis on the front of the box while the "screw" pulls the transporter in and out, thus changing its angle.

*Figure 36 show the mechanical design concept of how to change the angle of the transporter.*

**Collector module**

The basis of this design is to let debris flow into the container. On each side there are two motorized threaded shafts that drives the doors up and down when the electric motor is running. Subsequently this makes it possible to open and close the container so that the debris can enter and be captured inside. The fact that you can open each side separately makes it possible to also drive and collect debris in reverse, making it unnecessary to stop and turn around to change direction. The shaft also holds the doors and metal structure, together, see figure 37.

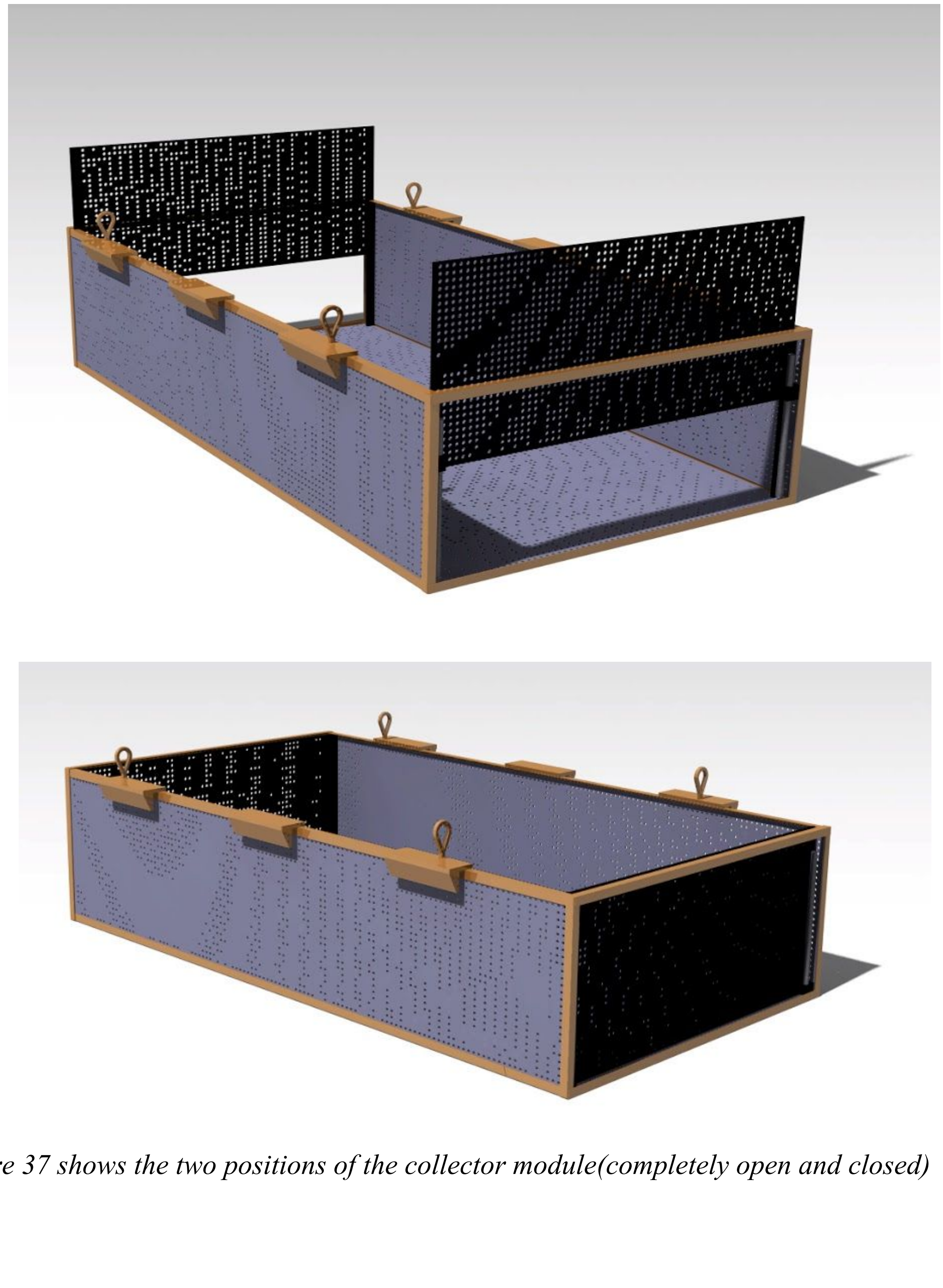


*Figure 37 shows the two positions of the collector module(completely open and closed)*

ECO Marine Collector is meant to operate with one side closed and one opened, See figure 38. When the container is full the doors are lowered and crane can hook onto the loops to lift it up in order to empty the container.

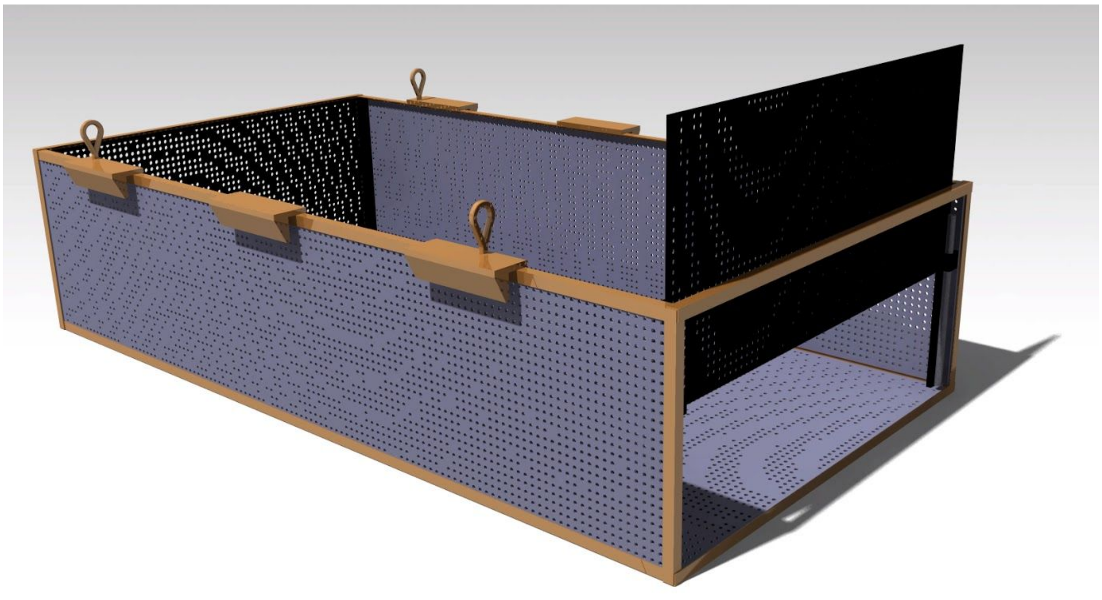


*Figure 38 show the collector module operation position, one door opened and one closed*

The collector module (see appendix 3 for assembly drawings) consists of a stainless steel structure, with six brackets which connects into the platform interface. The metal net is made of expanded metal(sträckmetall) with L=30[mm], B=12[mm], S=4,8[mm], T=2,5[mm]. The size of one net is 1000x2000[mm] and it weighs 30 [kg], see figure 39. The properties and dimensions and of the metal net is taken from the supplier product listing[20]. The size of the holes should be small enough to contain small debris like cigarette bumps but large enough to efficiently let water run through so that the container doesn't carry water.

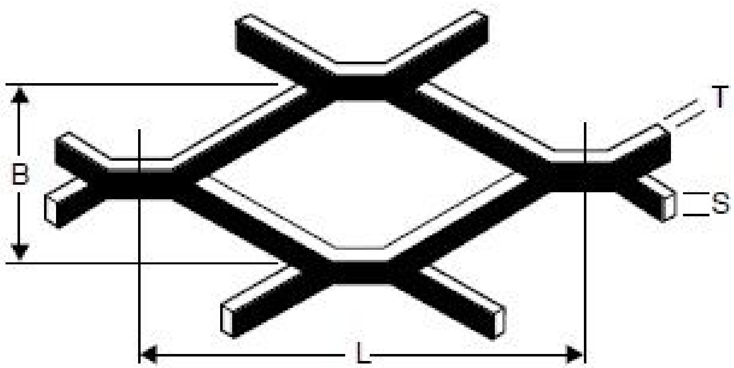



*Figure 39 show the metal nets(sträckmetall) structure*

## Cost estimation

A cost estimation of the two chosen concept has been made, see figure 40. The cost estimation is divided into three sections, one section for each product: ECO Marine, ECO Marine Collector and ECO Marine Harvester. The prices of the parts are taken from suppliers that are well known within the industry. In some cases parts are calculated on the basis of material cost and labor cost. The labor cost is based on 500 [SEK] per hour of work multiplied by the estimated number of hours it takes to produce the component. Due to lack of information, three parts don't have any estimated price and is marked with an **X.**

With consideration to the parts that are not priced, the total cost of ECO Marine is 722,500[SEK] and the price for module ECO Marine Collector is 32712[SEK] the module ECO Marine Harvester have a price of 100434[SEK]. The prices of the benchmarked product and material information was taken in the early 2017.

| | Price(SEK) or (Kr/kg) | Quantity | ECO Marine | Quantity | ECO Marine Collector | Quantity | ECO Marine Harvester |
|---|---|---|---|---|---|---|---|
| **Collecting garbage** | | | | | | | |
| Conveyor belt(Harvester) | 70000 | 0 | 0 | 0 | 0 | 1 | 70000 |
| Hatch(Collector) | 12 | 0 | 0 | 1 | X | 0 | 0 |
| **Contain garbage** | | | | | | | |
| Steeal structure(Collector) | 6120 | 0 | 0 | 1 | 6120 | 0 | 0 |
| Steeal structure(Harvester) | 8274 | 0 | 0 | 0 | 0 | 1 | 8274 |
| Grid(Collector) | 2216 | 0 | 0 | 12 | 26592 | | 0 |
| Grid(Harvester) | 2216 | 0 | 0 | 0 | 0 | 10 | 22160 |
| **Hull & structure** | | | | | | | |
| Material | 50 | 360 | 18000 | 0 | 0 | 0 | 0 |
| - Labor | 200000 | 1 | 200000 | 0 | 0 | 0 | 0 |
| Floor | 2216 | 4 | 8864 | 0 | 0 | 0 | 0 |
| Steel beams | 4136 | 1 | 4136 | 0 | 0 | 0 | 0 |
| Electric motor | 77000 | 2 | 154000 | 0 | 0 | 0 | 0 |
| Battery | 28000 | 8 | 224000 | 0 | 0 | 0 | 0 |
| **CABINE** | | | | | | | |
| Material | 45 | 300 | 13500 | 0 | 0 | 0 | 0 |
| - Labor | 100000 | 1 | 100000 | 0 | 0 | 0 | 0 |
| Control table | X | 1 | X | 0 | 0 | 0 | 0 |
| Chair | X | 1 | X | 0 | 0 | 0 | 0 |
| | Sum (SEK) | | 722500 | | 32712 | | 100434 |

*Figure 40 show a price estimation of ECO Marine, ECO Marine Collector and ECO Marine Harvester*

# 5. Conclusions and recommendations

During the project, a concept has been developed that according to us solves the problem of how to separate garbage from the water surface in canals better than the existing solution in Gothenburg. However the design is not entirely completed, partly in detail design but also due to the endless possibilities in modularization strategies. The following subjects will describe what we think are the main pros and cons of Eco Marine as well as commenting on what needs to be further developed.

## Comparison to Renström and USP (unique selling point)

When put to comparison to Renström, ECO Marine holds several similar traits due to the fact that they are cleaning products based on existing vessel technology. To propel itself ECO Marine uses the exact same powertrain, motors and batteries as Renström, as well as means of steering as there were no needs for further improvements within these areas. Furthermore the garbage is kept in place in a similar way, that is to say with a removable container. However the containers of Collector and Harvester are made out of a metal net so that all water following into the container simply runs through. This was a key problem according to the operators as they were describing how container could collect amounts of water while the bilge usually stopped working due to debris getting stuck in the system.

Subsequently the **main differences** to Renström are the floatation structure design as well as the means of collecting the debris. Due to the catamaran type hull that lets the **water flow through the vessel** without pushing it forward as well as the tools **constant working activity**. These are the main unique selling points of ECO Marine and its tools as they allow the driver to **smoothly operate** the vessel in a more **fluid motion** with no need to stop and lift up the garbage, like in Renström that utilizes a scoop, thus increasing time and energy efficiency.

## Comparison to requirements

A list of recruitment was established at the project start. The list consist of three problem statement:

- The product must be able to float and propel on water.
- The product must be able to collect garbage from the surface of the water
- The product must use electricity as its source of power

ECO Marine solves two problem, the last problem is solved with either Harvester module or Collector module. Next phase consisted of interviewing people with different connections to the current product. This enabled a new requirement list to be made, see figure 11. When comparison the requirement list with ECO Marine Harvester and the Collector there are requirement/desires which the chosen concept not met[M], or which has not been evaluated due to time[T]:

- Collect garbage, from the sides [M]
- Total product life span [T]
- Advertising space [M]
- Tolerance towards bumps [T]
- Mooring system [M]
- Access to clean the propellers [M]

## Personal reflections

Both of the group members Albin Hansson and Felix Sjöstrand consider the project as very fulfilling and a good chance to further develop skills in executing product development projects. We think that the thesis was particularly fun for the lack of constraints we were initially given. We had to independently figure out how and where to gather the information needed to proceed in the process. Consequently also allowing us to think creatively when generating ideas, hence the thesis project allowed us to work the parts of development that we personally find most interesting; ideation and concept development of innovative new products.

## Recommended continued work

While working on the project, several new ideas were generated during the process. As well as some ideas that were initially there but not looked into closely due to lack of time. For instance one very interesting aspect of development of utility vessels is the potential in not having to rely on workers day schedule buy implementing autonomous drive. Due to lack of time, the project couldn't encompass such a feasibility study. However the fact that the operator's cabin is produced as a separate module makes it possible to replace it with a autonomous drive module if such development were to be made.

Furthermore the detail design is not completed in the finals steps. The end work should be seen as a slightly developed concept as not all parts have been look into close enough for the information to be adequate for manufacturing. For instance the beams holding the structure together have not been analyzed from a mechanics of materials point of view, which would be completely necessary before even building a prototype. Nor have fixings such as weldings, bolts and nuts and so forth been analyzed. In order to identify if the containers can withstand the load from the garbage, one should also perform some FEM analysis before building. It is likely that the metal net itself wouldn't be able to hold several tons making it necessary to add beams for increased stability. Subsequently there have been no form of ergonomics test or simulation as the driver's cabin haven't been developed in detail, which would also be necessary before prototyping.

One idea that came about during the project was if it was possible to have the containers as completely separate modules that could float by themselves. In that case they could be released when full and the platform could just lock into another container and continue working without having to wait for a truck to come and empty the debris. Thus leading to even more workflow in the process.

The most interesting future possibilities derive from potential in continued creative work on developing new modules for other types of needs and scenarios. Some ideas for continued work are solar cell floors/roofs, modules for shore rescuing applications or firefighting from the canals.

## 6. References

[1] Slat B. How the oceans can clean themselves - a feasibility study. The Netherlands, The ocean cleanup; 2014.

[2]. Johannesson H, Persson J, Pettersson D. Produktutveckling. 1st ed. Stockholm: Liber; 2013.

[3]. Pugh S. Total design. 1st ed. Addison-Wesley; 1990.

[4]. Burenius J, Lindstedt P. Skapa oöverträffat kundvärde - hur du praktiskt går tillväga, del 2 i värdeserien. Fälth & Hässler; 1999.

[5] Kvale S, Brinkmann S. Den kvalitativa forskningsintervjun. Lund: Studentlitteratur AB; 2014.

[6]. Fakta om skräpet i havet [Internet]. Håll Sverige Rent. 2017 [cited 21 March 2017]. Available from: http://www.hsr.se/fakta/fakta-om-skrapet-i-havet

[7]. Tonvis med skräp under ytan i kanalen [Internet]. Göteborgs-Posten. 2017 [cited 23 March 2017]. Available from: http://www.gp.se/nyheter/g%C3%B6teborg/tonvis-med-skr%C3%A4p-under-ytan-i-kanalen-1.79129

[8]. [Internet]. 2017 [cited 21 March 2017]. Available from: http://www.hsr.se/sites/default/files/skraprapport_lagupplost.pdf

[9] Moore C, Philips C. Plastic Ocean: How a Sea Captain's Chance Discovery Launched a Determined Quest to Save the Oceans. USA: Tantor Media inc; 2012

[10] 1. Fishing For Litter Scotland [Internet]. Kommunernas Internationella Miljöorganisation; 2006. Available from: http://www.fishingforlitter.org.uk/assets/file/Report%20FFL%202011%20-%2014.pdf

[11] Workshop: Plastic island [internet] 2009 [cited 30 may 2017] Available from: http://www.plasticreef.com/?p=166

[12] Erixon G, Erlandsson A, von Yxkull, Mo Östergren B, Gröndahl P. Modulindela produkten. Stockholm: industrilitteratur; 1994.

[18] Produkter [Internet]. GreenStar Marine. 2017 [cited 30 May 2017]. Available from: http://greenstarmarine.se/produkter/

[19] SP sveriges tekniska forskningsinstitut [internet]. sp.se. 2017 [citet 25 may 2017]. available from: http://www.sp.se/sv/index/services/ip/sidor/default.aspx

[20] Lager- prislistor nr 104 [Internet]. 2017 [cited 30 May 2017]. Available from: http://stenastal.se/PageFiles/9141/Lagerprislista_nr_106_170408.pdf

**Patents:**

[13] US9493215B2 - Floating debris harvesting system [Internet]. Patents.google.com. 2016 [cited 25 May 2017]. Available from: https://patents.google.com/patent/US9493215B2/en?q=celaning&q=boat

[14] US3219190A - Device for collecting flotsam, especially waste oil spillage on a water surface [Internet]. Patents.google.com. 2017 [cited 25 May 2017]. Available from: https://patents.google.com/patent/US3219190A/en?q=celaning&q=boat

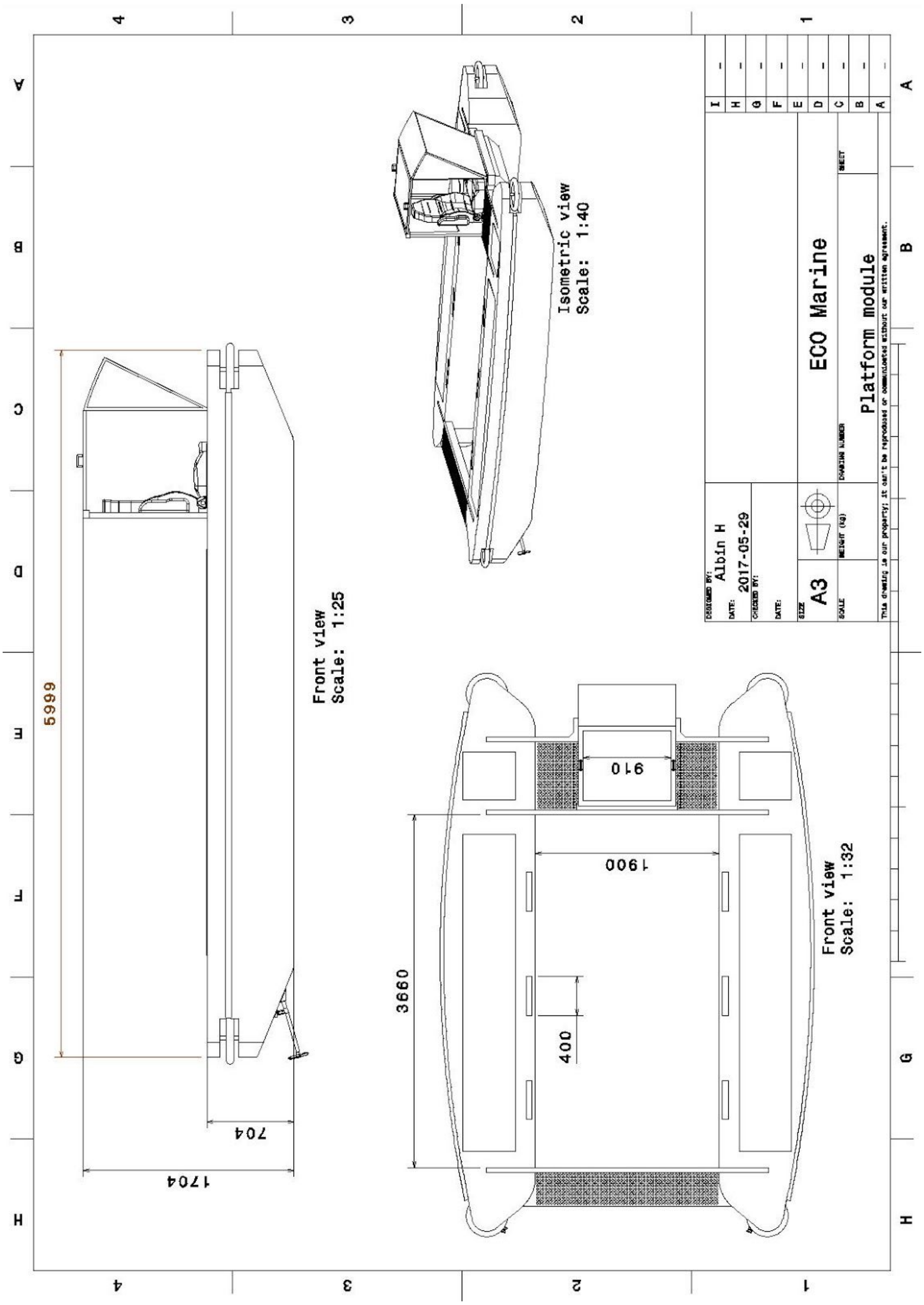
[15] US3928206A - Apparatus for the collection of buoyant foreign matter [Internet]. Patents.google.com. 2016 [cited 25 May 2017]. Available from: https://patents.google.com/patent/US3928206A/en?q=celaning&q=boat

[16] US3850807A - System for removing floating oil from water [Internet]. Patents.google.com. 1974 [cited 25 May 2017]. Available from: https://patents.google.com/patent/US3850807A/en?q=System&q=removing&q=floating&q=oil&q=water

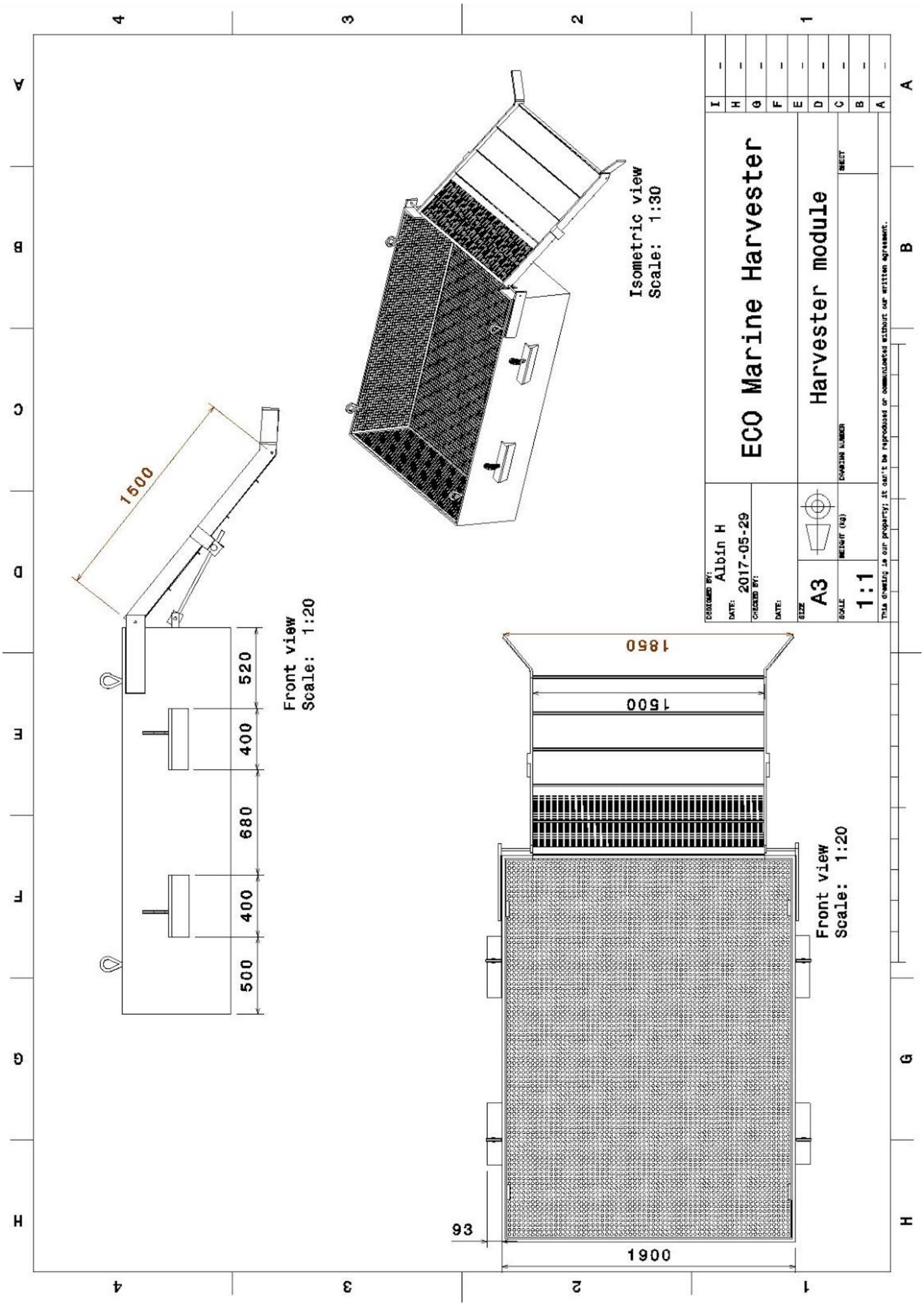
[17] US3817385A - Method and a device for collecting substances floating in a liquid surface [Internet]. Patents.google.com. 1974 [cited 25 May 2017]. Available from: https://patents.google.com/patent/US3817385A/en?q=floating+matter&q=conveyor&q=oil&q=floating&q=water&before=19760708&scholar

# 7. Appendices

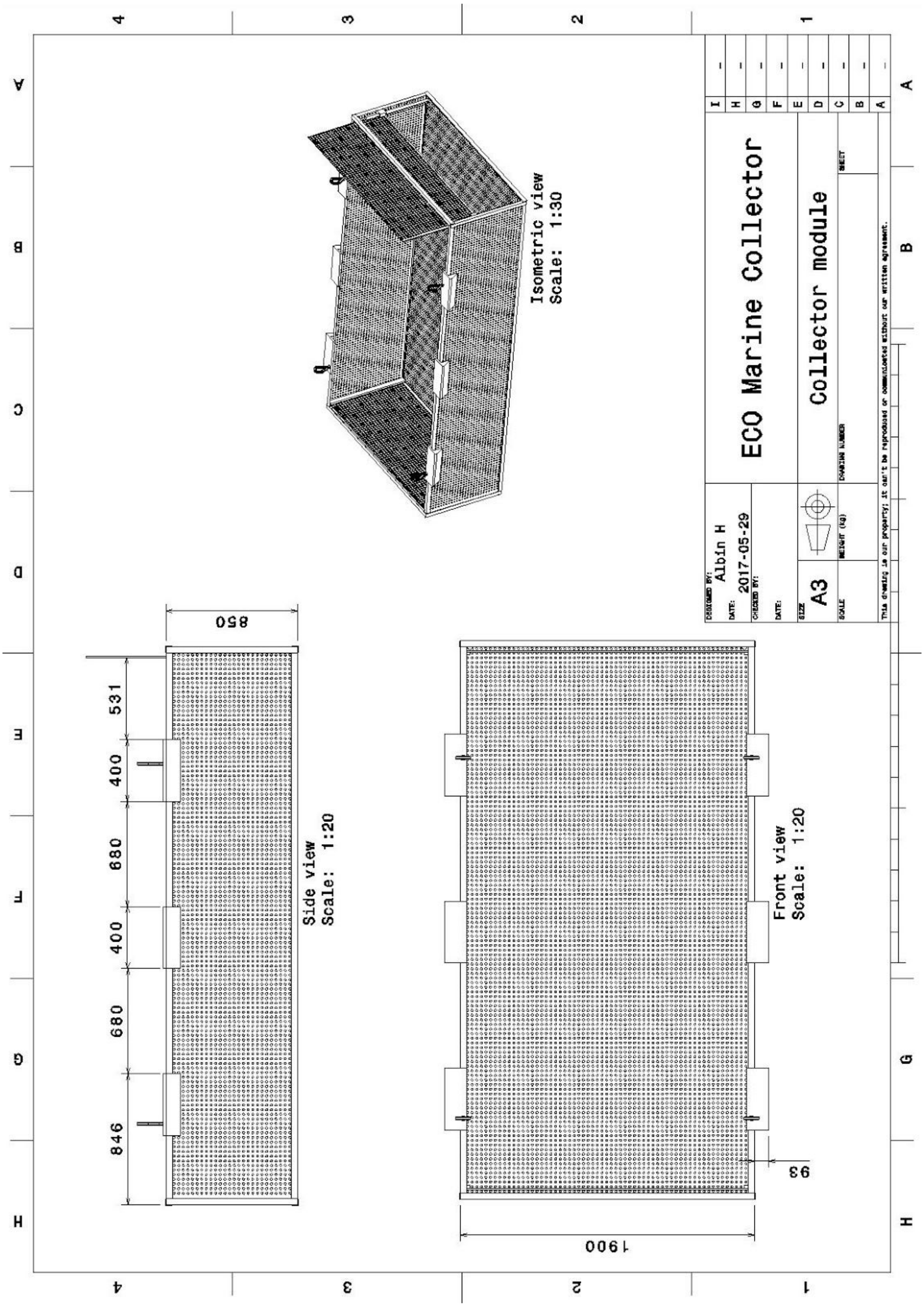
## Appendix 1



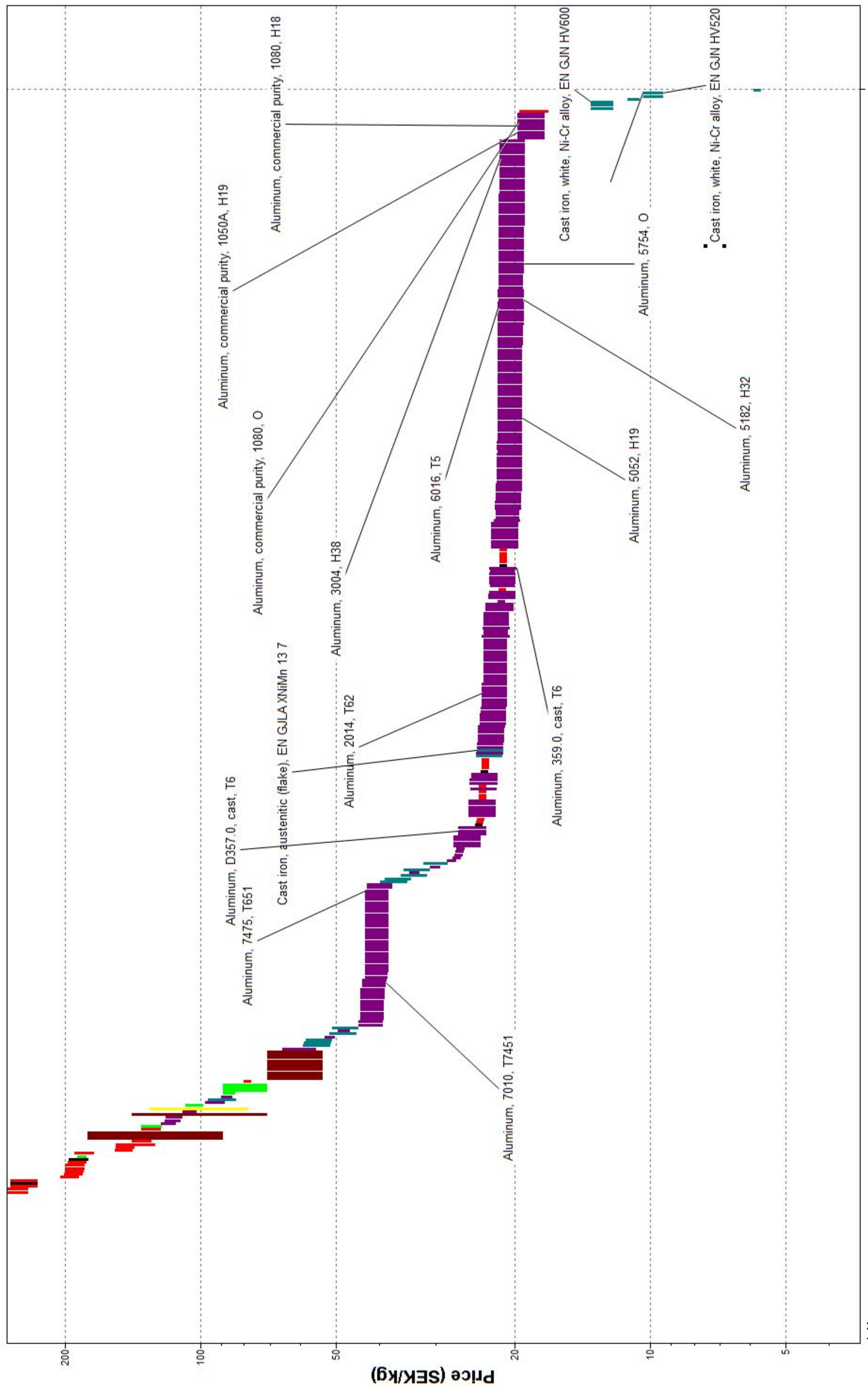
**Appendix 2**


ECO Marine Harvester
Harvester module
DESIGNED BY: Albin H
DATE: 2017-05-29
CHECKED BY:
DATE:
SIZE A3
SCALE 1:1
WEIGHT (kg)
DRAWING NUMBER
SHEET
This drawing is our property; it can't be reproduced or communicated without our written agreement.
Isometric view Scale: 1:30
Front view Scale: 1:20
Front view Scale: 1:20
1500
520
400
680
400
500
1850
1500
93
1900

**Appendix 3**


ECO Marine Collector
Collector module
DESIGNED BY:
Albin H
DATE:
2017-05-29
CHECKED BY:
DATE:
SIZE
A3
SCALE
WEIGHT (kg)
DRAWING NUMBER
SHEET
This drawing is our property; it can't be reproduced or communicated without our written agreement.
Isometric view
Scale: 1:30
Side view
Scale: 1:20
Front view
Scale: 1:20
850
531
400
680
400
680
846
93
1900

## Appendix



Aluminum, commercial purity, 1080, H18
Aluminum, commercial purity, 1050A, H19
Aluminum, commercial purity, 1080, O
Aluminum, 3004, H38
Aluminum, 6016, T5
Cast iron, white, Ni-Cr alloy, EN GJN HV600
Cast iron, white, Ni-Cr alloy, EN GJN HV520
Aluminum, 5754, O
Aluminum, 5182, H32
Aluminum, 5052, H19
Aluminum, 359.0, cast, T6
Aluminum, 2014, T62
Cast iron, austenitic (flake), EN GJLA XNiMn 13 7
Aluminum, D357.0, cast, T6
Aluminum, 7475, T651
Aluminum, 7010, T7451
200
100
50
20
10
5
Price (SEK/kg)