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# industriDESIGN

## **Design and development of the outer housing of a small wind turbine for Windforce ©**

**Design och utveckling av det yttre huset av en liten vindturbin för Windforce ©**

César Alonso Martínez

**BACHERLOR THESIS 2014**

**Field of Industrial Design and Product Development**

**Exchange student (Erasmus Program)**



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## **Design and development of the outer housing and vane of a small wind turbine for the company Windforce**

CÉSAR ALONSO MARTÍNEZ

This bachelor thesis has been performed at the School of Engineering in Jönköping University (Sweden) during the spring semester in 2014. The project has been developed during an exchange program and will be validated as the Final Project Work for the Degree in Industrial Design and Product Development in the University of Zaragoza (Spain).

Tutor: **Magnus Andersson**

Extent: **15 points**

Date: 15/07/2014

Filing number:



# Abstract

The aim of this project was to design and develop an outer cover/housing for an already existing product. This product is called Wind Flower and is a new small wind turbine released by the Swedish company Windforce, which manufactures wind power solutions and solar systems.

After the research stage, the project will be handled focusing on the user needs and applying industrial design methodologies that will include a design brief, a work breakdown structure, functional analysis, sketches, models and more.

The final result presented in this report is one of the many solutions that exist to the design problem, but still focused on the user and respecting the design principle “*design follows function*”.

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# Summary

This report starts with an introductory phase that talks about the background of the project and the company itself. Later the main objectives and limitations of the work will be explained to make the reader understand the purpose of the project. A theoretical background regarding the industrial design issue and the wind energy topic will precede a chapter that will include design methodologies. These methods will be implemented in a later phase and all the knowledge gathered will be demonstrated as well. In the last chapters the final result will be shown through visualizations and pictures, and conclusions will be stated in order to summarize the main findings of the project. The last two chapters will show the references and the attachments.

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# Acknowledgements

I would like to thank the following people that have helped to make this project happen and have shown their support or shared their knowledge as a guide.

Magnus Andersson

*Project supervisor, Jönköping University (Jönköping, Sweden)*

Ulf Bolumlid

*Windforce's CEO and energy advisor*

Thomas Arnell

*Lecturer in Industrial Design, Jönköping University (Jönköping, Sweden)*

Lars Ericsson

*Professor in Industrial Design, Program coordinator of the master program in Industrial Design, Jönköping University (Jönköping, Sweden)*

Nils-Eric Andersson

*Bachelor Thesis coordinator, Jönköping University (Jönköping, Sweden)*

Keywords: wind power, small wind turbine, Windforce, housing, cover, vane, industrial design, design thinking, fiberglass, glass-fiber, micro-wind, mini-wind, milling machine.

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# 1 Introduction

## 1.1 Background

In this first stage the background of the project will be described, and important information about the company and the product in question will be discussed.

### 1.1.1 Windforce

Windforce is a Swedish company that develops and produces small wind turbines, solar panels and other smart systems. They are aware of the huge amount of clean and natural energy existing around and they seize it. But this is not the only cause that drives the company; they comprehend the importance of caring for the planet and fight for a cleaner world with environmental-friendly solutions, deploying engineering processes to achieve this. The company offers not only individual products but also complete hybrid systems that combine wind and solar energy-based solutions at affordable prices. Windforce also markets other devices in the energy technology field, and can provide alternate options to its customers tailored to their needs.



*Image 1. House with hybrid system installation (source: see References)*

Among their wind power solutions, they provide several small-scale wind turbines varying in size, power output and in lesser capacity, appearance.



Image 2. Windforce turbines offer (source: Windforce website)

### 1.1.2 The Wind Flower

The latest model they have been working with (and on which this project is based) is the one called Wind Flower. As its name remarks, it is a small wind turbine with the shape of a flower.



Image 3. Windflower working (source: Windforce website)

The main components of the Wind Flower can be seen in the Image 4. Wind Flower components:



*Image 4. Wind Flower components*

This distinctive product is the result of many months of experimentation and now it has the best yield for spin in its size, inducing competition with the Windstar 1000 another model of the company (check the Image 5. Yield comparison between the Wind Flower and the Windstar 1000 to see the comparison). This high efficiency is partly due to smart design that locates the rotor behind the center of the mast, so when the wind is turbulent and direction-changing, the Wind Flower adapts to it quickly and does not spin around like common turbines that lose power efficiency due to this design flaw.



*Image 5. Yield comparison between the Wind Flower and the Windstar 1000 respectively (source: Windforce website)*

Another great feature of the Wind Flower is that it was conceived to work not only on masts above the ground but also on roofs, depending on their shape and placement. While conventional small wind turbines twirl around their mast due to the turbulences of the wind when it hits a roof (and therefore not providing much energy), the special Wind

Flower's design harnesses the wind flow and does not lose momentum so it keeps producing power. The Wind Flower is almost silent while working and storm proof (it reaches maximum speed at 14 m/s). In addition, its components are durable and provide a product life of around 25 years.

Technical data of the Wind Flower (from windforce.se):

- > Rotor diameter: 2 m
- > Weight net/gross: 28/32 kg
- > Startup wind speed (cut-in): 2 m/s
- > Rated output: 1000W at 12 m/s
- > Max. power output: 1200W at 14 m/s
- > Max. allowed wind speed: 50 m/s
- > Voltage: DC 24V, 48V
- > Measurement data: 12 hr
- > Movement Control: Rudder designed as flower petals when the structure does not require advanced steering technology
- > Mounting diameter: 50 mm
- > Additional info: Generator with 14 neodymium magnets  
Self-regulating rotor  
Series connection possible with more wind flowers  
230 Volt on grid  
Sold as a kit of parts for easy assembly

### 1.1.3 The design competition

Due to the Wind Flower being a new product with many market possibilities Windforce have released a contest for the outer design. The task was to design the main cover for the bracket of the Wind Flower as well as the vane to put it in the right direction of the wind.

After the competition was released Windforce CEO, Ulf Bolund, contacted the School of Engineering in Jönköping (Sweden) looking for a student who could help them with the design. So Magnus Andersson, teacher in the field of Industrial Design, contacted me and I discussed and clarified the task objectives with Ulf before accepting.

## **1.2 Objectives**

The main objectives of the project proposal was to design the outer housing which covers the bracket that holds the generator and the blades, including the coverage of the bottom part when the bracket is assembled with the mast plus the coverage of the top part where the bracket is assembled with the generator. In addition, the task also included the design of the wind vane, which would be attached to the outer housing by the customer. Both designs should be based on two halves of fiberglass material each, according to the requirements of the company.

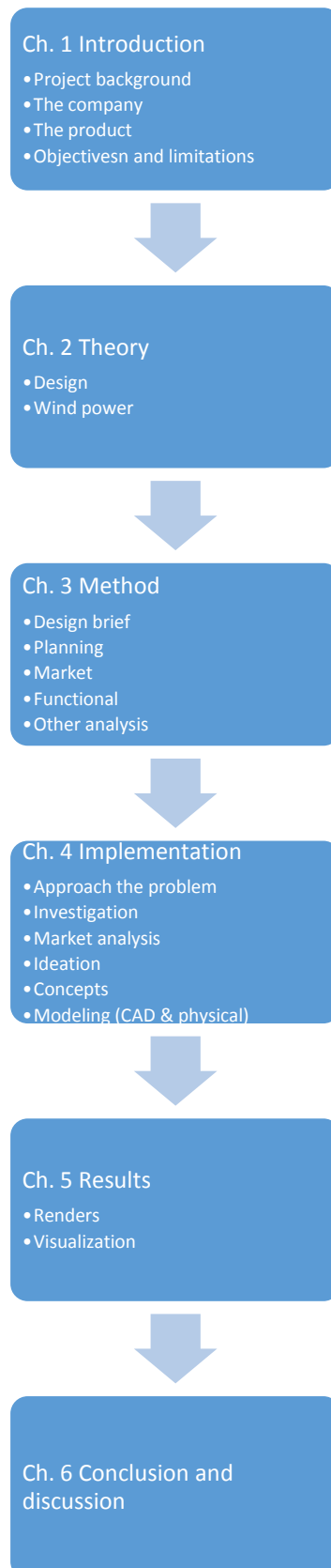
## **1.3 Delimitations**

This project will be partly delimited by my lack of technical knowledge in the field of aerodynamics and the restrictions of the company. As one of the requirements is to build the outer housing and the vane in fiberglass, there will be no material selection analysis in this report. The design will be influenced by two factors: one is the fact that the vane and the cover have to be assembled separately and cannot be integrated in one piece; and the other is the requirement to manufacture both pieces in two halves each. This last one will affect the production process decision as well.

Therefore, the main components of the Wind Flower (the technical ones) will not be covered by this work because they are already designed. Nevertheless, the company allows me to make small changes on the bracket's design (such as holes and pins) in order to improve it and make it easier to assemble the housing and vane.

## I.4 Disposition

The construction of the report looks like follows:



## 2 Theoretical Background

This chapter will focus on defining some relevant concepts within the design field so as to introduce the reader on topic. There will also be references to the theoretical background that has to do with the wind energy in order to show which aspects are necessary to be taken into account.

### 2.1 Design

Design is a general term that can be seen from different points of view. For Don Kumaragamage (2009), it is as a strategic approach for someone to achieve a unique expectation. It defines the specifications, plans, parameters, costs, activities, processes and how and what to do within legal, political, social, environmental, safety and economic constraints in achieving that objective.

Kim Goodwin (2011) argues that *Design* is the craft of visualizing concrete solutions that serve human needs and goals within certain constraints and other relate it more with the term *creativity*; “Design is what links creativity and innovation. It shapes ideas to become practical and attractive propositions for users or customers. Design may be described as creativity deployed to a specific end”, states George Cox (2005, p. 2).

#### 2.1.1 Design Thinking

As the word “design” makes more sense as a verb rather than a noun, it has been put together with the activity which goes along with; thinking. The term Design Thinking came up when Herbert A. Simon (1969) defined *Design* as a “way of thinking”. So it can be seen as a method for problem-solving.

One example of a design thinking process could have seven stages: define, research, ideate, prototype, choose, implement, and learn. Within these seven steps, problems can be framed, the right questions can be asked, more ideas can be created, and the best answers can be chosen. The steps are not linear; they can occur simultaneously and can be repeated (Simon, 1969).

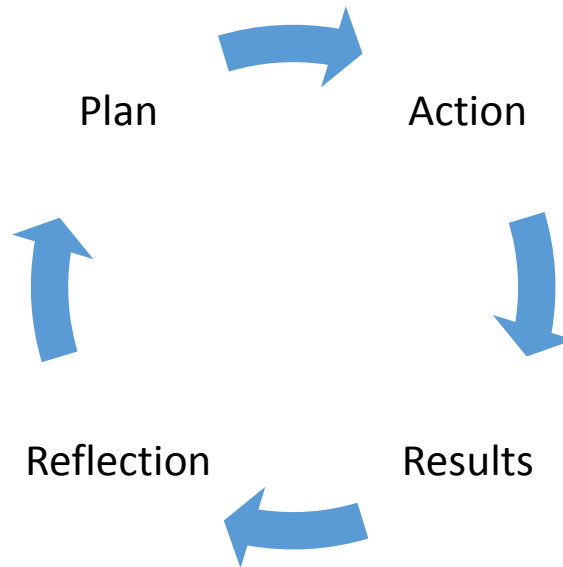
#### 2.1.2 Industrial Design and Product Development

Within the general concept of Design, the Industrial Design is the branch that takes part in this project. It can be defined as the set of activities that are carried out in order to fulfill the different steps of development of a product, from the identification of a need,

through the generation of ideas, the evolution of these, its technical definition for production, the definition of a strategy of communication for the market and the tasks of coordination and management needed for the success of the rest (University of Zaragoza, 2010).

### 2.1.3 The Design Process

The process of a normal design task can follow different steps. First of all it is necessary to state the problem and the objectives. After doing some research and collecting information from different sources and analyzing it, ideas are generated and valued. The next step is to develop solutions at the same time that these are analyzed, creating a feedback in a circular process based on the pattern Action > Results > Reflection > Plan. See Figure 1. Cyclic approach of Action Research. When the best solution is achieved, it is improved and refined until the final design comes.



*Figure 1. Cyclic approach of Action Research (Williamson, 2002)*



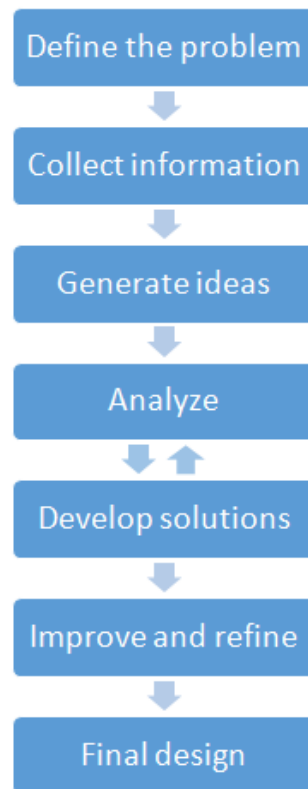


Figure 2. The design process (Chicago Architecture Foundation) (NASA, 2008)

Bruno Munari (1979) proposed a design process for general applications and for projects that do not require high technical requirements, like formal object designs, user-oriented products, et cetera. It that can be represented as follows:

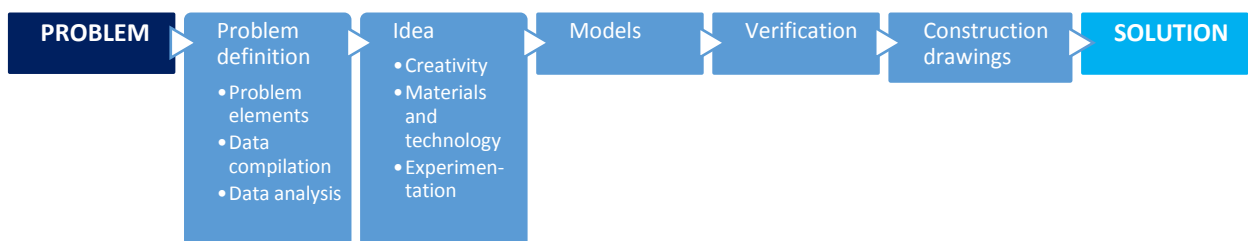


Figure 3. Design process flow by Bruno Munari (University of Zaragoza, 2010).

## **2.2 Wind energy**

This part will focus on theoretical knowledge about the wind energy and the different ways of taking advantage of the power that it provides.

### **2.2.1 Wind power**

Wind power comes when wind energy is transformed into a useful form of energy. One example of this transformation today can be seen in wind turbines, which seize the wind flow rotating their blades and convert it into electrical power. But humans have been harnessing the energy of the wind for thousands of years, for instance around 200 B.C. using windmills to grind cereal grains in Persia (converting wind power into mechanical power), or wind pumps in China (converting wind power into water pumping). Or even earlier, around 5000 B.C., using sails to propel boats along the Nile River (Wind Energy Foundation, 2014).

The use of this kind of energy keeps growing nowadays and it is expected to progress in such a fashion. Its rising popularity is due to several facts: it is renewable, so it means a good alternative to fossil fuels; it is plentiful and widely distributed, so this means that wind power would not be restricted for only part of the population; it is clean and produces no greenhouse gas emissions during operation; it does not require much land to be installed (Fthenakis & Kim, 2009); and finally, its effects on the environment are not as serious as those from other power sources (REN21, 2011, p. 11).

### **2.2.2 Small wind turbines**

Wind turbines are devices based on electrical generators that convert kinetic energy from the wind into electrical power. Although large wind turbines are the most common way to seize the wind power by means of wind farms that produce hundreds of Megawatts every year, this project will focus on small wind turbines, due to the fact that the Wind Flower is one of them.

There are two main types of wind turbines, the ones with vertical axis (VAWT, standing for Vertical Axis Wind Turbine) and the ones with horizontal axis (HAWT, Horizontal Axis Wind Turbine).

#### **2.2.2.1 HAWT**

In this kind of wind turbine, the rotational axis is parallel to the ground. This is the most common technology given its efficiency and reliability. The small wind turbines based on this disposition are normally composed by a generator, the blades which number can vary from two to several pairs, a central piece to hold the blades and a mast that holds everything on top.

Their design needs a vane to place them in the right direction of the wind. Its disadvantages are that they do not work very well with a quick direction-changing wind,

their low efficacy with turbulences and the rotor's noise. Normally they stand on a mast and are not recommended to be placed on a roof because of the turbulences that the wind makes when hitting it.

### 2.2.2.2 VAWT

The axis in this type is perpendicular to the ground and they have lower rotational speed than the HAWT. They do not require a vane and can be placed closer ones from other if put in arrays, since they have omnidirectional blades instead of rotational ones. VAWT turbines can be placed closer to the ground due to their capacity to work with a lower wind speed than the HAWT, so the maintenance is simpler. They are also generally more silent than the HAWT and more recommended for low-power installations, but more expensive in materials, less efficient and less reliable when talking about stability or durability.

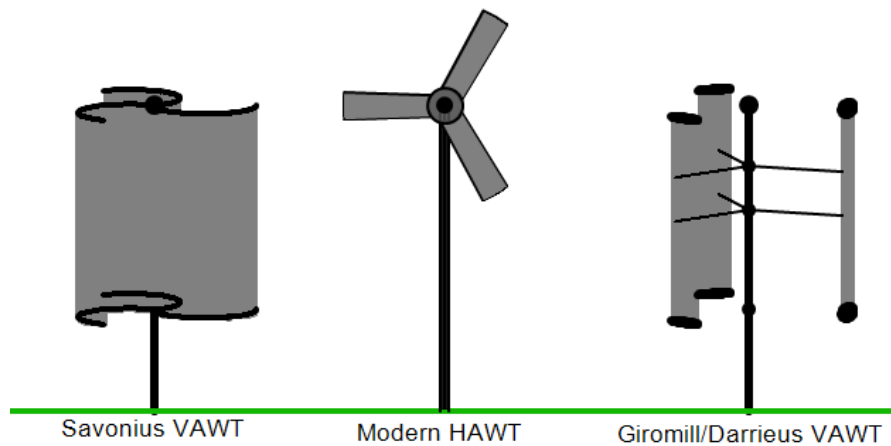


Image 6. The three sub-types of wind turbines (sources for images: see References, 7).

	HAWTs	Lift VAWTs	Drag VAWTs
<b>Advantages</b>	<ol style="list-style-type: none"> <li>1. Efficient</li> <li>2. Proven product</li> <li>3. Widely used</li> <li>4. Most economic</li> <li>5. Many products available</li> </ol>	<ol style="list-style-type: none"> <li>1. Quite efficient</li> <li>2. Wind direction immaterial</li> <li>3. Less sensitive to turbulence than a HAWT</li> <li>4. Create fewer vibrations</li> </ol>	<ol style="list-style-type: none"> <li>1. Proven product (globally)</li> <li>2. Silent</li> <li>3. Reliable &amp; robust</li> <li>4. Wind direction immaterial</li> <li>5. Can benefit from turbulent flows</li> <li>6. Create fewer vibrations</li> </ol>
<b>Disadvantages</b>	<ol style="list-style-type: none"> <li>1. Does not cope well with frequently changing wind direction</li> <li>2. Does not cope well with buffeting</li> </ol>	<ol style="list-style-type: none"> <li>1. Not yet proven</li> <li>2. More sensitive to turbulence than drag VAWT</li> </ol>	<ol style="list-style-type: none"> <li>1. Not efficient</li> <li>2. Comparatively uneconomic</li> </ol>

Table 1. Advantages and disadvantages of HAWTs, Lift VAWTs and Drag VAWTs (Randall, Timmers, & Skies, 2003;2001;2003)

As the the World Wind Energy Association (2013) states, the early HAWT technology has dominated the market for over 30 years. Based on the study of 327 small wind manufacturers as of the end of 2011, 74% of the commercialized one-piece small wind manufacturers invested in the horizontal axis orientation while only 18 % have adopted the vertical design. 6% of the manufactures have attempted to develop both technologies.

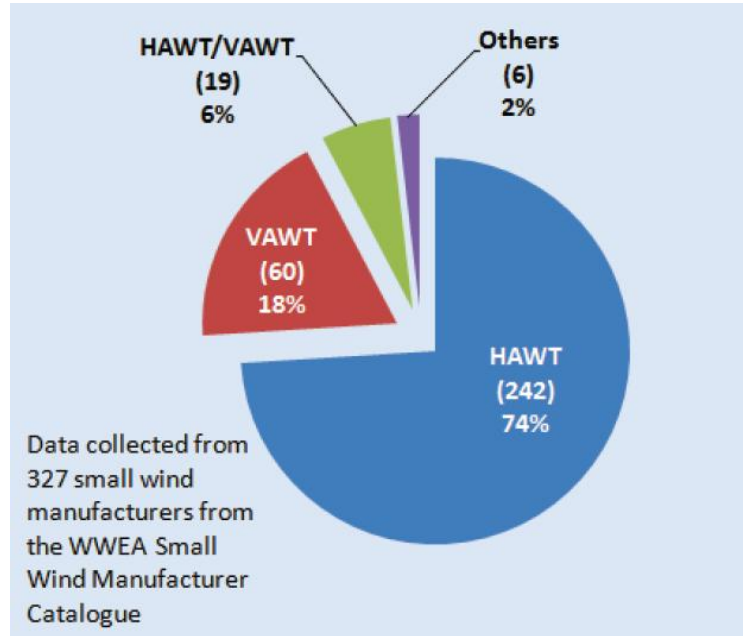


Figure 4. SWT (Small Wind Turbines) orientation by manufacturers by 2011 (World Wind Energy Association, 2013).

### 2.2.3 Micro-wind and mini-wind

The small-scale generation to produce electric power by individuals is called microgeneration. When talking about micro-wind turbines, they can vary from 50 W to a few kW. Although the use of these turbines may be motivated by a bad grid power or lack of electrical power, their use is growing as an environmentally conscious approach. Mini-wind refers to the use of more than one small wind turbine and it is defined by a top power value of 100 kW. Apart from contributing to the domestic power supply, users of micro-wind and mini-wind devices can also sell the unused power back to the electrical supplier.

In the end of 2011, the mini-wind world production reached 576 MW and it keeps growing every year. In addition, there already exist more than 330 small wind turbines manufacturers in more than 40 countries worldwide, with China and the United States of America being the main markets (World Wind Energy Association, 2013).

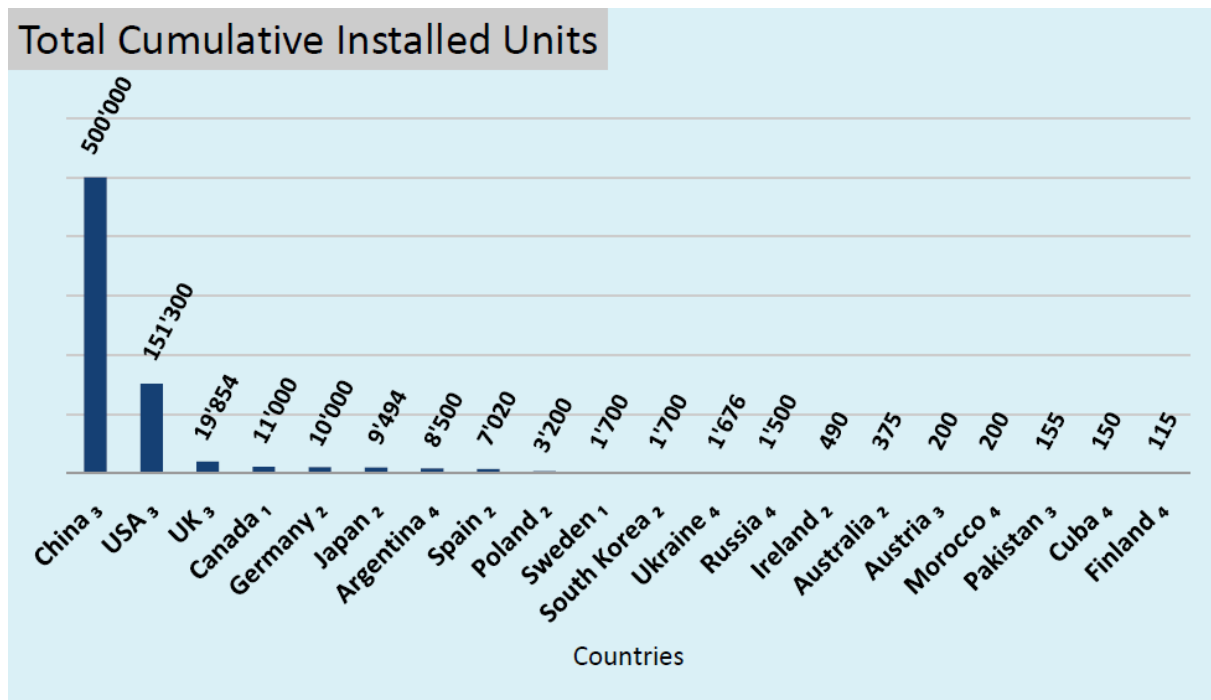


Figure 5. Total Cumulative Installed Small Wind Units Worldwide (World Wind Energy Association, 2013).

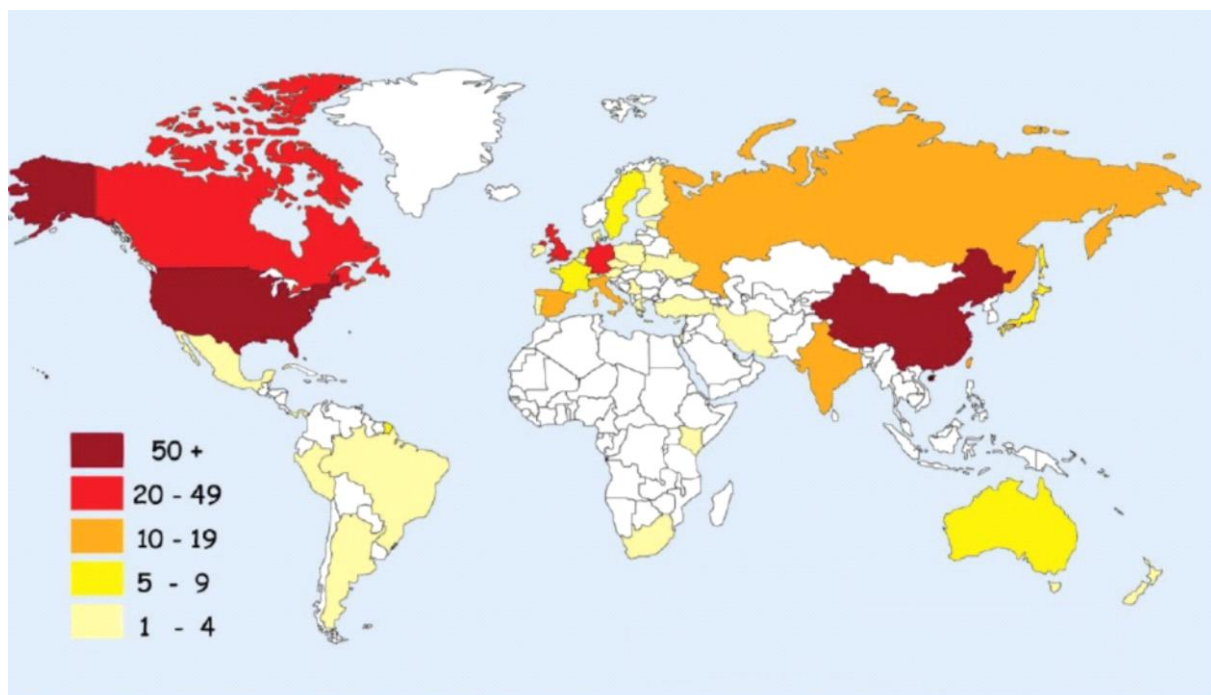


Figure 6. Small Wind Manufacturers Map Distribution Worldwide As of the End of 2011 (World Wind Energy Association, 2013).

## 3 Method

In this section the methods used will be described from a theoretical perspective, and applied later in chapter four.

### 3.1 The design brief

The design brief is a vital part to any design project as it will provide the designer with all the information needed to exceed the client's expectations. A design brief should primarily focus on the results and outcomes of the design and the business objectives of the design project. It should not attempt to deal with the aesthetics of design or its possible solutions and if it is done in the right way it will ensure that the clients get a high quality design that meets their needs (Cass, 2008).

### 3.2 Work Breakdown Structure (WBS)

As B.A. Hamilton notes in his Earned Value Management Tutorial (1998), the Work Breakdown Structure (WBS) is a tool that defines a project and groups the project's discrete work elements in a way that helps organize and define the total work scope of the project. Each descending level of the WBS represents an increased level of detailed definition of the project work. Additionally it is a dynamic tool and can be revised and updated as needed by the project manager.

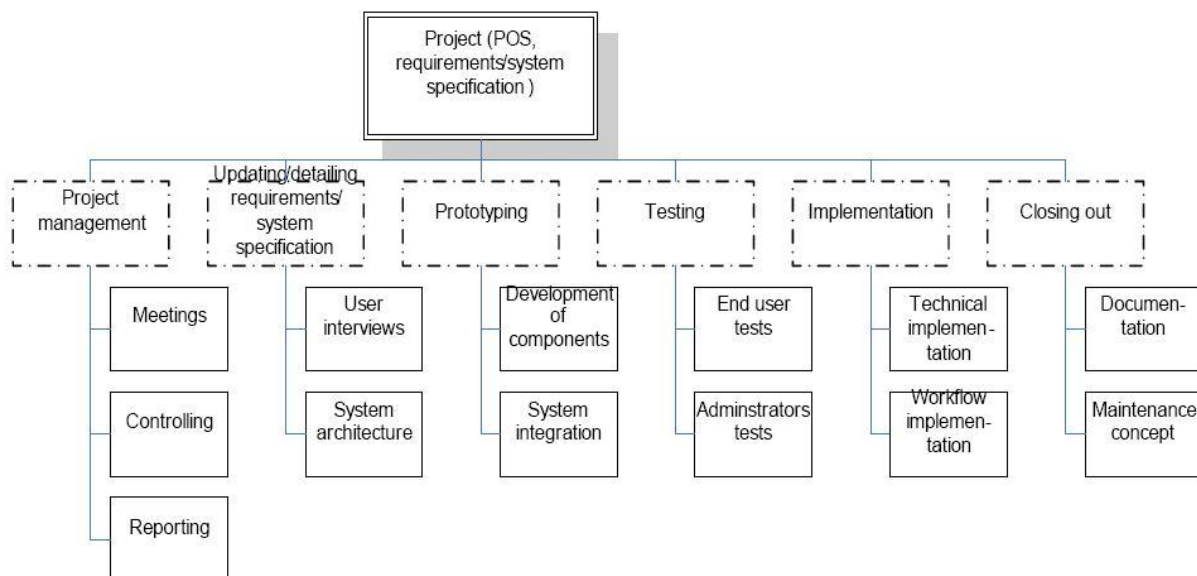


Figure 7. WBS waterfall diagram example (Institute for Geoinformatics, Münster, 2007)

### 3.3 Project planning

In order to follow an organized and logical flow of work that ensures the success of the project, a project planning is needed. One good project management tool is the Gantt chart. It helps to plan and coordinate all the tasks that have to be done within concrete margins of time. It consists of a vertical axis representing the tasks to be done in the project and a horizontal axis representing the time spent in each task.

Gantt charts give a clear illustration of the project status, but they have one problem; that they do not indicate task dependencies. This means that it is not possible to tell how one task falling behind schedule affects other tasks (Rouse, 2007).

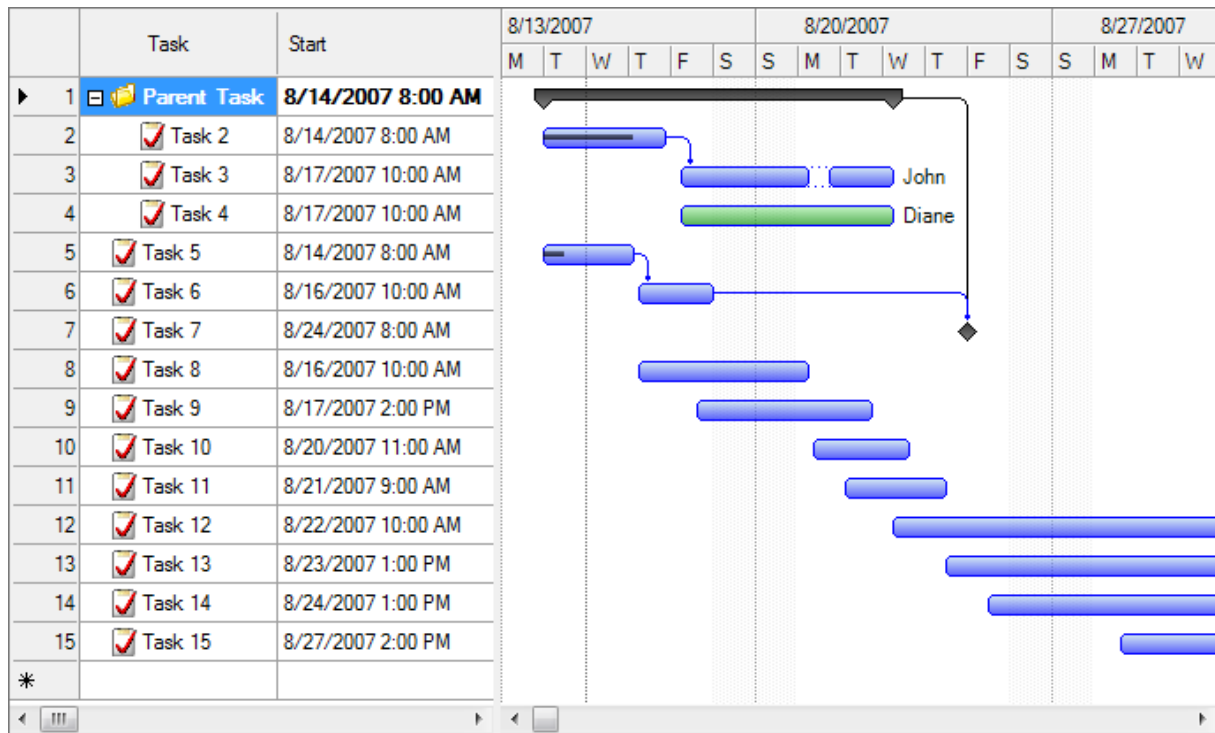


Figure 8. Gantt Chart example (DlbSoft Gantt Chart Library).

### 3.4 Market analysis

The market analysis is the section in a project plan where information about the commercial market in which the business is based is presented. It also remarks the purchasing habits of customers in that market and information about competitors.

#### 3.4.1 Competitor analysis

A competitive analysis is a critical part of any market analysis plan. With this evaluation, it can be established what makes the company's product or service of unique, and therefore what attributes it highlights in order to attract its target group (Entrepreneur).

For this project, it will include an overview of the general competitors' products and specifications as well as a deeper analysis of one concrete competitor from different points of view (product range, market relevance, energetic efficiency, customer care, company's website, et cetera).

#### 3.4.2 Stakeholder analysis

According to Dr. L. Bourne (2011), "building and managing relationships with senior stakeholders is essential for success."

The company's stakeholders will be all the people, groups or organizations that are influenced by any step of the product's lifecycle. The stakeholder analysis in this project will summarize the main groups affected by any action of Windforce regarding the Wind Flower from its conception and design, through its production and distribution, use and finally waste (Certo, 2005).

### 3.4.3 Target group

A target group is a group of customers towards whom a business company has decided to aim its marketing efforts and ultimately its merchandise (Kurtz, 2010). It is defined by common needs, benefits, lifestyle, demographics, etc., and will define the main steps that the company will follow to design, develop and distribute a product.



*Image 7. Target group visualization (source: printwand.com)*

The objective of many companies regarding their communication approaches is to create an affinity or loyalty between them and the customer, so it will mean a retribution for them in the future.

## 3.5 Functional analysis

Understanding product functions is a key aspect of the work undertaken by engineers involved in complex system design (Aurisicchio, Bracewell, & Armstrong, 2013).

Although this project is more about a formal-based work, one industrial design principle inspired by Louis Sullivan (1896) quotes that *"form ever follows function"*. And it is a fact that form and function cannot be separated when performing a design: they are strongly related and complement each other. Therefore, during the preliminary stage of this project, a functional design diagram will be implemented in order to gain knowledge about the function and relevance of every component and sub-component of the Wind Flower.



### **3.6 Empirical investigation**

Empirical research is the way of gaining knowledge through experimentation or observation rather than forming knowledge from theories or beliefs. Some examples that can be implemented in this project would be interviews, simple observation (evidence), experiments and tests.

### **3.7 Ideation and sketching**

Ideation is the creative process of generating, developing, and communicating new ideas, where an idea is understood as a basic element of thought that can be visual, concrete, or abstract. It is an essential part of the design process, both in education and practice (Jonson, 2005, p. 613) (Broadbent, 2004, p. 54). Creative ways of displaying this ideation can be sketching or brainstorming.

### **3.8 Syntactic, Semantic and Pragmatic**

Design is widely identified with the shape of products, but a wider focus is required if “interdisciplinary design” wants to be addressed. Traditional interdisciplinary design deals mainly with the syntactical composition of parts within a whole (Schwarzfischer, 2011, Vol. 33, s. 345). This means that it has to do with the shape of objects and its size, weight, scale, proportions, colors, textures, anthropometry, etc. (University of Zaragoza, 2010). However, this is not enough to identify a design due to the fact that persons vary in time and situational roles, so it is necessary to consider different ideals simultaneously (Schwarzfischer, s. 345). Semantics provide the main meaning to a design, and therefore also the product recognition, function and use identification, brand perception or socio-cultural values. Finally, the pragmatic part gives a description about the main objective function, the benefits of the product or its complementary features (secondary functions). Also treats with the components layout, the productive processes, use sequence or biomechanics (University of Zaragoza).

### **3.9 Computer-aided design (CAD) modeling**

Computer-aided design (CAD) helps designers to create elaborate three-dimensional virtual objects (3D models) with the help of CAD software. It helps to visualize in a clearer way the shape of a piece or product and also supports verifying its dimensions, proportions, assemblies, etc. Volume or weight calculations can be also made from CAD designs, as well as static or dynamic mechanical simulations.

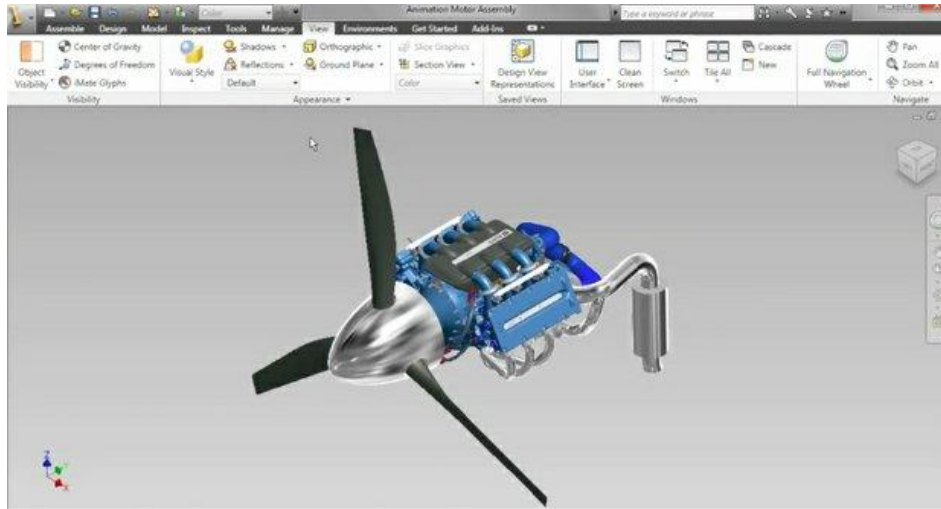


Image 8. CAD file example (source: [downloadbungama.com](http://downloadbungama.com))

### 3.10 Physical modeling

This kind of modeling, unlike the CAD one, is real and based on models and mock-ups that are made in the middle and final stages of the project. It helps verify the real dimensions, shapes, proportions and ergonomics of a product and normally implements all its functional elements as well. These models are very useful to check use and adaptability features, and they allow the designer to correct measures that in technical drawings would be only theoretical and difficult to see and adjust.

The techniques are very wide and a large range of materials can be used to build physical models, despite the fact that these materials may not be the same as in the final product. Obviously, neither the final shape aspect nor the final colors have to be the same as in the final product (López, 2009).

## 4 Approach and Implementation

This chapter will include the descriptions of how the work was performed. This will be done looking at the design process described in the theoretical background (chapter 2) and implementing the methods from chapter 3. As a reminder, this is the schema that will be followed during this section (except the ‘final design’ stage that will be described in the Result chapter):

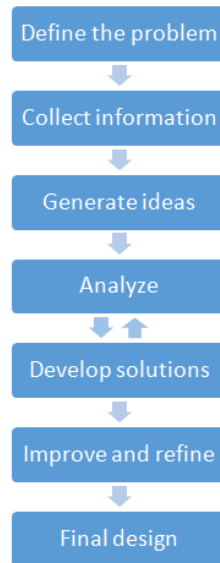


Figure 9. Design process model to implement.

## 4.1 Define the problem

### 4.1.1 Design brief

Due to the fact that the company did not provide any design brief, I will make a description of the main objectives to be achieved in this work. The goal of this project is to design and develop a total of two pieces that complement the Wind Flower wind turbine, manufactured by the Swedish company Windforce. These pieces are the outer cover/housing that covers the holding bracket (top and bottom assemblies included) and the vane that will be attached to it, which will put the Wind Flower in the right wind direction.

The design specifications are as follows:

- › The outer cover and the vane will be designed in two halves each and assembled later.
- › Both pieces will be designed with the prospective view of being produced in fiberglass material.
- › The outer housing's section will have an aerodynamic shape similar to a drop.
- › The thickness of the fiberglass pieces will be between 3 and 4 mm.
- › The bottom part of the bracket will be assembled to the mast with 10 bolts of 6 mm each, so the outer housing should seize them to be assembled to the bracket in its bottom part.
- › The top part of the bracket will be assembled to the mast with 6 bolts of 8 mm each, so the outer housing should seize them to be assembled to the bracket in its top part.



## 4.2 Collect information

### 4.2.1 Investigation of the company

Lot of useful information was found in Windforce's website <http://windforce.se/>. Here I could discover their philosophy and their products. They offer a wide and variable range of products, from simple hybrid controllers to complete smart systems composed by wind turbines, solar panels and other devices. Windforce's main idea can be seen in the homepage of their website, where they say:

*"Our idea is simple!*

*We at Windforce want to make it possible for everyone to take advantage of solar and wind energy. The products and packages we offer are of the highest quality at the lowest possible price without hidden fees or add-ons afterwards. We also help with counseling the purchase, assembly, installation and maintenance.*

*Our products consist of small wind turbines, solar cells and other smart accessories that will enable you to produce your own electricity and vacuum tube collectors for heating and hot water. Renewable emission-free energy that also provides you with cheaper energy bills. Our products have unique performance on energy efficiency and low noise at fixed low prices."*

While completing self-education about the company, I was also looking for general information about the wind power devices and market.

#### 4.2.1.1 Visit to Windforce CEO's place

After knowing about the design competition I contacted with Windforce's CEO, Ulf Bolumlid, and arranged a meeting with him. I went to his house and workplace in Falköping (Sweden), where I could have a closer view at the company's wind turbines while they were working and specifically at the Wind Flower prototypes.



*Image 9. Wind Turbines and solar panels for tests.*

I had the opportunity to ask for his doubts regarding the wind power industry but also about the manufacturing processes. We also discussed information about how and what Windforce uses to deal with everything as a company.



*Image 10. Two of the first Wind Flower prototypes*



*Image 11. Last Wind Flower prototype*

#### **4.2.1.2 Interview and Empirical Analysis**

I also conducted an informal interview with Ulf and asked him about questions and doubts about the project and the company that could not be clarified by looking through the website. Some of these questions and their respective answers were like:

- › Do you have any product catalog? No.
- › Which CAD program do you use for your designs? - No answer -
- › How big is the company? Small and run by very few people, but expecting to increase the employees in the near future.
- › Do you export your products abroad? Yes.
- › How deep should I go into the design? All that the customer will see.
- › Do you offer any job or internship opportunities? Maybe yes.
- › When will be the approximate deadline? Around end of May.
- › When are you planning to start the production? Already 12 Wind Flowers in production and expecting producing the new outer housing and vane this summer.
- › Factors to take into account for the design? Stakeholders, eco-design, suppliers? Logistics and the reduced space in the final product's box, so the vane and the housing cannot be in one single piece because the volume would be too high.



- › I do not have an advanced aerodynamic physics knowledge, does it cause any problem for the design of the vane or outer cover? No, just be between some margins of measures and will be OK.
- › What about manufacturing processes? Many parts from suppliers and some of their blades produced by them in a workshop.
- › Which is your background as a designer? Involved in car design but many years ago.
- › Should the company logo be included in the final product? Yes, in the vane.
- › Do you have any technical drawings of the Wind Flower? No.
- › Is the famous quote “form follows function” one of your principles? Yes, absolutely.



*Image 12. Ulf Bolund tracing the bracket's outline.*

#### **4.2.1.3 Results**

I was surprised by some facts but the one that most impressed me was that they did not have any technical drawing of the Wind Flower, considering that they already had 12 in production. So, when I asked how I was supposed to start with the design, Ulf took a large roll of heavy paper and one single bracket and traced its silhouette and the one of a provisional vane on it. He also gave me 3 blades to help me with the proportions. So then I left Ulf's house and workplace carrying a 1:1 drawing, some notes and 3 blades of the Wind Flower.



## 4.2.2 Market analysis

I studied the wind power market in general and the small wind turbines market in particular and after collecting a lot of theoretical information (see chapter 2.2), I looked for the competitor's offer, at the main stakeholders implicated and also tried to define a target group.

### 4.2.2.1 Competitor analysis

I extracted some information about small wind turbine manufacturers from the Small Wind World Report Update Summary (2013) which provides worldwide statistics of the small wind market, trend analysis, country/region reports, reports on policies, standards, certification & testing and also market forecasts within the industry of small wind turbines. The main competitors coming from abroad are from China and the United States, the two countries with the most Cumulative Installed Capacity (225'000 and 198'000 kW respectively) (World Wind Energy Association, 2013). The description of some of the competitors and their product type offer, size in kW and countries of presence can be found in the Attachment 3.

The conclusion after looking at all the competitors found is that all of them offer similar products (either VAHT wind turbines or HAHT ones), with more/less power output or bigger/smaller sizes and number of blades. But I could not find any company that offered a product as differentiated as the Wind Flower. And the truth is that this Winforce's peculiar turbine has a working principle that no other turbine uses in the small-scaled wind turbine market nowadays. I consider this to be a critical, competitive advantage that will result in good results and income for the company, if Windforce is able to properly capitalize on its value.

### 4.2.2.2 Stakeholder analysis

In this section I will briefly name the things to take into account for every stakeholder that can take part into the Wind Flower's lifecycle:

STAKEHOLDER	TAKE INTO ACCOUNT
Manufacturer	Clear technical drawings Design for Manufacture (DfM)
Distributor	Logistics, light-weight European pallet measures Enough space for every component inside the final box
Retailer	Clear product specifications
Customer	Appearance

	Technical information Design for Assembly (DfA) User manual
Maintenance staff	Design for Assembly (Easy to disassemble and assemble, standardize, etc.)
Removal staff	Easy to separate materials

#### **4.2.2.3 Target group**

In order to focus the design more into specific features and for having more clear to whom will be the merchandise of the product aimed to, I will list some of the qualities of the ideal customer of the Wind Flower as well as other market segmentations:

- › Individuals concerned with the environment and eco-friendly products.
- › Those with enough income to afford having a smart system in their houses but aware at the same time of the importance of renewable energy.
- › People living in private chalets/houses with garden with an area about 700-1000 m<sup>2</sup> – So they have enough space to place a mast for the wind turbine and a solar panel (if they get the full hybrid system).
- › Individuals living in households or cottages not connected to the electric grid so they may need to get power from other sources.
- › Living in flats with own roof but not in urban surroundings – In order for them not to have any problem with the local neighbourhood and also because no buildings around could stop the wind.
- › Better with a gable roof than with a flat one – So this roof's shape can seize the wind better and does not produce as much turbulence as a flat one when the wind hits it.
- › Families with children – Due to the fact that a flower shape is more related to women and children rather than to men.
- › Farms.
- › Camping and caravan sites.
- › Greenhouses and cultivations.



*Image 13. Typical family model (source: see References)*

#### **4.2.3 Material research: Fiberglass**

Fiberglass or GRP (Glass Reinforced Plastic) is a composite material, formed from a plastic or resin matrix and reinforced later with fibers made of glass. The interesting point about this material in this project is its manufacturing properties. Different resins may then be added to fiberglass once it is woven together to give it added strength, as well as allow it to be molded into various shapes. Common items made of fiberglass include swimming pools and spas, doors, surfboards, sporting equipment, boat hulls and a wide array of exterior automobile parts. The light yet durable nature of fiberglass also makes it ideal for more delicate applications, such as in circuit boards (Johnson, 2014).

Fiberglass may be mass-produced in mats or sheets or custom-made for a specific purpose. A new bumper or fender on an automobile, for example, may need to be custom-made to replace a damaged area, or for the production of a new model. For this, one would create a form in the desired shape out of foam or some other material, then layer a fiberglass coated in resin over it. The fiberglass will harden, then can be reinforced with more layers, or reinforced from within. But a massive sheet of a fiberglass and resin compound may be manufactured and cut by machine (Johnson).



*Image 14. Fiberglass matrix (source: boatdesign.net)*

Seeing all the applications and possibilities of fiberglass, there should be no problem or restrictions for the design of the required pieces of the Wind Flower. However, I will have to take into account that the production method of this material will need open cavities in order to place the plastic matrix into each of the halves' mold.

#### 4.2.4 Functional Analysis (FA)

This was developed to check all the functions implied and their relevance in the product. The Functional Analysis will be of great help in the ideation phase in order to prioritize decisions. The way of doing a FA starts stating a verb and a noun that describe a function, and then classifying this function in one of four classes: Primary (P), in case the function implies the objective that the product was made for; Necessary (N), if it must be implemented in the product to make it work effectively; Desirable (D), when it is not a primary or necessary function but provides additional value to the product; and finally Unnecessary (U), if it has no relevance in the design. Below is a table identifying each component of the Wind Flower, its classification, and the appropriate action to take.

VERB	NOUN	CLASS	ACTION
Protect	Bracket	D	Good sealing
Hide	Bolts	D	Put them as deep as possible
Improve	Aesthetics	P (as requirement of the company)	Complement Wind Flower's design
Provide	Aerodynamics	N	Study aerodynamic shapes
Set	Direction	P	Well attached (mainly applies for the vane)
Ensure	Light-weight	D	Thin thickness and empty spaces between the two halves
Facilitate	Assembly	D	Standardize screws & nuts

Table 2. Functional Analysis of the Wind Flower.

## 4.2.5 Aerodynamics

Despite the fact that I do not have extensive technical knowledge about aerodynamics, I looked for shapes that cause the least turbulence and tried to apply the best solution. What I found was that a drop-shape section would not be the kind that seizes the wind best, as I first thought. A drop shape combined with a pointy front would make the wind follow the curvature lines of the surface and therefore produce less air disruption in the tail. Hence, I will try to implement this shape in the section of the outer housing design of the Wind Flower.

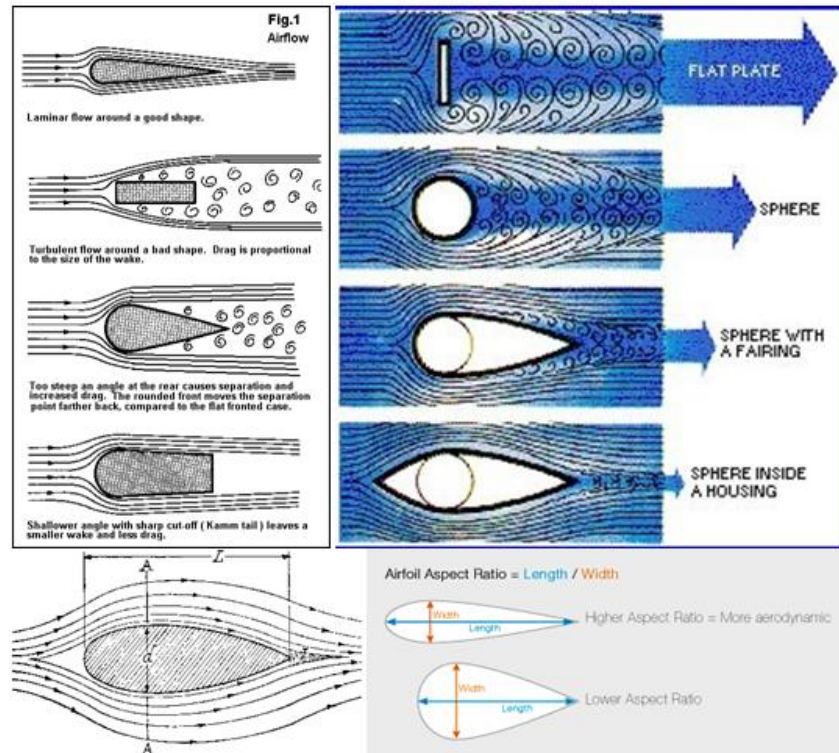


Image 15. Examples of aerodynamic shapes

As for the vane, I read aerodynamic studies and found that the efficiency of the vane is not the same depending on the height in which it is positioned, due to the air flow around the rotor and blades. Right behind the rotor the wind speed will be lower than in upper flows because the blades take energy from the wind. In ideal conditions the wind speed behavior would be like this:

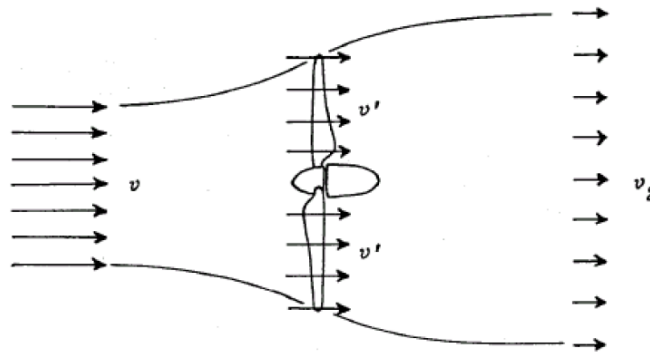


Image 16. Wind speed around a rotor in ideal conditions

In addition, behind the rotor and above all behind the peaks of the blades, there are produced turbulences that destabilize the air (and the vane in it) and reduce the rotor power. This are behind the rotor does not follow a laminar way, but a “screw” path that increases the turbulences.

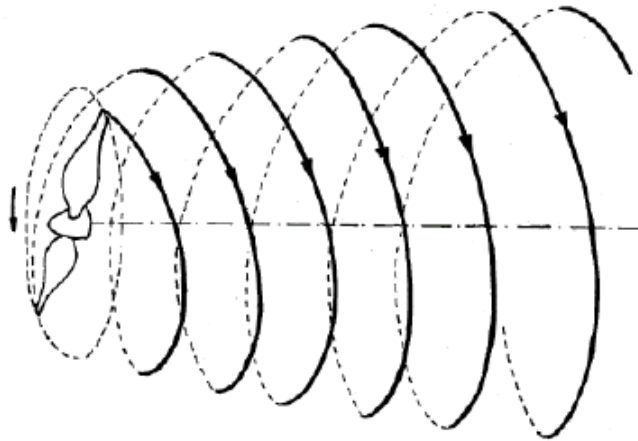
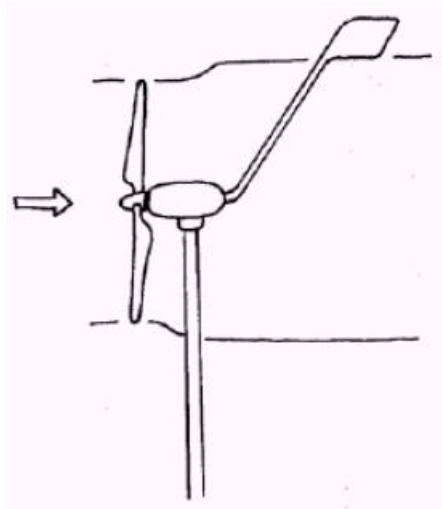


Image 17. Air turbulence behind the rotor

The vane plays a fundamental role and that is why its design should be thought carefully. The advantage of the Wind Flower is that it takes the good features from both kinds of turbines with rotor-orientation: leeward and windward. Leeward turbines have their rotor behind the mast. Their advantage is that they are positioned in the wind direction automatically, but they have the disadvantage that the mast interferes the wind before it hits the blades. Windward turbines have the rotor before the mast. They can seize the wind better but their drawback is that the axial force of the wind tries to take the rotor out of the wind flow due to the torque force existing because the distance from the rotor to the mast. The bigger this distance is, the bigger will be the torque force and the least efficient the wind turbine will be. The Wind Flower can have its rotor behind the mast without the disruption that it induces and also be self-oriented even without a proper vane. But as the aim is to make it the most efficient possible, I will look for the best position for the vane.



If the vane is inside the air tunnel behind the rotor, the wind speed there will be slower than in the flows around and the area of the vane will have to be bigger to have the same result. That is why some small wind turbine manufacturers mount it high lifted over the zone of influence of the rotor (see Image 18. Turbine with high lifted vane). In this way, its area can be reduced.



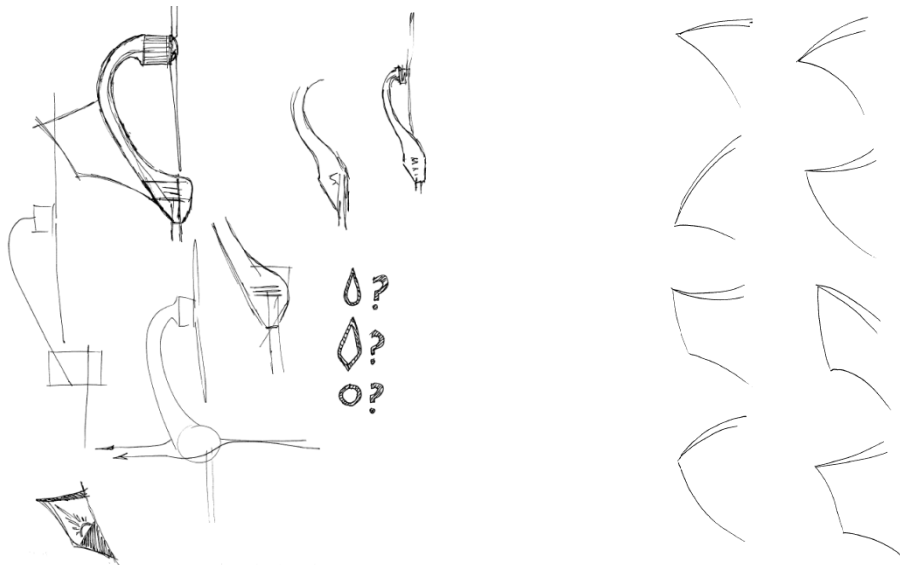
*Image 18. Turbine with high lifted vane*

As the company wants the vane attached to the holding structure, I cannot use a high lifted vane. Nevertheless, I will try to implement a vane that seizes the wind out of the zone of influence of the rotor.

## **4.3 Generate ideas and analysis**

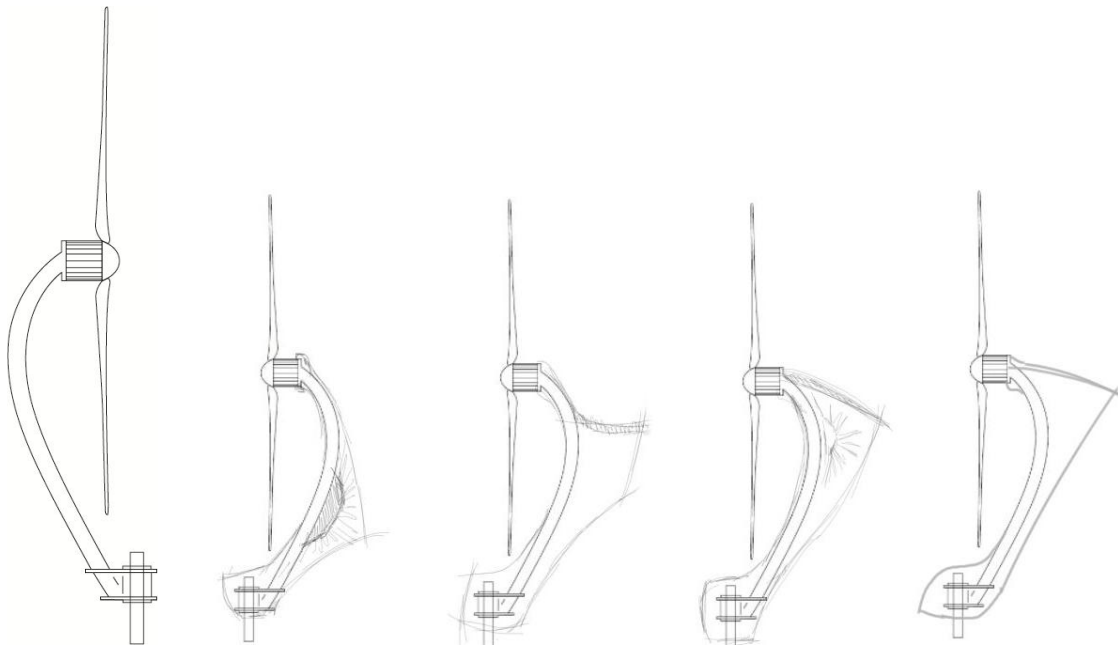
### **4.3.1 Ideation and sketching**

First ideas came after visiting the company and I considered different solutions for the shapes of the bracket cover and vane's outlines.



*Image 19. First ideas.*

Later I checked how it would look like with different combinations of vanes and shapes of the bottom part of the outer housing. But first, I created a template with the basic outline of the Wind Flower.



*Image 20. Template and first attempts*



\* Bracket cover + Vane integrated

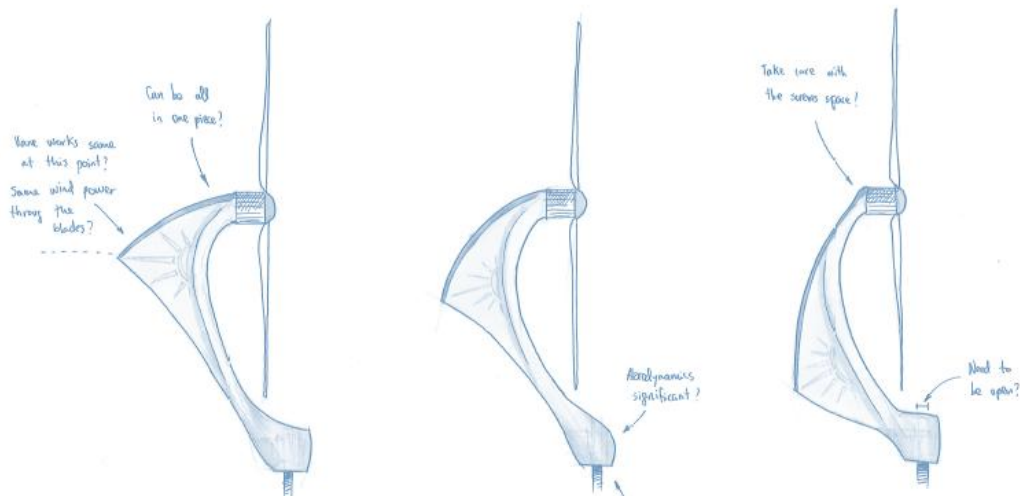


Image 21. Bracket cover & Vane integrated Sketches.

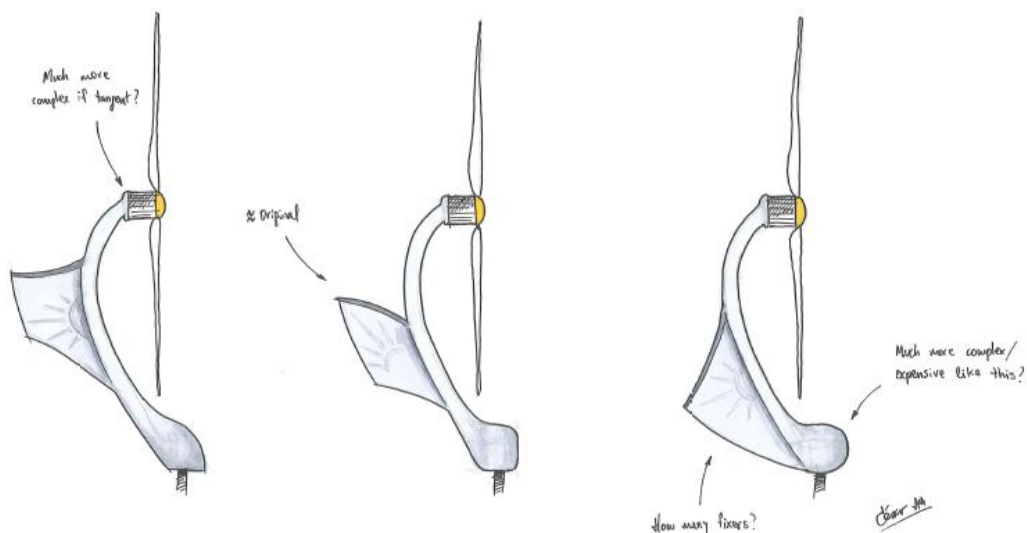
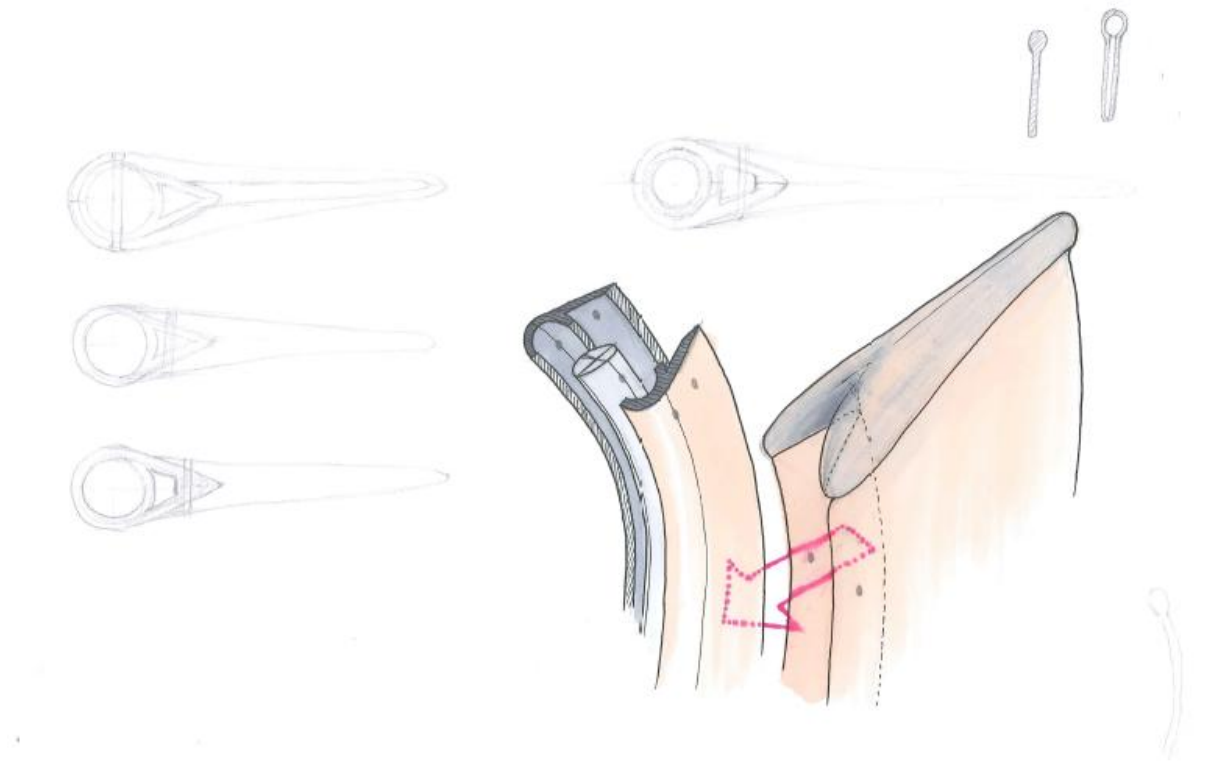


Image 22. Bracket & Vane separated Sketches.

I also started trying to figure out how the assembly and interior would exist of the housing and vane. One thing to take into account was that the top part of the vane should be thicker in order to provide strength to the structure, but it was difficult to implement and attach to the cover.

Following instructions of the company, I will have to take into account that the main outer housing that covers the bracket will be pre-assembled inside the final delivery box and the vane will be disassembled. This is important information due to the fact that each component will be assembled by two different persons, and one will be more experienced and prepared than the other.



*Image 23. Assembly example of the outer housing and the vane to the bracket.*

### **4.3.2 Syntactic, Semantic and Pragmatic**

In this section some of the fields to do with the syntactic, semantic and pragmatic design branches described in the method chapter will be described. The Design for Assembly responds to the Pragmatic view, the Shape study to the Syntactic one and the color study to the Semantics.

#### **4.3.2.1 Design for Assembly (DfA)**

It is important that the pieces to design allow for good access and let the person assembling/disassembling know the right way to do it. That is why I will have to carefully consider the placement when designing the locations for the bolts and nuts.

This is not only important for the staff that will mount the main cover over the bracket; another challenge will be the assembly of the vane, which will be done by the final customer. While the assembly of the two halves of the cover can require special tools to join, the final assembly of the vane will have to be suitable for any user that only has basic tools like standard screwdrivers and wrenches. In case that special bolts are required, the company should provide a special tool in the box to assemble them as well.

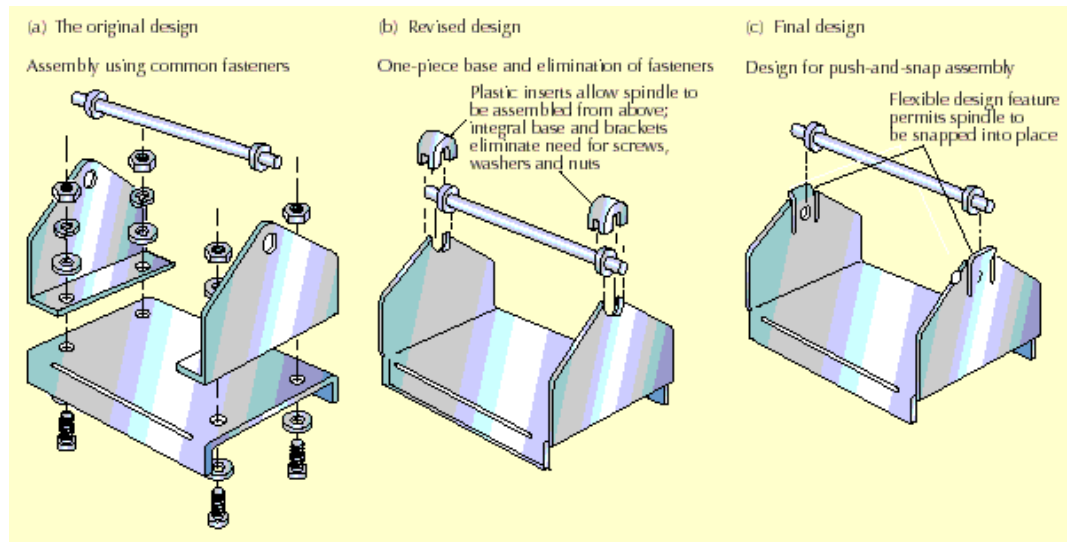


Image 24. DfA progression example.

#### 4.3.2.2 Shape Study

##### Aesthetics

As the Wind Flower contains mainly curved shapes, the housing and the vane should be in accordance with it. In addition, as the idea of *flower* has a female connotation, the appearance may have something to do with these qualities:

- > Curved outlines
- > Quiet but energized
- > Not aggressive
- > Tangent lines
- > Clean design
- > Colourful (colour studied later)



Image 25. Feminine objects' examples.

On the other hand, the female connotation can make male buyers not to buy the product so, as it will happen with the color connotation, I will try to implement some men-related

shapes and outlines (e.g. pointy ends, sharper edges, more aggressive silhouettes). This will equilibrate the genre in the design balance.

The outer housing of the Wind Flower should be in accordance not only with the Wind Flower itself but also with other products that can be around, like garden tools or children toys, so I will have to take them into account too.



*Image 26. Garden tools' examples*

Of course, above the connotation form values, it is essential that the shape is aerodynamic enough to provide the maximum efficiency to the Wind Flower, as was described in the point 4.2.5 (Aerodynamics). That is why the aesthetics will be always present but will come after the functional part is fulfilled.

#### **4.3.2.3 Color study**

Another connotation to take into account is the color. As Windforce is a company that promotes sustainable energy and an eco-friendly philosophy, the green color would fit perfectly in some components of the Wind Flower. But on the other hand, an exceeded similarity with a real structure like a flower may result in a rejection from the customer. In addition, in the case that the buyer/final customer is male, the possibilities of purchasing a product with almost the same look as a real flower but in a bigger scale, would be less likely. So I will implement other colors more standard of male-related in order to have a balance. Plane colors like white or cool gray can be implemented in the general surfaces and small details in green or blue will play the role well.



Image 27. Color communication (connotations)

## 4.4 Develop solutions and refinement

### 4.4.1 Concept ideas

After analyzing all the information collected I thought about three different concepts that fulfill the requirements and specifications settled in the previous steps.

The first concept is based in very rounded shapes and curved lines with a large vane. The bottom of the housing is like a “ball” that evolves the holding part of the bracket and the vane seems to be part of the cover due to its tangency on the top part, so the design itself is very in accordance. The main area of the vane is located in the down part of the wind turbine in order to get wind that does not come from behind the blades and also focusing on physics. The lower the height it is, the less momentum will be produced by the weight of the vane and the easier will be for the Wind Flower to spin around its axis.

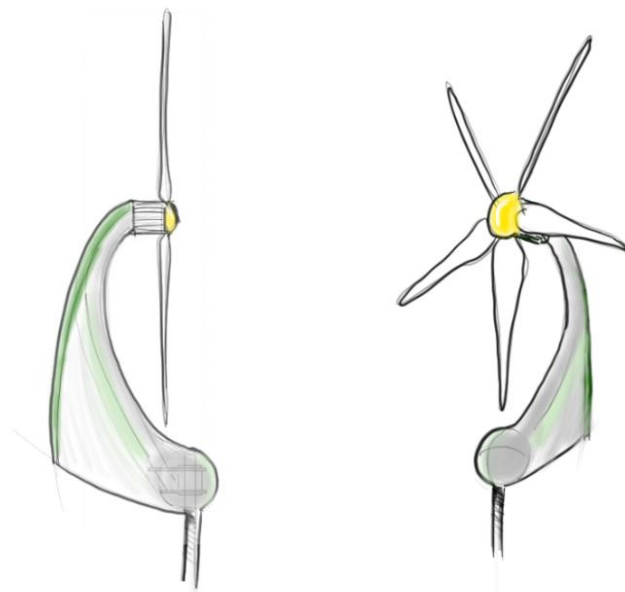
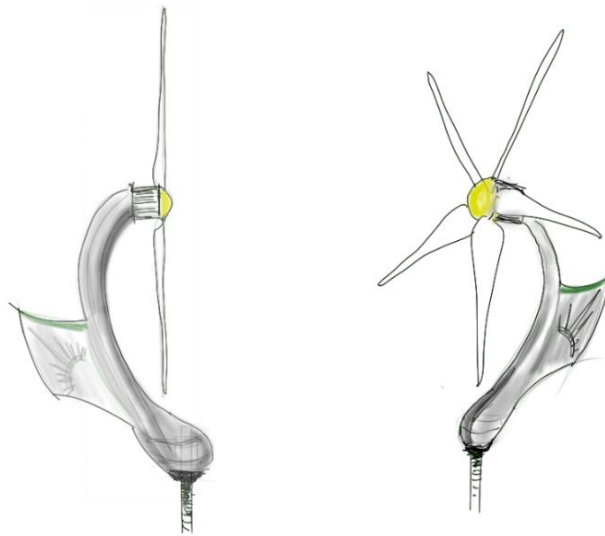


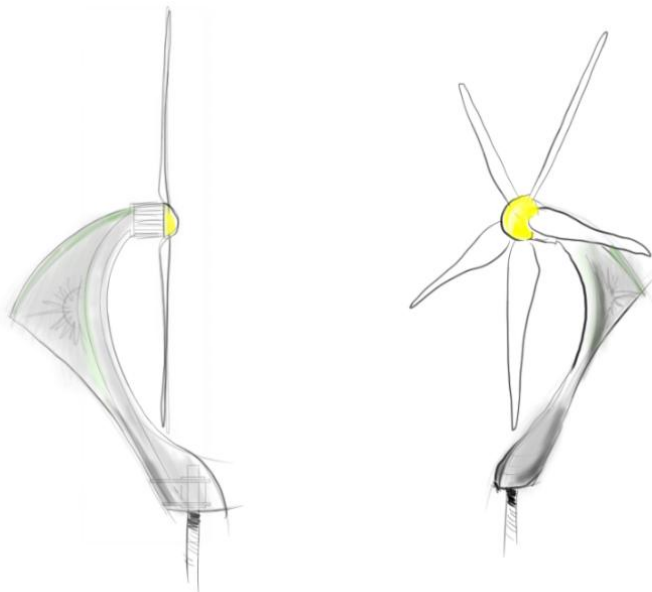
Image 28. Concept 1. Rounded

The second one has also a rounded bottom part but with a pointy edge on the front of the outer housing to make it more aerodynamic (as was described in the Aerodynamics point). It also has pointy edges in the vane and remembers more about a male-shape product. The outline of the shape is similar to the original (the provisional one that use the current Wind Flower turbines), but with a more aggressive silhouette.



*Image 29. Concept 2. Round & Sharp*

And the third one had the vane attached in the upper part of the housing and was based in tangent lines that transmit continuity in a futuristic shape. The bottom part of the outer cover is flat and it is designed to boost the wind to the vane zone.



*Image 30. Concept 3. Continuity*



#### 4.4.1.1 Selection and design variants

When I had to decide between the three concepts I found that all of them had good features that I would like to incorporate in the final design. I discard the third one despite the nice futuristic view, for having a vane too large to assemble and too high positioned, which would mean a worse efficiency due to the aerodynamic theory explained in the point 4.2.5.

I found possible a combination between the two first concepts by taking the functional features of the first (low vane to seize the wind, rounded aerodynamic bottom, weight focused on the down part, tangent lines) and the appearance of the second (pointy edges, aggressive outline, similarity to the original vane).

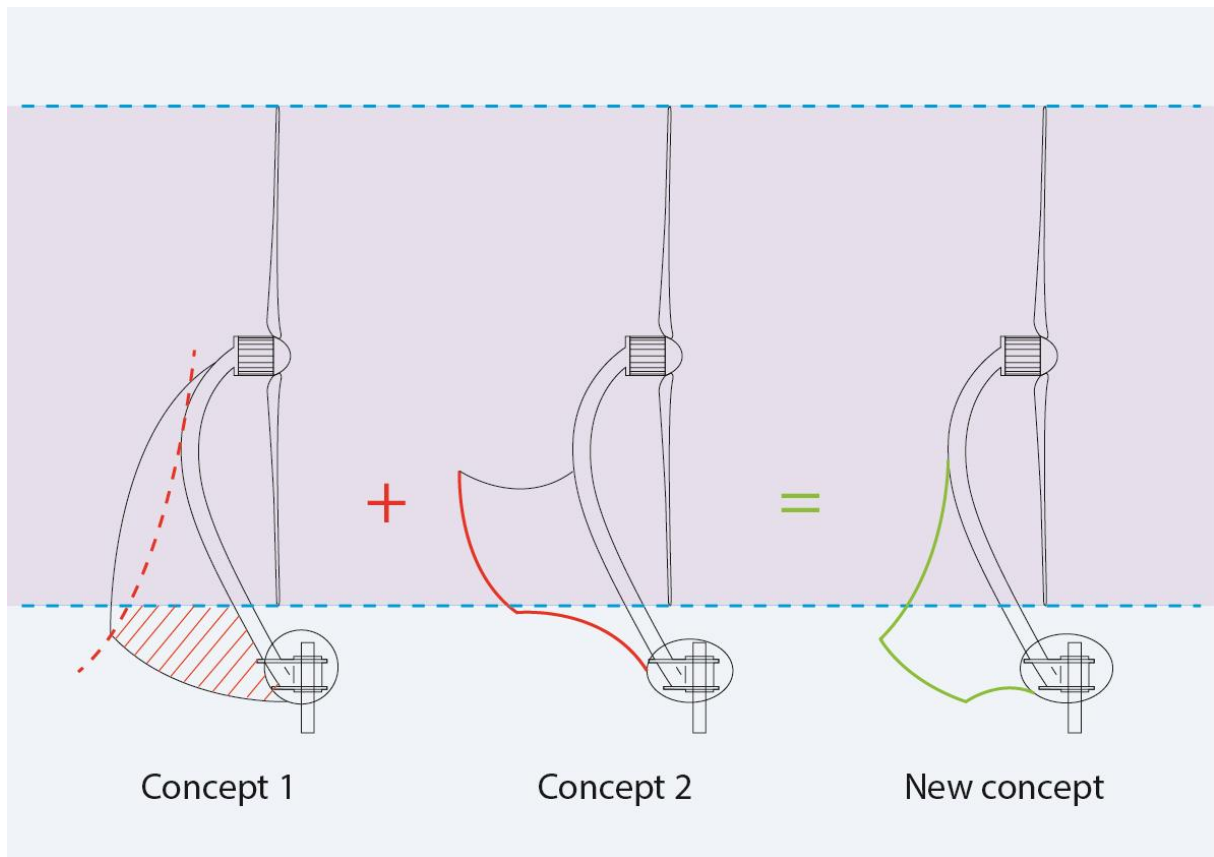


Image 31. Concept combination

With the new design, all the good physical and aerodynamic properties are preserved and the aesthetics take part as well. The main area of the vane is located under the peak of the blade so it will seize the “clean” wind that has not been slowed down or made turbulent by the rotor and blades.

After the main design outlines were defined, different possible sections were thought for the outer cover tube, but the “wing-shaped” section (the right one of the image below) that was described in the Shape Analysis was the one that I decided for being the best regarding aerodynamic properties and also the one with the most accordance into the final design (pointy front).

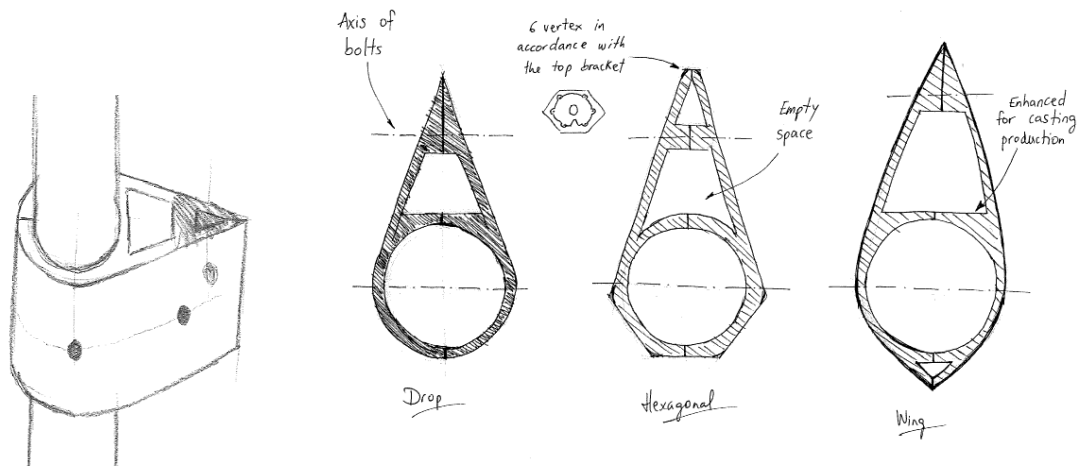


Image 32. Internal view of the tube and different sections

The inside of the cover will be empty but saving the thickness specified by the company for fiberglass, which is 3-4 mm. The two halves will be designed without blasting material in order to be manufactured in a more efficient and cheap way in case of using casting as a production method.

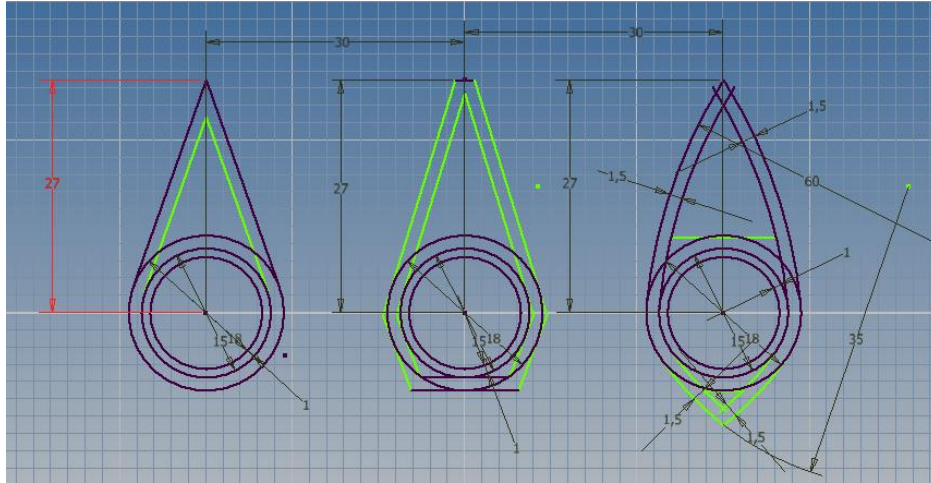
#### 4.4.2 CAD modeling

After building the bracket with the measures that Windforce provide me, I started testing with different sections and modeling methods. The programs I used to model are Autodesk Inventor Professional 2013 and SolidWorks 2013. And the rendering tool I used is KeyShot 4.2 Pro.



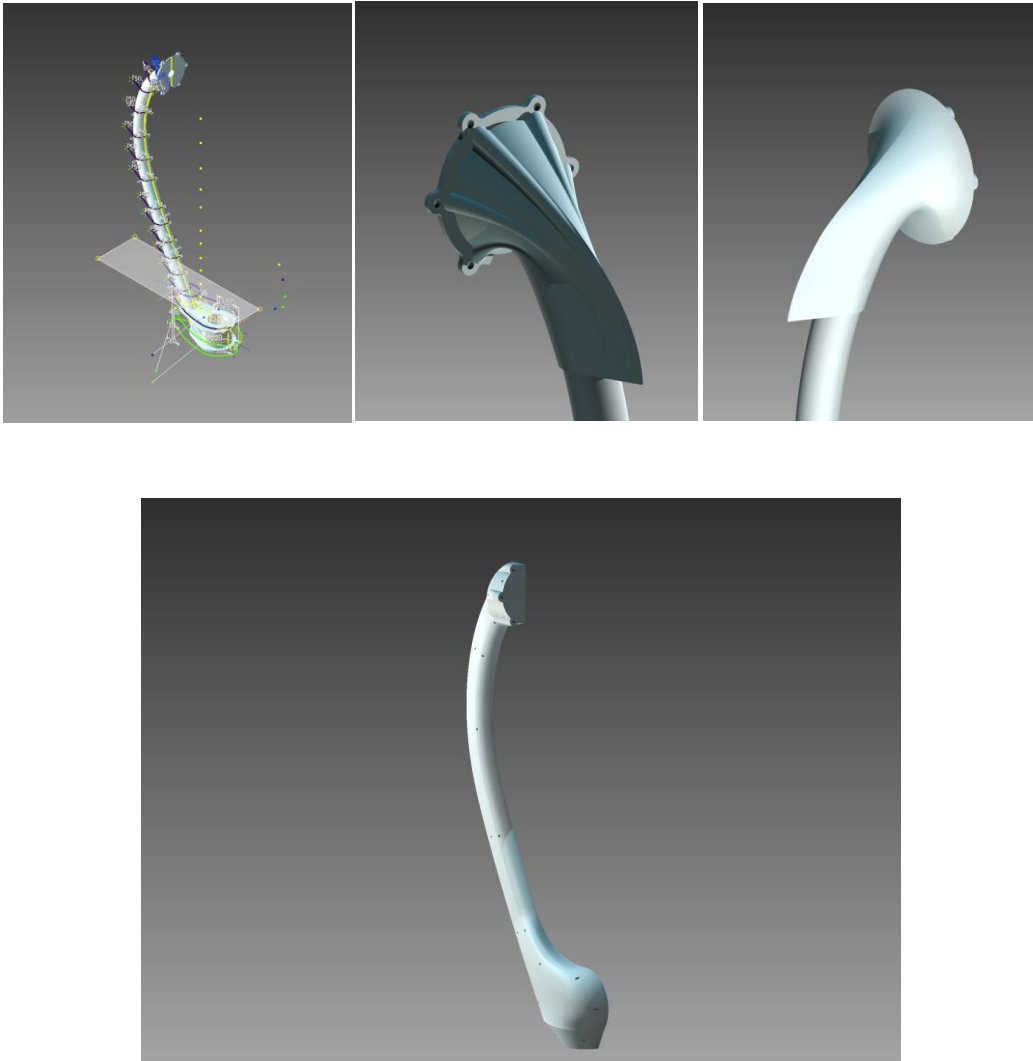
Image 33. Bracket construction in CAD



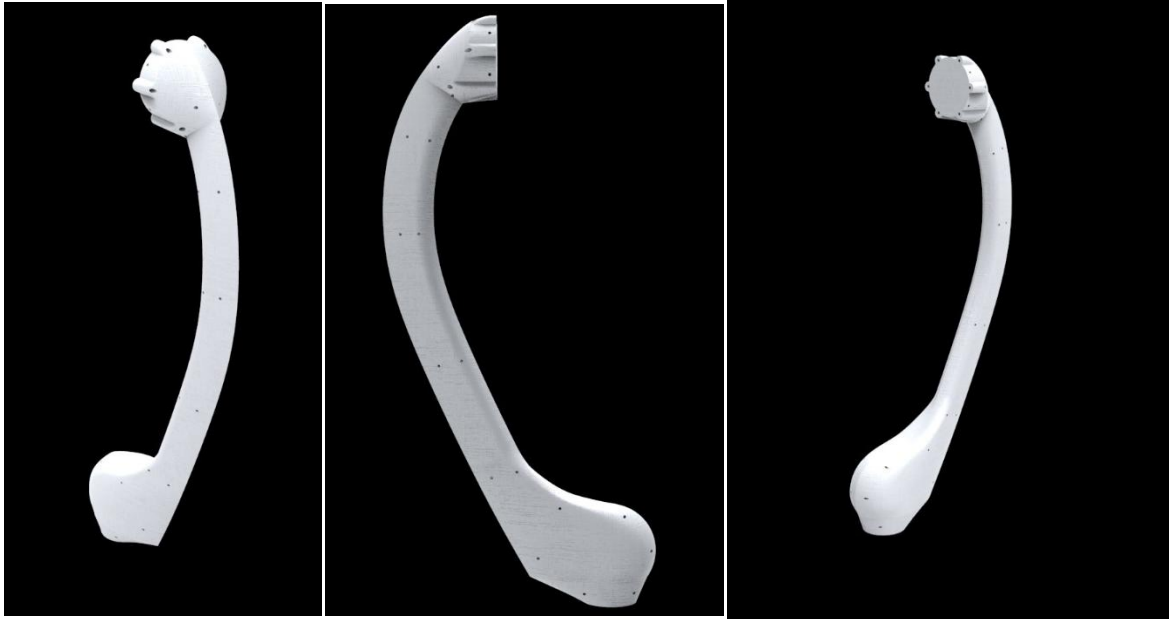


*Image 34. Different section attempts*

This was the most tricky part of the project because I had not made an outer housing before and I did not know the right software tools in a deep way. Here are some screenshots from Autodesk Inventor of the different tests of the cover shape.

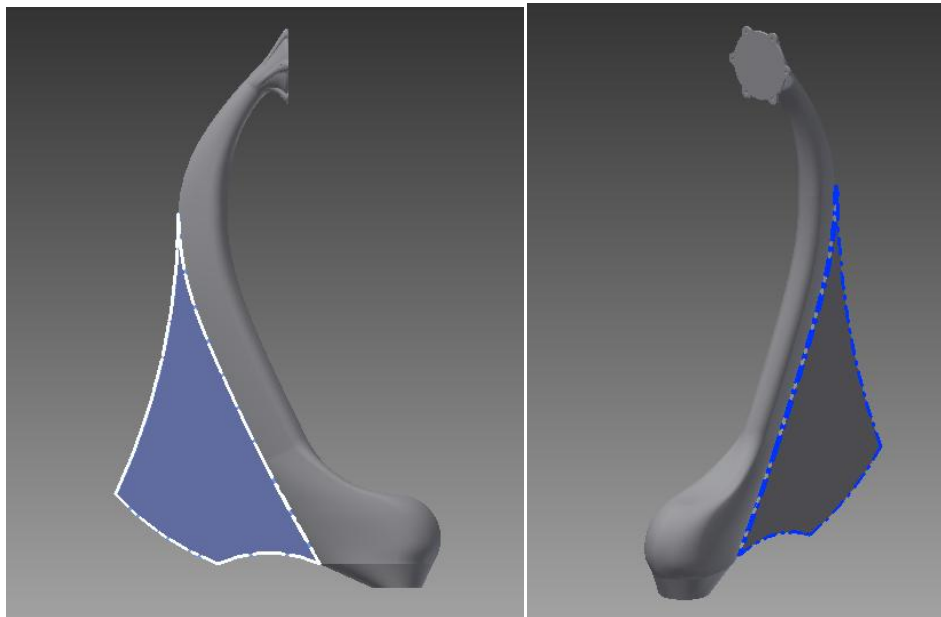


*Image 35. View of one of the halves of the provisional outer housing*

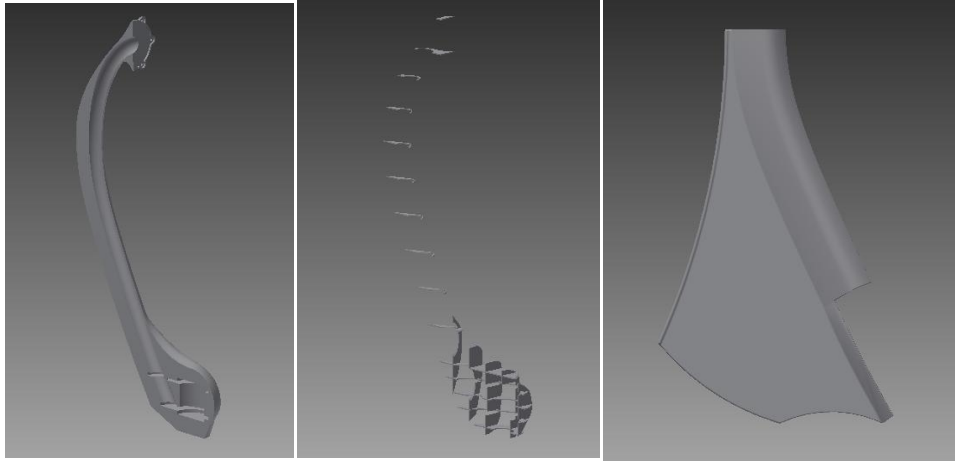


*Image 36. Different render tests of the outer housing with KeyShot*

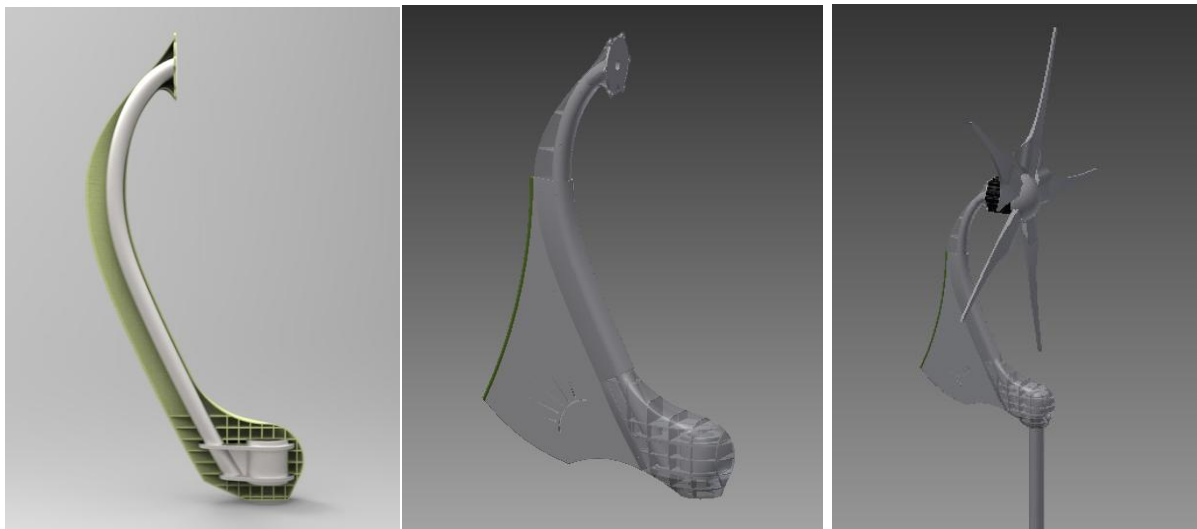
As I was not satisfied with the final appearance of the bracket cover I tried to refine the design until I had thinner thicknesses and a better looking. After finishing with the outer housing I started modeling the vane in order that they adapted to each other.



Later I built the shells from the solid of the cover and also the ribs to add strength to the structure. And the same with the vane.

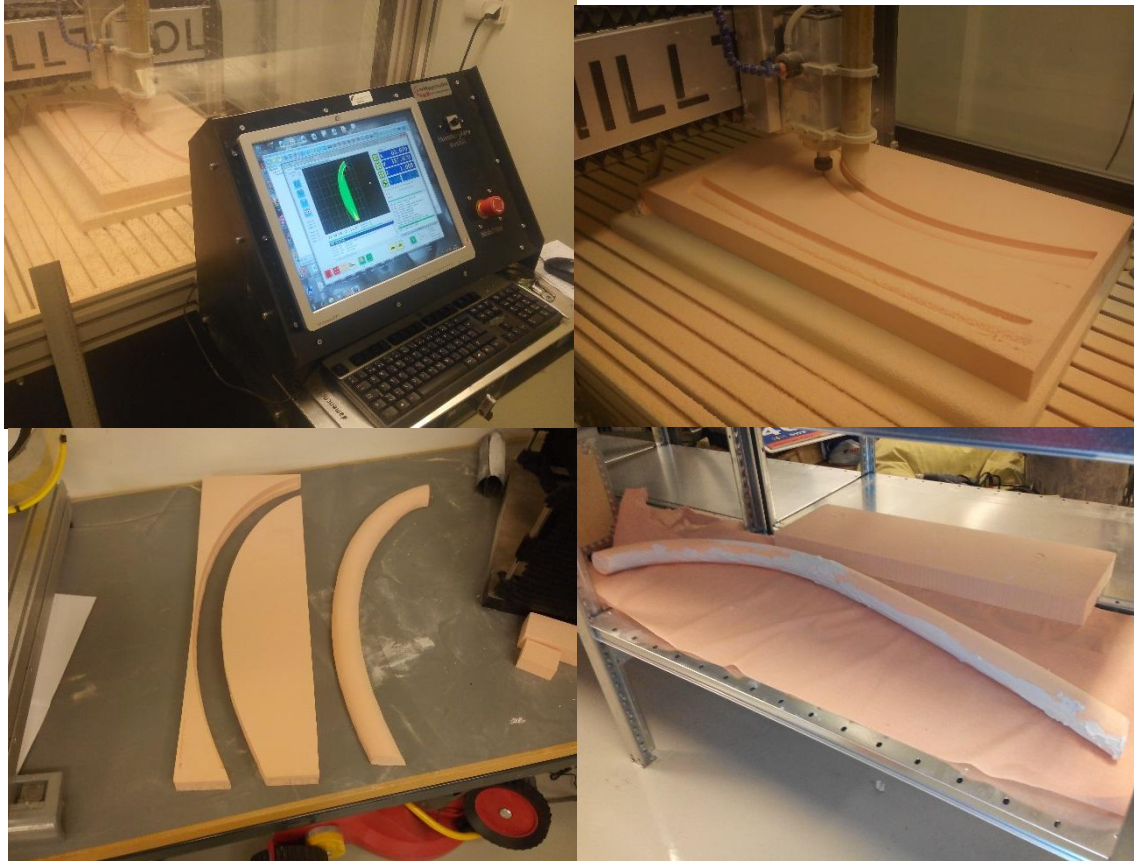


Once I had the parts required for this thesis project I built the rest of the pieces of the Wind Flower and made the final assembly.



#### 4.4.3 Physical modeling

At the same time I was modeling in CAD I made some trials with the bracket design in order to check proportions and work over it later on with other techniques. For modeling the bracket tube I used an automatic milling machine (See images below). The final physical model in scale 1 to 1 which will include all the elements of the final design will be done later.



*Image 37. Building of the bracket with the Milling Machine*

## 5 Result

In this chapter it will be shown the main results and findings of this project. The result of all this work can be seen in the next rendered images and descriptions.

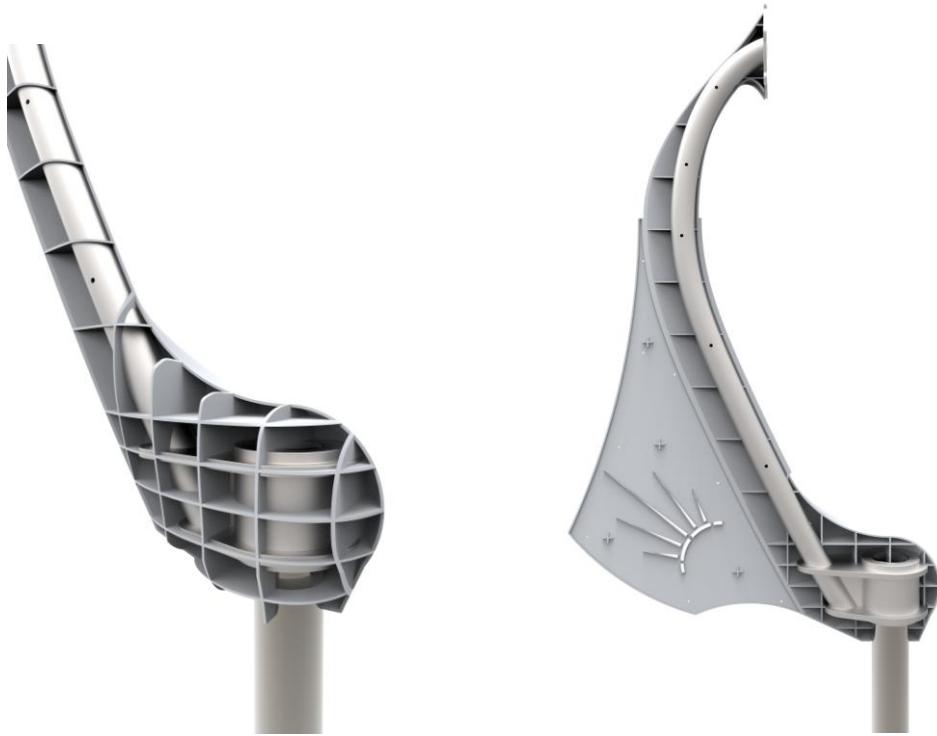


The final model has been rendered trying to represent the plastic properties of the fiberglass and the final colors. The colors chosen are cool gray for all the elements but the generator, that come from a supplier. A dark blue with green tones has been selected for some parts like the blades or the details on the bottom of the outer cover and the top edge of the vane. This combination of colors is harmonic and provides serenity to the whole design. The logo of Windforce has been implemented extruded in the vane surface.



The final design of the Wind Flower includes the holes for the M4 crosshead screws and nuts that will attach both shells of the vane to the outer housing and to each other shell. This will be done by the customer who will only need a standard screwdriver or other tool for crosshead screws. As for the assembly of the outer housing, it has been decided finally that both shells will be glued together around the bracket and placed into the final box. This is due to the fact that it will be the company who will make this assembly and therefore there would be useless to spend money in assembly tools when there will be no need to disassemble it again because it has no mechanical components inside or anything that can break during the product's life. The front edge is a bit pointy as I explained in previous steps, and the crossed section has the shape of a drop with a pointy front as well. This section varies according to the cover outline.

The ribs in the inside part of the cover shells hold and protect the bracket, as well as they add additional strength to the whole structure. The vane also has some supporting material in the inside, not only the fixing points but also the main drawing of the brand logo helps adding consistency to the assembly.



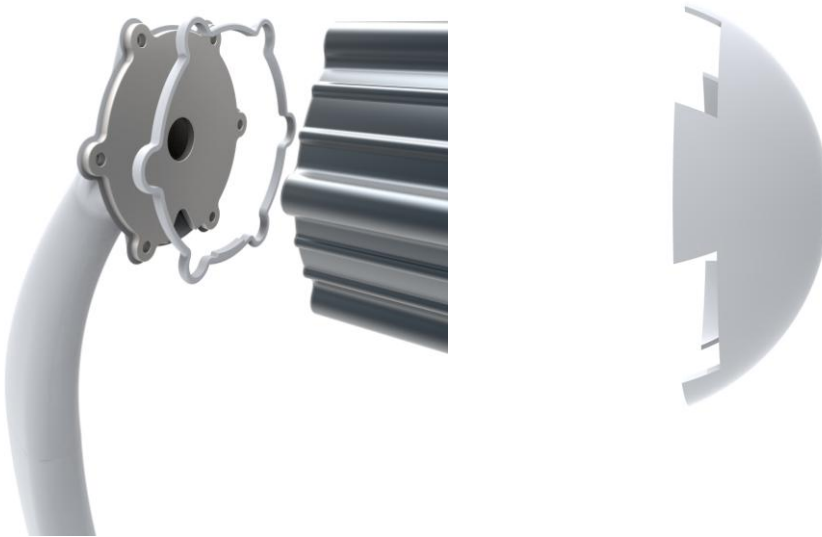
The vane is formed by a top part where it evolves the cover tube and a down part that follows the path of the rear housing. This is due to the fact that the bottom part of the outer shells is too big to be covered by the vane and material would be wasted. The vane is attached to the outer housing and the bracket through 8 screws, from which 3 of the cross the bracket tube as well. The two screw holes in the bottom of the vane are attached only to the cover (see image below).



Due to manufacturing features, the front part of the top outer cover is made in a separated piece so it can be assembled once the bracket has been placed inside the

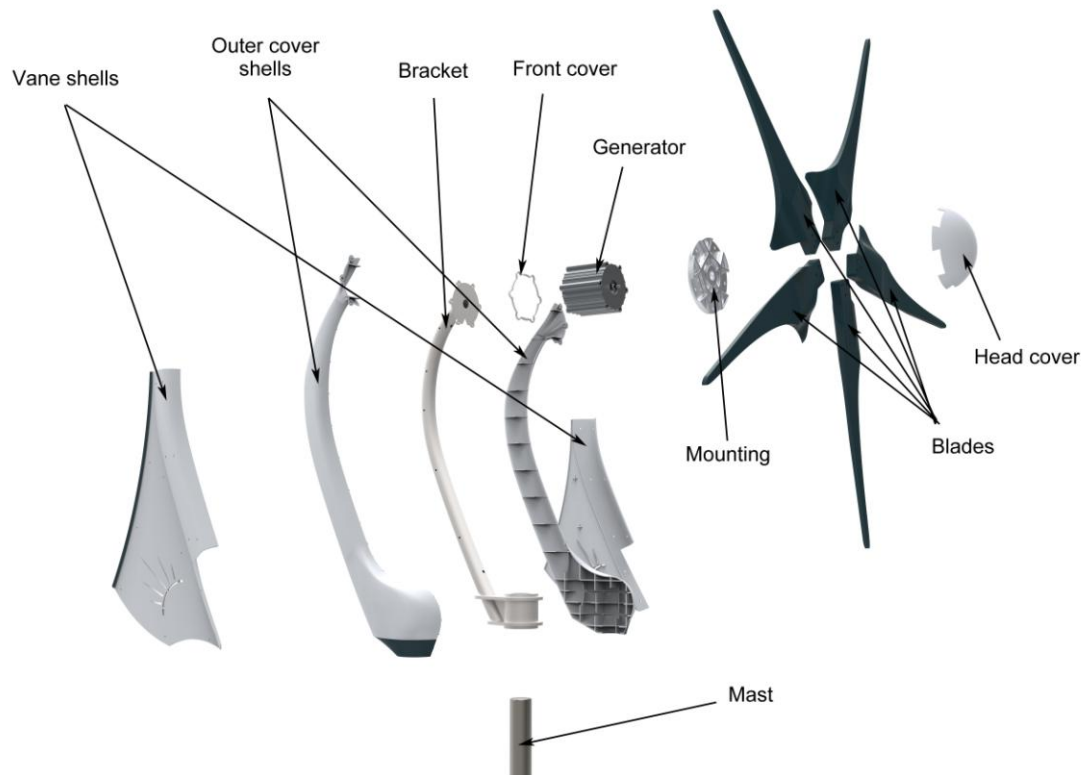


housing and both shells stick together. Otherwise the bracket top part could not enter in the shell due to the circular shapes in the edges of the hexagonal outline. The final design also includes the front head piece, which covers the assembly of the blades with the mounting piece. Both designs can be seen in the images below.



In the next image it can be seen an exploded view of the final assembly which includes all the elements apart from the assembly tools and the electrical components such as cables.





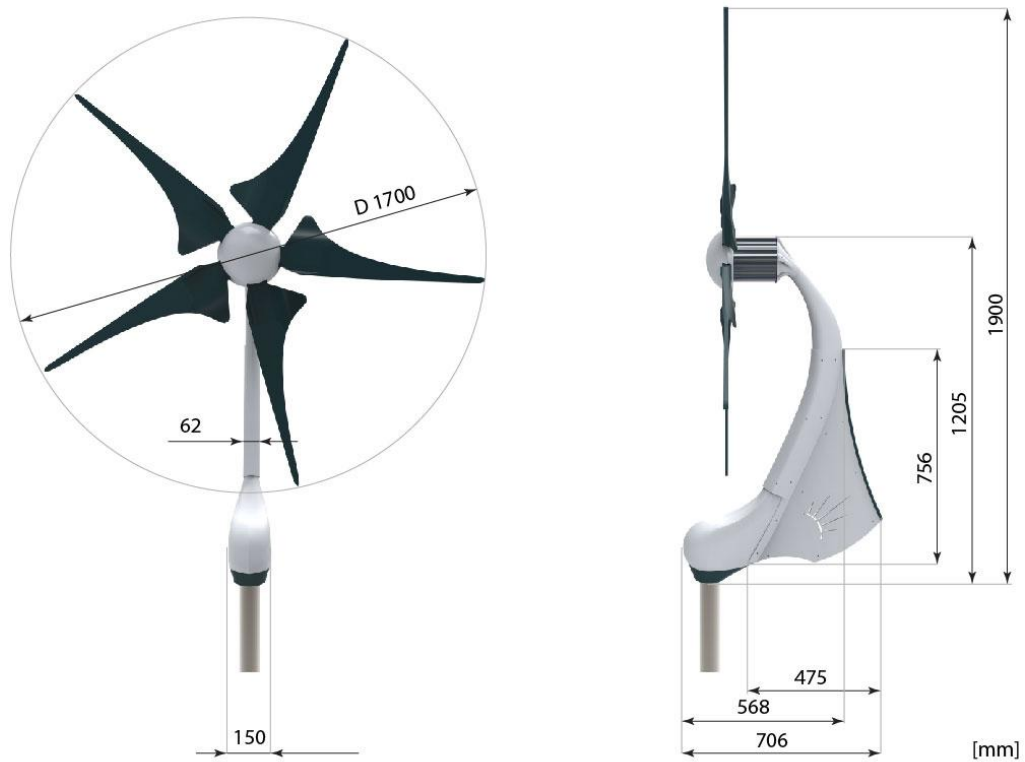
The assembly of the main parts designed during this thesis project can be seen in the image below. This includes both shells of the housing and vane with the bracket plus the front top cover.



The Wind Flower will be attached to a mast of a variable height between 4 and 7 meters and it can have a variable thickness too due to the fact that there will be a fixing piece included in the set that will adapt the diameter of the mast to the hole and will contain also the bearings to make the turbine spin around its axis. Unfortunately, the company was unable to provide details of this design so it could not be included in these final renders.



The main measures of the Wind Flower can be seen in the next image. It has a diameter of rotation of 1700 mm and a total height of almost 2 meters. The unit of measuring of the image below is millimeters (mm).



To finish with this result point, here are two rendered examples of how would a Wind Flower look like in different households with other energy solutions like solar panels:





### Final model in real scale

Here are some pictures of the final model in scale 1:1 of the outer cover and vane of the Wind Flower. The materials used are high density foam for most of the outer housing (big blocks), ABS plastic for the top of the cover (using a 3D printer) and foam board for the wind vane (big sheets). Due to unexpected reasons beyond my control the amount of material available in the workshop (high density foam) was not enough and some of the machines required to work it were not functioning. Thus, I had to do many tasks manually which took more time than expected and also improvise ought to the lack of material. After building and painting only half of the symmetric model I glued some mirrors onto a big wooden board and stuck the half of the model onto them. Thereby, the viewer can experience the total view of the entire product with only half of it.







## 6 Conclusion and discussion

This project has covered all the design process steps and showed the results of a solution to a problem of an existing product. As it was settled in the beginning of this paper, the aim was to develop a suitable design of an outer housing and a vane that fits with the already existing design of the Wind Flower, and it has been done successfully. The descriptions and research information of this work provide a deeper understanding of this new and growing technology and the results provide a broader view of the possibilities that the industrial design can offer. The Wind Flower means an alternative to the typical cases of small-scale wind turbines, which have a completely different structure and method of orientation. These features together with a harmonic and modern design can make the product success in the wind energy market.

My personal reflection about this project has different points. First I would like to mention that I thought that working with a company which has existing products in the market (this is, that they are not just starting) would be very different. I discovered a lot of things about the wind energy world and the ways to seize it and also I acquired much knowledge about ways of working in a company that differ from the typical ones. I also have to say that I did not have a lot of support from the company regarding the provision of information, like design features, technical drawings or physical pieces that would have made the work much easier and reliable.

Some limitations have to be mentioned as well. First of all, I must say that the trickiest part was the CAD modeling part due to my lack of knowledge about some designing tools and the continuing problems that emerged from the CAD software. But I have learned a lot of it too. In addition, and again owing to a lack of knowledge, the aerodynamic considerations may have some implications that I had not taken into account because my background is not specialized in that. And finally, it has to be said that the work does not finish here. It will be needed further studies of the shape regarding not only the aerodynamic properties but also the manufacturing methods, which will play a big role concerning the final price of the product and consequently, the income of the company.

To sum up, this has been a challenging project but I consider that the outcome has fulfilled all the requirements and objectives settled in the beginning. Suitable designs have been done over the initial design of the product and a lot of knowledge has been learned. Despite the work has covered all the design phases, there is still a lot to do if the company proceeds with the production of the outer housing and vane, but with the right moves the final results will be rewarding.

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### References for some of the images:

- Image 1. House with hybrid system installation (source: see References): <http://windforce.se/egenel.php>
- Image 6. The three sub-types of wind turbines (sources for images: see References, 7): [http://en.wikipedia.org/wiki/Wind\\_turbine](http://en.wikipedia.org/wiki/Wind_turbine)
- Image 13. Typical family model (source: see References) <http://www.gardencitymft.com/imgs/happyFamilyRS.jpg>
- Image 15. Examples of aerodynamic shapes: [https://www.google.es/search?q=aerodynamic+shapes&rlz=1C1AVSA\\_enES423ES423&es\\_sm=122&source=lnms&tbm=isch&sa=X&ei=J-FyU7WqCq7P4QTqYHgCA&ved=0CAgQ\\_AUoAQ&biw=1366&bih=653](https://www.google.es/search?q=aerodynamic+shapes&rlz=1C1AVSA_enES423ES423&es_sm=122&source=lnms&tbm=isch&sa=X&ei=J-FyU7WqCq7P4QTqYHgCA&ved=0CAgQ_AUoAQ&biw=1366&bih=653)

Image 16. Wind speed around a rotor in ideal conditions, Image 17. Air turbulence behind the rotor, Image 18. Turbine with high lifted vane:

[http://www.amics21.com/laveritat/introduccion\\_teorias\\_turbinas\\_eolicas.pdf](http://www.amics21.com/laveritat/introduccion_teorias_turbinas_eolicas.pdf)

Image 24. DfA progression example.:

[http://outreach.ewu.edu/share/courses/pnemetzmills/2009opsm330/OMCh3/RTF5\\_5.gif](http://outreach.ewu.edu/share/courses/pnemetzmills/2009opsm330/OMCh3/RTF5_5.gif)

Image 25. Feminine objects' examples.:

[https://www.google.es/search?q=female+objects&rlz=1C1AVSA\\_enES423ES423&es\\_sm=122&source=lnms&tbm=isch&sa=X&ei=y91yU7W7H6v64QSj84GwBQ&ved=0CAgQ\\_AUoAQ&biw=1366&bih=653#q=feminine+objects&tbm=isch](https://www.google.es/search?q=female+objects&rlz=1C1AVSA_enES423ES423&es_sm=122&source=lnms&tbm=isch&sa=X&ei=y91yU7W7H6v64QSj84GwBQ&ved=0CAgQ_AUoAQ&biw=1366&bih=653#q=feminine+objects&tbm=isch)

<http://www.examiner.com/article/best-toys-guide-releases-2012-holiday-hot-toys-list>

Image 26. Garden tools' examples: <http://www.yell.com/biz/aj-mowers-hitchin-901471182/>

Image 27. Color communication (connotations):

[https://www.google.es/search?q=color+communication&rlz=1C1AVSA\\_enES423ES423&es\\_sm=122&source=lnms&tbm=isch&sa=X&ei=wuByU7jzOZSq4gSd8oCQCA&ved=0CAgQ\\_AUoAQ&biw=1366&bih=653](https://www.google.es/search?q=color+communication&rlz=1C1AVSA_enES423ES423&es_sm=122&source=lnms&tbm=isch&sa=X&ei=wuByU7jzOZSq4gSd8oCQCA&ved=0CAgQ_AUoAQ&biw=1366&bih=653)

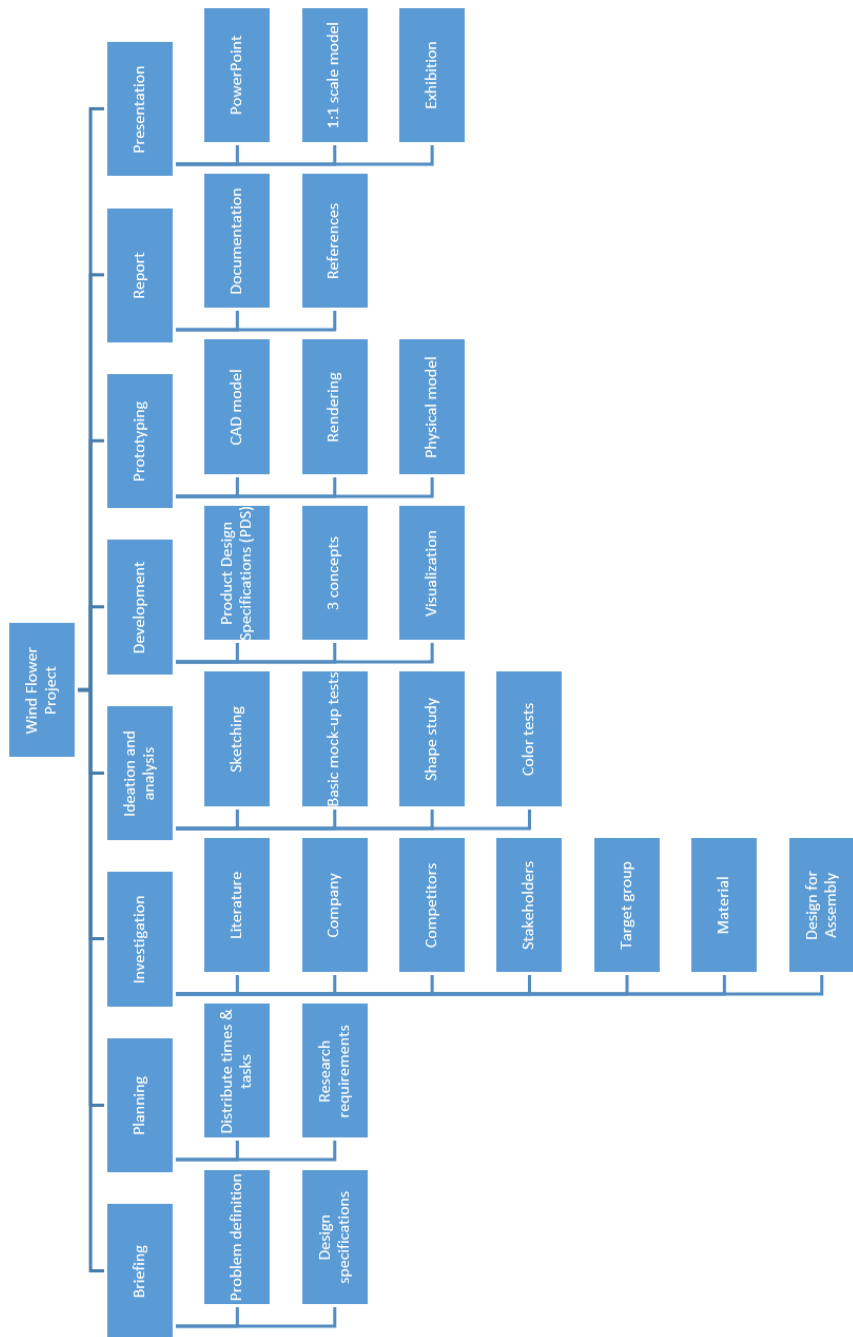
Last images. Rendered examples of households:

[https://www.google.es/search?q=house+with+solar+panels&rlz=1C1AVSA\\_enES423ES423&oq=house+with+solar+panels&sourceid=chrome&es\\_sm=122&ie=UTF-8](https://www.google.es/search?q=house+with+solar+panels&rlz=1C1AVSA_enES423ES423&oq=house+with+solar+panels&sourceid=chrome&es_sm=122&ie=UTF-8)

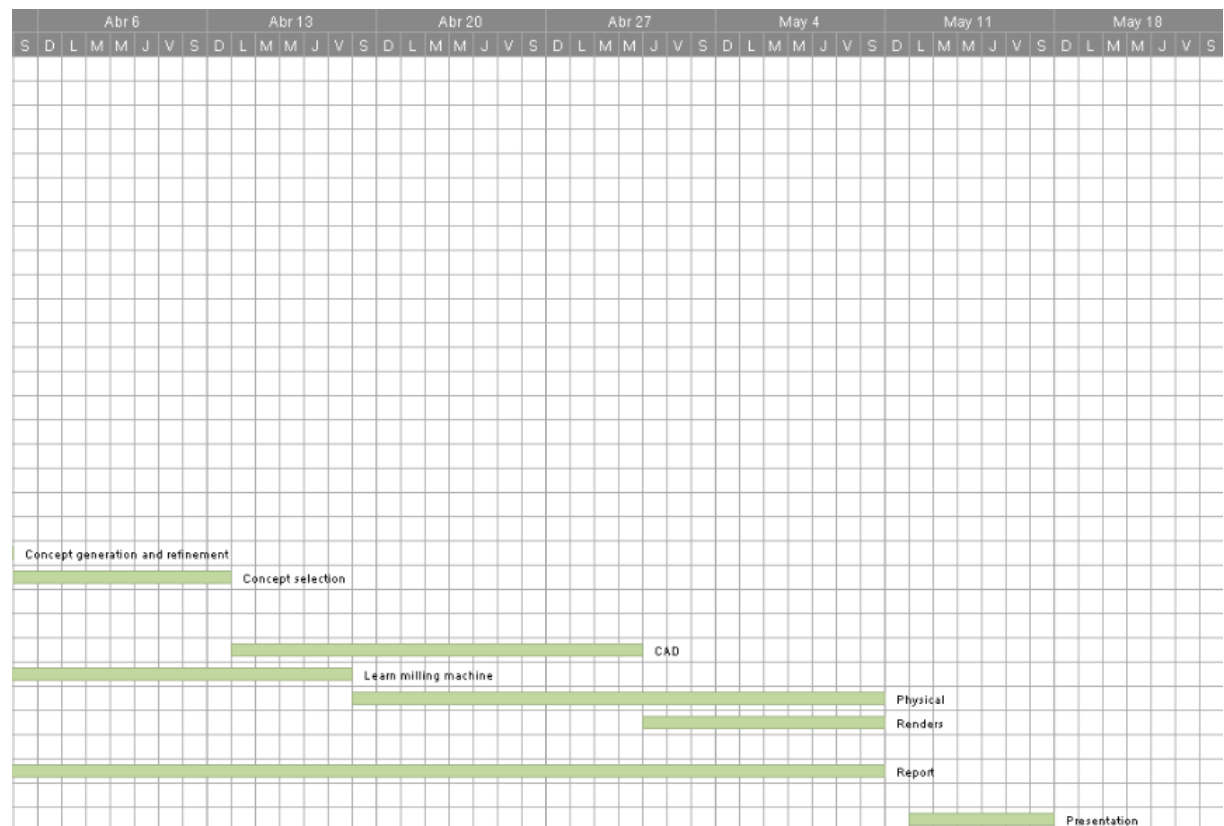
## **8 Attachments**

Attachment 1	Work Breakdown Structure
Attachment 2	Gantt Diagram
Attachment 3	Competitors' descriptions

Attachment 1                      Work Breakdown Structure



## Gantt Diagram



Attachment 3

Competitors' descriptions

## Inensus

[www.inensus.de](http://www.inensus.de)



**Products:** wind monitoring, grid-tied converter, power safety systems, battery charge controllers

**Presence:** Germany, Senegal

INENSUS is a leading provider of services and power electronic products in the field of small wind and decentralised energy systems with its head office at the Energieforschungszentrum EFZN (Energy Research Centre) of Lower Saxony in Goslar, Germany.

Besides standard products like the compact wind and solar monitoring system aeolog INENSUS also manufactures small- to medium-volume series of customised products. The customised products are Operation Control-, Overvoltage Protection- and Safety Systems as well as Charge Controllers, Wind Heating Controllers and Data Acquisition Systems, which are all adapted to the special requirements of the respective small wind turbine. INENSUS distributes the SIEB & MEYER aeolon exclusively worldwide and offers technical support.



## KLiUX energies

[www.kliux.com](http://www.kliux.com)



**Products type:** VAWT

**Products size (kW):** 1.8/3.6

**Applications:** GC/HB

**Presence:** Spain

Kliux Energies is a Spanish company, with international presence, that specializes in DISTRIBUTED ENERGY SOLUTIONS based on renewable sources. Kliux has worldwide exclusivity rights to manufacture and sell the GEO1800 VERTICAL AXIS WIND TURBINE, developed by Geolica Innovations which also integrate into hybrid system with solar photovoltaic technology. Its unique aerodynamic design results in a noiseless, energy generating turbine that also performs extremely good in architectural integration and visual impact. THE TRULY URBAN WIND TURBINE.



## Montanari Energy

[www.montanarienergy.it](http://www.montanarienergy.it)



**Products type:** HAWT

**Products size (kW):** 1/2.5

**Applications:** GC/SA

**Presence:** Italy

We at Montanari Energy believe in the value of wind and our objective is to develop the finest technology in order to allow everyone to generate all the energy they need from this free, clean and endless resource.

Designed by some of the finest Italian engineers operating in the small-wind sector, our turbines are excellent products incorporating Italian design at its best.

We at Montanari Energy believe that everyone can one day be pioneers of the world again. It will be a freer and richer world, a world that deserves our full attention.



## PhonoWind

[www.phonowind.com](http://www.phonowind.com)

**Phono® Wind**

Products type: HAWT

Products size (kW): 0.3/1/2/3/5

Applications: GC/SA/PP

Presence: China, Germany, UK, USA

Phono Wind manufactures high quality, competitively priced photovoltaic small wind turbines. Since 2004, Phono Wind turbines have been used widely throughout the world – in Germany, Spain, Italy, Japan, Czech Republic, Slovakia, Israel and the United States.



## ShenZhen Effsun Wind Power

[www.effsun.com](http://www.effsun.com)



深圳市艾飞盛新能源有限公司  
SHENZHEN EFFSUN NEW ENERGY CO.,LTD

Products type: HAWT

Products size (kW): 0.3/0.4/0.5/1/2/3/5/10/20

Applications: GC/SA/HB

Presence: China

ShenZhen Effsun Wind Power CO.,LTD is a High-tech Enterprise of the wind power industry in China.

Our company owns a strong technical force, we have build a long term technical cooperation with South China university of technology and Central South University. Our company is a manufacturer integrating R&D, manufacturing, sales, after-sales service.

Our annual production capacity is over 20'000 units, most of them are sold to domestic market, and exported to over 40 countries, such as the United Kingdom, France, the United States, Canada, New Zealand, Australia, Argentina and India.



## Windspire Energy

[www.windspireenergy.com](http://www.windspireenergy.com)



Products type: VAWT

Products size (kW): 1.2

Applications: GC/SA

Presence: USA, Australia, Belgium, Canada Costa Rica, Denmark, France, Ireland, Italy

Affordable, attractive, and ultra quiet, Windspire® wind turbines give you the power to create clean energy from the natural wind just outside your door. At only 30 feet tall and four feet wide Windspire wind turbines are appropriate for urban, suburban and rural environments. Elegantly engineered, scalable and made in America, Windspires come as a complete system.

Designed for use where you live and work, Windspires are currently powering homes, small businesses, schools, museums, parks, vineyards, and commercial buildings.

Join hundreds of Windspire owners and start generating your own clean energy today.



## Zhejiang Huaying Wind [www.huayingwindpower.com](http://www.huayingwindpower.com)



Products type: HAWT  
 Products size (kW): 2/5/10/30  
 Applications: GC/SA/DH/PP  
 Presence: China

Zhejiang Huaying Wind Power Generator Co., Ltd, a member of Tongkun group--china's leading industrial conglomerate, is a high tech startup company specialized in research, production and marketing of small and middle sized wind turbine system. Located 120km away from Shanghai, the company enjoys excellent traffic convenience. The company has made a pioneering step in the development of a brand new series of downwind- variable blade pitch wind turbines. ISO9001 quality system established and CERoHs certified, the company has a complete series of strict testing and quality guarantee methods for all of the wind turbine and system.



## ZKEnergy Technology [www.zkenegy.com](http://www.zkenegy.com)



Products type: HAWT  
 Products size (kW): 0.4/0.6/1  
 Applications: GC/SA/HB  
 Presence: China

In ZKEnergy Technology Co., Ltd. is a professional high-tech enterprise engaged in the development, production and application in the field of clean energy, small and medium-sized wind power and solar integrated application systems. Innovation, cooperation, responsibility and integrity are our core values.

