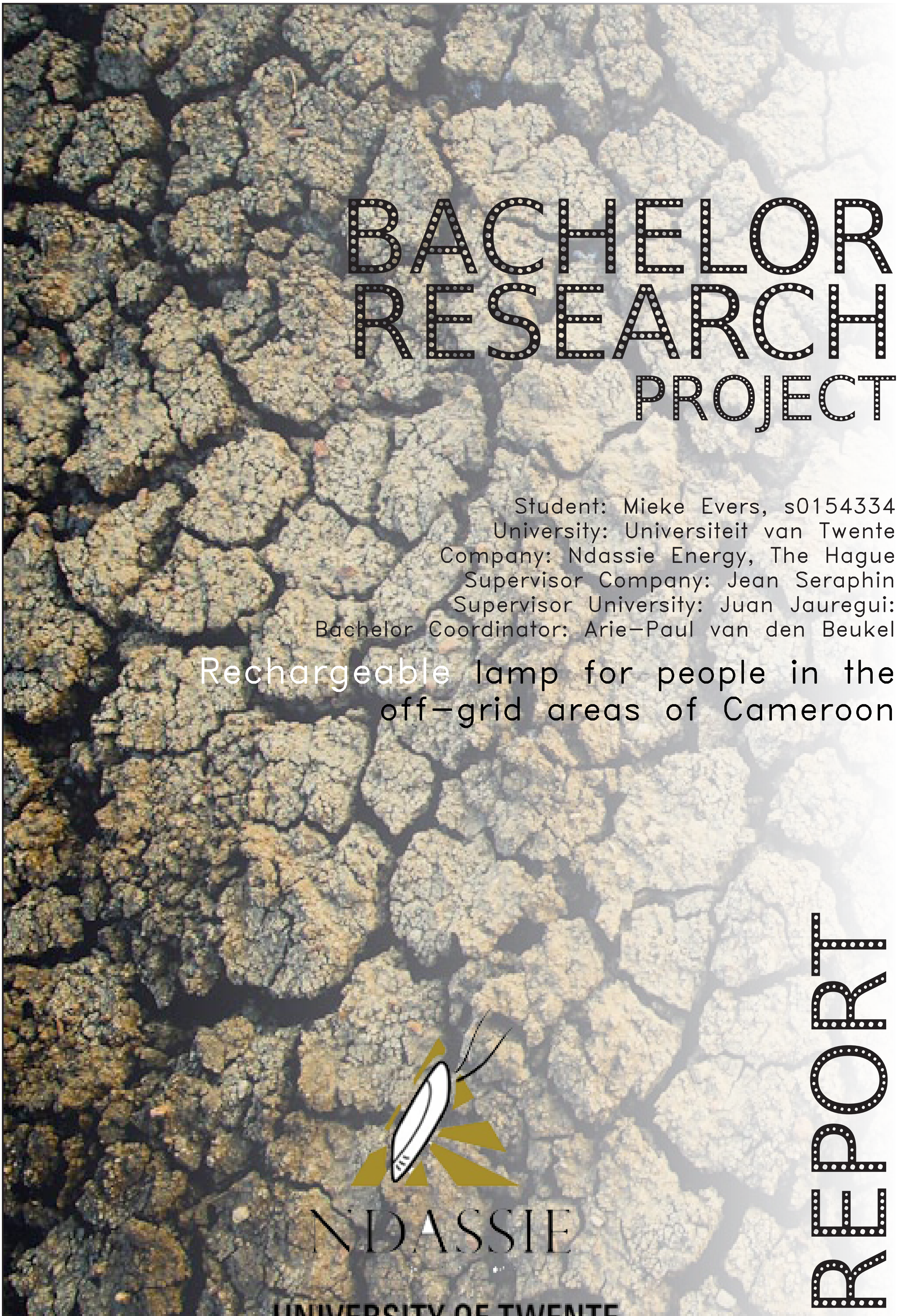


BACHELOR RESEARCH PROJECT

Student: Mieke Evers, s0154334
University: Universiteit van Twente
Company: Ndassie Energy, The Hague
Supervisor Company: Jean Seraphin
Supervisor University: Juan Jauregui:
Bachelor Coordinator: Arie-Paul van den Beukel

Rechargeable lamp for people in the off-grid areas of Cameroon

NDASSIE

UNIVERSITY OF TWENTE.

REPORT

PREFACE

This report describes the process and results of my Bachelor Research project: "The design and manufacturability of a solar powered portable lamp for people of the Bottom of the Pyramid (BOP) living in the off-grid communities in Cameroon", executed on behalf of Ndassie Energy. This project was conducted at Ndassie's office in The Hague, within a period of 3 months.

I would like to thank Juan Jauregui for the advise he gave me throughout the project. Even though it took me a long time to finish this project, he was still willing to examine my work and I thank him for that. I would also like to thank Arie-Paul van de Beukel to have faith in me as he was willing to give me a last chance in completing this Bachelor Project.

I would like to thank Jean Seraphin, for giving me the chance to work on this project. Although the collaboration has not always been as I would have liked, I learned a lot from him. Especially from his culture and entrepreneurship. Also thanks to Mei, Percy and Gracy who were Chinese interns working on the same project.

At last I would like to thank my family and boyfriend, for having faith in me and helping me out during difficult periods.

EXECUTIVE SUMMARY

This bachelor-research-project describes the design process of a chargable lamp that has been designed for the company Ndassie Energy. This lamp is part of a ”Business in a Box” product containing a Dockingstation, a solar panel, two-hundred lamps, administrative necessaries, promotion material and a Demo Kit. This product has been designed by four interns, which all design another part. My part was designing the chargable lamps that can be charged in Docking Station which can charge five times four lamps in the same time.

Ndassie Enery is a small company, situated in the Hague (Netherlands), which is just a few years old and run by Jean Seraphin. During the first phase of this project, the company was mapped out by defining the stakeholders, analyzing the business model and executing a SWOT analysis. Hereafter the project goals were determined and the project was framed.

The target group of the Ndassie lamp are the poor people of Cameroon, living on less than two dollars a day (Bottom of Pyramid) and are living in rural off-grid areas. The most important goal of this lamp is giving people light, so they don’t have to use a (dangerous and unhealthy) Kerosine lamps. By providing these people light, Ndassie hopes to contribute to the Millenium Goals.

During the analysis phase, all the information needed to design the lamp was gathered. The reports of previous interns were investigated in which the information referring to the lamp was the most important. Also some reports of interns that did a similar design project (referring to the BOP market) for different companies were examined.

To design an unique and successful product, it was important to do a market research in similar (subsitite) products and other possible solutions.

The decision was made to firstly determine the Battery and the LED’s before considering concepts. This was done, because these two components are restrictive to the design of the lamp. An general research in these components has been done, where after a list of requirements has been set up and the battery and the LED’s were determined.

The next step was to set up an general list of requirements. These were put together by taking in consideration; the most important performances, the requirements of the employer and the end-user. By summing up the list, the information that was collected during the analysis phase was also used.

Eventually the choice was made to use an SLA battery with the characteristics: 6V, 5.5 Amp/h. This battery provides eight trough-hole LEDS which each radiate 76 lumen. With these parts, the three concepts were invented. The first concept has a functional design in which the most of the requirements were taken shape. The second concept was mainly a functional design, in which the focus was on producing (/manufacturing) the lamp as inexpensive as possible. The third

concept has a playful design imitating the shape of a firefly (as a Cameroonian cultural symbol for light).

The negative and positive points of each concept were weighed up against each other. In order to choose the right concept, a table has been made in which each concept for each requirement was ranked. As a result of the outcomes the first concept was chosen, as this concept meets functionality, affordability and the right appearance.

The chapter "Detailed Design" contains a morphological chart, through which the choices has been made in the execution of various functions (for example the on/off indication) and the choice of different shapes (designs) of parts (for example the shape of the bottom part). Remaining decisions that were described in this chapter were the color scheme, the graphic design of several parts and the (complete) architecture of the lamp.

The next chapter was dedicated to the Solidworks model, in which some renderings of the final result can be seen.

In deciding upon the materials that are going to be needed to manufacture several parts, the software CES was utilized. Trough a list of requirements and by defining the performances the materials was chosen.

The following chapters describes the conclusion, the recommendations and the discussion. The main conclusion of this project was that the cost-price turned out to be too expensive for the set target group. This is due to the too ambitious requirements of the employer. Suggestions to improve the lamp and make it a successful product were made in the chapter "Recommendations" (in which a distinction has been made between two different target groups).

The very last chapter describes the discussion of my findings of this Bachelor-Research Project. With a critical note I reviewed myself in what I could have done differently what would have led to a successful result.

SAMEN-VATTING

In deze bacheloropdracht is een oplaadbare lamp ontworpen voor het bedrijf Ndassie Energy. Deze lamp is onderdeel van een Business in a Box product wat onder andere een Dockingstation bevat die van energie voorzien wordt door middel van zonnepanelen. In dit dockingstation kunnen vier keer vijf lampen opgeladen worden. Het business in a box model wordt ontworpen door vier interns, waarvan ik er 1 van ben.

Het bedrijf Ndassie is een klein bedrijf, gesitueerd in Den Haag en wordt gerund door Jean Seraphin. In de eerste fase van het project is het bedrijf in kaart gebracht, waarbij gekeken is naar de stakeholders, het business model en er een SWOT analyse is gedaan. Hierna zijn de project doelen opgesteld en is er een framework opgezet.

De lamp die in deze bacheloropdracht ontworpen is, is bedoeld om arme mensen in Kameroen die leven van minder dan 2 dollar per dag (Bottom of Pyramid), die wonen in afgelegen plekken zonder electriciteit, te voorzien van licht. Hierbij is het belangrijk dat de (gevaarlijke en ongezonde) Kerosine lampen die ze op dit moment gebruiken, vervangen worden door de ontwerpen Ndassie lamp, waarmee Ndassie wil bijdragen aan de Millenium Goals.

In de analyse fase is er gezocht naar alle informatie die nodig is om de lamp te ontwerpen. Hierbij zijn o.a. de verslagen van de vorige interns bekeken, waaruit de belangrijkste (voor de lamp gerelateerde) punten gehaald. Ook zijn verslagen van studenten die een soortgelijke ontwerpopdracht hebben gedaan bij een ander bedrijf voor de BoP market bekeken. Hierbij is met name gezocht naar bruikbare informatie voor de Ndassie Lamp.

Om een uniek en succesvol product te ontwerpen, was het belangrijk dat er een marktonderzoek gedaan zou worden naar soorgelijke producten en mogelijke andere toepassingen.

In dit ontwerpproces is er voor gekozen eerst de batterij en de LED's te kiezen voordat er concepten werden bedacht. Dit omdat deze zeer bepalend zijn voor het ontwerp. Allereerst is er algemeen onderzoek gedaan naar deze twee onderdelen, waarna er een lijst van eisen is opgesteld en de batterij en de LED's zijn bepaald.

Vervolgens was het belangrijk om de algemene lijst van eisen op te stellen. Deze zijn opgesteld door onder andere te kijken naar de belangrijkste performances, de eisen van de werkgever en de eindgebruiker. Bij het opstellen van deze lijst is er ook gebruik gemaakt van de informatie dit is gewonnen uit het marktonderzoek.

De keuze voor de battery is gevallen voor een SLA battery met de specificaties 6V, 5.5 Amp/h. Deze voorzien 8 trough-hole LEDS die elk 76 lumen uitstralen. Met deze onderdelen zijn 3 concepten bedacht. Daarbij is het eerste concept een functioneel ontwerp waarbij de meeste wensen en eisen tot uiting zijn gebracht. Het tweede concept is vooral een functioneel ontwerp, waarbij de focus lag op het produceren van een zo goedkoop mogelijk product. Het derde concept

heeft een speels ontwerp in de vorm van een vuurvlieg (dit als een cultureel symbool voor licht).

In de keuze van het concept zijn de voor en nadelen tegen elkaar afgewogen. Er is ook een tabel gemaakt waarbij er voor elke eis, voor elk concept een normering is gegeven. Uiteindelijk is gekozen voor het eerste concept, gezien deze voldoet in functionaliteit, betaalbaarheid en het uiterlijk.

In het hoofdstuk "Detailed design" is er middels een morfologisch schema een keuze gemaakt in de uitvoering van verschillende functies (bijvoorbeeld de aan/uit indicatie) en de keuze van bepaalde vormen (ontwerpen) van onderdelen (bijvoorbeeld de vorm van bodem-onderdeel (bottom-part)). Overige beslissingen in dit hoofdstuk zijn de kleurkeuze, het grafisch ontwerp van een aantal onderdelen en de (complete) architectuur van de lamp.

Hierna is een hoofstuk gewijd aan het solidworks model, waarbij er een aantal renderingen en technisch tekeningen in de bijlagen zitten.

Bij de keuze voor de verschillende materialen (van de componenten die geproduceerd moeten gaan worden) is er gebruik gemaakt van het programma CES. Middels een lijst van eisen en het bepalen van de prestaties zijn de materialen gekozen.

De volgende hoofdstukken van het verslag omschrijven de stijfheidsanalyse van het "bottom-part", waarin een droptest is gedaan, de productie van de lamp waarbij alle geproduceerde ondelen gemaakt gaan worden middels spuitgieten), het assembleren en het transport van de lamp. Deze hoofdstukken omschrijven aanbevelingen, aangezien het project anders te omvangrijk zou worden.

In hoofstuk acht is een overzicht te vinden van de geschatte kosten voor de lamp. Hierbij zijn met name de directe kosten in acht genomen.

De laatste drie hoofstukken beschrijven de conclusie, aanbevelingen en de discussie. De belangrijkste conclusie is dat kostprijs van de lamp te hoog is uitgevallen om geschikt te zijn voor de BOP market. Dit komt mede door de te ambitieuze eisen die gesteld zijn door de werkgever. In het hoofdstuk dat de aanbevelingen omschrijft, zijn er verschillende suggesties gedaan om het wel een succesvol product te laten worden (waarbij onderscheid gemaakt wordt tussen twee verschillende doelgroepen). Daarnaast zijn er aanbevelingen gedaan aan Ndassie, om het een succesvoller bedrijf te maken.

In het allerlaatste hoofstuk worden mijn bevindingen van het Bachelorproject beproken. Ook is er kritisch gekeken naar wat ik beter had kunnen doen in dit project om tot een succesvol resultaat te komen.

TABLE OF CONTENT

1. INTRODUCTION

Globally, there are 2.5 billion people that live on less than 2.5 dollar a day. They are seen as the poorest social-economic people in the world; the so called "the bottom of the pyramid". These people often live in underdeveloped countries and have to rely on Kerosene-lamps to light their houses. Use of these lamps is associated with a variety of risk factors. Ndassie Energy aims to develop a safe and sustainable lighting solution for this specific target market. One of the key parts of this lighting solution is the lamp unit. The design of which is the key topic under discussion in this bachelor thesis.

1.1 Ndassie Energy, an innovative Dutch socio-development company

This assignment is carried out on behalf of Ndassie Energy (hereafter Ndassie). This social development company is situated in The Hague. The company was founded by Jean Seraphin in 2008, after he had won the ABN AMRO Entrepreneurship Summerschool. The prize consisted of professional guidance for his new enterprise and five thousand Euros of financial support. Currently, Ndassie only has a few employees and approximately five interns that design the company s lighting solution and do the fine-tuning of the business-model.

The main goal of Ndassie is to get the people that live at the so called Bottom of the Pyramid (BoP) out of the darkness and poverty. By providing a cheap and safe lighting solution for these people, Ndassie not only improves living conditions but also facilitates an environment in which people can be more productive.

Lighting solutions that are currently used in large parts of rural Cameroon are unsafe and associated with several risk factors (e.g. kerosene lamps). Firstly, due to its inherent characteristics, kerosene lamps are likely to start a fire. The kerosene lamp can simply fall over on a rough surface because of his top-heavy design. Secondly, it is dangerous to refill the lamp because fuel can be easily spilled inside the house. Finally, kerosene needs to be pure to be used safely: often people use cheaper kerosene with a small percentage of gasoline that will cause a decrease in the flash point. To illustrate the health risk: inhaling particulate-laden kerosene fumes is as toxic as smoking two cigarettes a day. It is therefore very important for many underdeveloped countries to find a safe and cheap alternative to kerosene-lamps (Ehow Health, 2012).

Ndassie recognized this problem and started to develop a product that keeps the people in rural areas out of darkness without kerosene lamps. The company specifically focuses on people who are living in rural areas of Cameroon.

Cameroon, the country where the product will be launched, is the homeland of the owner and founder of Ndassie. After a successful launch in Cameroon, the product is supposed to be introduced in other underdeveloped countries.

By providing poor people in Cameroon with Ndassie's sustainable system (lighting solution), the company wants to contribute to the Millennium Development Goals (UN, 2012), as established by the United Nations:

1. *End Poverty*

– Providing poor people in rural areas with lighting (with which they can do better business);

– Create Employment (Owning a Ndassie Docking station, manufacture employment, service of Docking station, Distribution etc.);

2. *Environmental Sustainability*

– Using Solar Energy to light up their homes and in the future provide energy through solar panels for all the houses;

3. *Health*

– Stop the use of dangerous and unhealthy kerosene lamps;

– Provide health information via the TV on each docking station.

Besides contributing to the Millennium goals, the interest of Ndassie is also to make profit. This way the company can expand its markets to other developing countries and can invest more in the development of a better and cheaper product. It is important for the company to realize a unique product that satisfies the needs of end-users.

Ndassie is currently working on the development of the sustainable lighting system, promotion material, financing and fundraising. This needs to be realized by a team of five interns and 2 employees. A group of 4 interns is employed with the design of the Ndassie lighting system. The design of the lamp is the key goal of this thesis. Mey does the final design of the docking station, Gracy is designing the Demo-kit and Percy will design the electrical circuit for the entire product.

The company has the ambition to first release their system in Cameroon and after that expand sales to other countries in Africa and the rest of the world. Customers of Ndassie are NGO's and local investors.

1.1.1 The product

Ndassie came up with a sustainable system: a solar panel that supplies a docking station (see fig 1) with electricity. This station charges portable lamps, at a central point in the village. The docking station with the solar panel will be managed by a habitant of the village. He or she will also be the one that sells the portable LED-lamps. These lamps can be used in people's home, market booth, fishing boat or anywhere the owner desires. The lamps are required to be rechargeable on the shelves of a docking station in 4 hours time and provide light for duration of 50 hours on one load (Ndassie, 2012).

1.1.2 The Business model

The business model of Ndassie is divided in two parts: the business-to-business (B2B) model and the business-to-consumer (B2C) model. Ndassie sells its products as a total package ("Business in a Box"). This package will be sold to NGO's and other (local) buyers/investors (B2B). This intermediary will resell or rent out this package to local shop owners, churches or to other public actors (B2C). A clear overview of this can be found in the appendix.

The product that Ndassie wants to offer is a "business in a box": all the necessities for a shop owner to start his own business. This box contains a solar panel, the docking station with backup-energy-supply, 200 lamps to sell, bookkeeping necessities and promotional material. If desired; extra accessories to sell (for example a universal mobile-phone-charger) can be added to the box.

The direct customer of Ndassie will be an agent, which will resell (or rent out), the boxes to the third party: the shop-owners in the rural areas. These agents can be NGO's or local buyers. Ndassie will also provide training for the agents on everything there is to know about the product and Ndassie will also train them how to educate the shop owners, technicians, end-users and on how to promote the Ndassie product.

The agent has the possibility to sell, donate or rent out the "Business in a Box". By renting the product out, the shop-owner does not have to invest a large amount of money. This lowers the barrier for local shop-owners, while the agent can still share in the profit that will be made. Eventually the shop-owner can pay-off the agent and therefore become the owner of the docking station (etc.).

Once the shop-owner owns (or hires) a docking station, he should sell the lamps to locals. Locals owning a lamp are required to go back to the shop, every time they want to charge it. The shop-owner will receive a (fixed) price for each recharge.

1.1.3 Cameroon, Ndassie's operating market

Fig 1. The flag of Cameroon

The Portuguese sailor Fernanando Poo arrived at the River Wouri in Douala in 1472. There were so many shrimps in the river on which he arrived, that he decided to call the land Rio Dos Camaroes, which means "River of shrimps" in Portuguese. The name Cameroon is derived from this word.

Cameroon in a country located in Central Africa, also referred to as the hinge of Africa. Cameroon is surrounded by Nigeria, Chad, Central African Republic, Congo, Gabon and Equatorial Guinea. The Capital is Yaounde and the surface area of the country is around 475 thousand square kilometer (comparable to the size of California or Papua New Guinea). The west coast is bounded by the gulf of Guinea. To tourists the county is known as "Africa in miniature", because it is a mixture of desert plains in the north, mountains in the central regions and tropical rain forest in the south.

The average temperature of the coastal plain ranges from 22 to 29 degrees Celsius. This region is densely forested and one of the wettest places on earth with an average annual rainfall of 1030 cm.

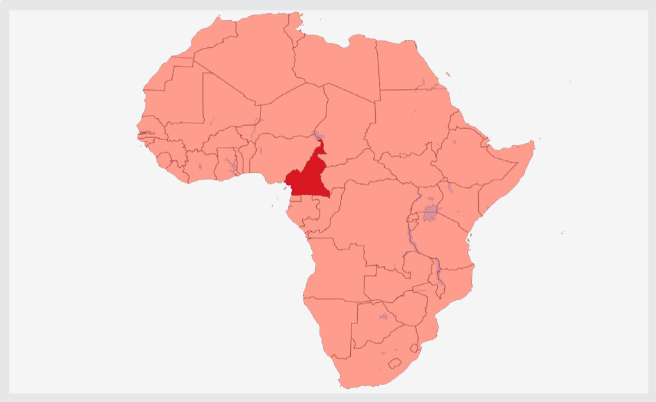


fig. 2 Location of Cameroon

The southern part has got two dry seasons from November to March and from June to August. This part is less humid than the coastal area and has an average temperature that varies from 23 to 26 degrees. The northern part contains an irregular chain of mountains and hills with the highest volcanic mountain of the west and central part of Africa. This Mount Cameroon is an active volcano and is 4100 meters high. This region has a mild climate, although the rainfall is high.

Cameroon has a population of about 18 million inhabitants comprising of over more than 250 ethnic groups speaking around 270 languages and dialects. The Republic of Cameroon became independent in 1960, after being a colony of the Germans (1884–1914) who lost the authority in World War I to the French and British (1916–1960). The county was divided into French Cameroon (northern part) and British Cameroon (southern part). In 1972, a new constitution replaced the federation with a unitary state, the United Republic of Cameroon . Cameroon has one of the highest literacy rates in Africa. On the other hand the country is hampered with one of the highest levels of corruption in the world. A significant share of Cameroon's population lives at the bottom of the pyramid.

fig. 3 Map of Cameroon

1.1.4 The Bottom of the Pyramid

People, who are very poor and often live on no more than two dollar a day, show several similar characteristics. They mostly live in rural areas or in the outskirts of big cities. Most of them are poorly integrated in the formal economy, which limits their opportunities to do business. They often sell their handcrafted products to local employers or middleman. Many of them lack access to proper health-care, electricity, water and sanitation services. If these people want to borrow money, they go to local moneylenders who ask very high interest rates. Most of them pay higher prices for basic goods and services than wealthier people do, for which they receive lower quality goods .

1.1.5 Stakeholder Analysis

Ndassie's stakeholders are actors that can affect or can be affected by the actions of the company. For the design of the lamp it is important to identify Ndassie's stakeholders and their perspectives and interest. To clearly understand the relationships between all stakeholders an overview has been made, which can be found in the Appendix. Diagram one represents a brief overview of all the key stakeholders that Ndassie has. In the second diagram (the separate stakeholders diagram in the appendix) more detailed information on stakeholders is provided. Please note that there are still a lot of sections in the diagram that are open, which will need to be filled in by Ndassie in the near future. The rectangles with a blue outline are defined, the filled in rectangles with a dark grey outline are possible stakeholders.

The stakeholders in the diagram that can directly influence the design of the lamp are the employees, interns and also financiers, as without money it is impossible to develop a product. The amount of money that is made available by the financiers affects the choice of materials, production methods and the quality of the components (to be bought) which the lamp is made off. The amount of money that can be spent on the development and production of the lamp affects the price-quality ratio. The higher the amount of lamps that will be produced, the better the price-quality ratio will be.

Besides these three stakeholder groups, the manufacturer, supplier and the assembler can also indirectly influence the design of the lamp. Other stakeholders that can indirectly influence the design of the lamp are the end-users. Research needs to be done in order to uncover the end-user's charac-

1.1.6 SWOT- analysis

Business to business

Strengths	**Weaknesses**
Keep people out of darkness and precarity	Young company with no product experience
Fair trade & sustainable business model	Production before sale (probably not enough money to finance everything from presale) = no profit certainty
CEO originates from Cameroon: knowledge of culture and local communities	Agent: NGO/investor represents Ndassie: service quality not guaranteed.
Innovative modular product	
Young small Social developing company: conceding factor	
Mock-up test on the field	
Opportunities	**Threats**
NGO can educate people via TV on docking station	Similar (competing) product earlier on market
Ndassie can get Media-attention via NGO	Improper spread by NGO/investor can lead to over demand à damage image Ndassie
Clean energy market is expanding: Ndassie can get cheaper and better Solar panels	Because of market constraint (low price) à unsustainable component (e.g. battery)
Achieve all Millennium Development Goals	

In order to better comprehend the company, a SWOT analysis of the Business to Business (B2B) model and the Business to Consumer (B2C) model has been made. It is important that the design of the lamp builds on the company's strengths and makes uses of available opportunities. The design of the lamp needs to minimize identified and anticipated weaknesses and threats, as displayed in the diagrams above and below.

Business to Costumer

Strengths	**Weaknesses**
Healthier and cheaper alternative to kerosene lamps	No control on the selling-price of the shop owner (lamp / charging) à fair-trade?
Low initial investment for shop-owner (rental option)	Shop owner may use solar panel for his private ends.
Modular product (also radio/mobile phone connector	
Shop-owner gets good service and education	
Opportunities	**Threats**
Semi- on grid communities (failure of power plant)	Competition from Power Plant (grid expansions)
Partnership with Power Plant for expansion	

1.2 Project Goals and Framework

The goal of this Bachelor-research project is to design a portable lamp (powered by a solar docking station) for people of the BoP living in an off-grid area in Cameroon. Because the lamp needs to be affordable for the people of the BoP, it needs to be easy to manufacture. This means that it is important to do research on which parts should be bought and which components should be produced by Ndassie. The lamp should be solid and of high quality, so it does not break after one drop on the ground. The environmental aspects need to be taken in account, because Ndassie wants to contribute to the Millennium-Development-Goals (as explained earlier).

This design-process will be conducted in collaboration with 3 other interns within Ndassie: Mei (graduating from the TuDelft) will make a redesign of the Docking station. Gracie will design a portable show-model of the entire system for promotion and Percy will design the electrical circuit of the Docking station, the promotion model and the lamp. All these projects are linked to each other and therefore good teamwork is needed.

Based on the context provided in the section above, we now establish the project framework for this bachelor thesis and the goals that have to be achieved. The project framework comprises the design of the portable Ndassie-lamp that can be charged on the shelves in the Ndassie-docking-station. The design of the lamp will determine the shape of the shelf on which the lamp can be (re)charged. For Ndassie, focus of the design lies on the manufacturability of the lamp and the shelves. The end-result will be a 3D-CAD-model of products, technical drawings, the bill of materials and a cost estimation: all the documents that are needed to manufacture the products.

The key domains within the project framework are:

- An analysis on previous findings of Ndassie Interns, in order to collect data to base the design of the lamp on;

- Market research on 1) existing substitute products that fulfill a similar function as the Ndassie lamp, and 2) other lighting solutions from which elements or parts might be adopted for the Ndassie lamp.

- Research on different modalities (types, models, solutions) for basic components available on the market, in order to set a range of options to pick from;

- Defining the list of requirements that determine the design of the lamp;

- Concept generation in which various components, materials and manufacturing methods are evaluated and preferred ones selected. Out of three developed concepts a final concept will be selected;

- Detailed design of the final concept will be based on the morphological chart. Detailed design will be visualized using a solidworks model;

- Based on the detailed design, options for the production, assembly and transport of the lamp will be evaluated and selected;

- Finally, a rough cost estimation will be provided based on the chosen design and corresponding method of production, assembly and transport.

2. ANALYSIS OF PREVIOUS FINDINGS

2.1 Previous findings of Ndassie interns

Ndassie has had several interns in the past that designed the business model, the docking station and a team that did research in Cameroon to better comprehend the needs of the BoP people in Cameroon.

2.1.1.The Solar Team

A team of five Integral Design Master students investigated in Cameroon whether the idea of Jean Seraphin (Ndassie would have a chance. First they did research in the Netherlands on Cameroon and the Ndassie product. Afterwards they went to Cameroon do field research and feasibility studies.

Although they researched both lamp as well as the docking station, their design focused mainly on the docking station. The team went to the birthplace of Jean in Cameroon which is ruled like a "kingdom". Every village has its own king. The students used this political model as inspiration for their design of the Docking station. Their project resulted in a mock-up docking station (Figure 1), which was inspired by a crown and was presented to Ndassie in June 2009.

fig. 4 Design by the Solar Team

2.1.2. Business Model: August Eckhardt

The first graduation project at Ndassie was done by a Strategic-Product-Design-Master-student August Eckhardt. His graduation project was to design a business model for Ndassie.

One off his first findings was that he had the idea that a micro credit could support users in coming up with the high investment of a solar product. With this micro credit, a local entrepreneur would get the opportunity to buy the "business in a box model" from Ndassie and start his own business with all the necessities. It will also provide him/her with all the promotional and administrative materials he/she needs to start his own business. Inhabitants will have less cost for sustainable lighting, because they don't have to purchase their own solar panel. Besides the income earned by selling all the lamps to locals, the entrepreneur will also earn his/her money by having people pay for (re)charges . The recharging should be cheaper than refilling a Kerosene lamp.

In his research of the end-user August Eckhardt found that besides the great need for light, the population also uses energy for their radios and mobile phones. The option to charge this equipment should be integrated in the design of the lamp. It is also very important that the design of the lamp adapts to the culture of the local community. For example the design of the lamp could be inspired by fire-flies, as locals have positive associations with these insects.

By calculations on costs and revenues August proofed that Ndassie could offer the end-user a financial advantage of 10-30 % by replacing the kerosene light by the Ndassie-lamp. If Ndassie would also provide the energy for radios and mobile phones, which are currently running on expensive dry cell batteries, the advantage should be 50 %.

There are several reasons why business hasnot yet seized the commercial opportunities at the BoP: corruption, poor infrastructure, non-existent distribution channels, and illiteracy, lack of robust and enforceable legal frameworks, religious or racial conflict, etc (Anderson and Billou 2007).

Companies that want to serve the poor and want to be successful, have to integrate the four A's:

- Availability - the extent to which customers are able to readily acquire and use a product or service;
- Affordability: the degree to which a firm's goods or services are affordable to the BOP costumers;
- Acceptability - the extent to which consumers and others in the value chain are willing to consume, distribute or sell a product or service;
- Awareness - the degree to which costumers are aware of a product or service.

The end result of August was a B2C (Business to Costumer) and a B2B model (Business to Business model)

2.1.3. Design of the Docking Station: Igor Schouten

Igor Schouten is a master student from the University of Delft, graduated in Integrated Product Design at Ndassie. His graduation project at Ndassie was to design the docking station. He went to the birth village of Jean in Cameroon to test his prototype.

Interesting findings of the BoP market

BoP lighting solutions can be divided into several categories: Traditional (kerosene) lighting, portable lamps with centralized energy supply, (Solar) Portable lamps with privatized energy supply, lamps with non-rechargeable energy supply and Home Solar Systems.

None of the conventional sustainable systems have a significant market share compared to the traditional kerosene lamps and torches. Several projects have aimed at creating solar Home Systems for BoP. For example projects done at Kamworks in Cambodia.

BoP consumers spend up to one third of their income on energy. A Kerosene lamp in Cameroon has a retail price of around 10-14 USD, adding 3 USD per month to refill the lamp with kerosene. Solar Home Systems cost between USD 100-500.

Igor designed a Docking-station in which all the villagers share 1 solar powered Charging station, instead of all having their own. The advantage of this is that the end-user does not need to buy his own solar-panel, which results in a lower initial investment. A communal solar panel also reduces the price to recharge the lamps. Normally, the people from the BoP who use Kerosene lamps need to refill there lamps once a week. Charging the Ndassie lamp in a centralized docking station will be a similar ritual as refilling the Kerosene lamps. Another great advantage of owning a docking station is that it creates jobs. The maintenance of the system will be conducted by the educated owner of the docking station, which also provides security. The owner of the docking station can give direct consumer support service.

A disadvantage of a centralized docking station, is that is gives no direct reason to improve the electricity-access for every habitant. They still have

fig. 5. The Docking station design of Igor Schouten

to walk a long distance to recharge their lamp. Besides that, there is a risk if the docking station owner decides to stop his business. The customer then cannot recharge its lamps. Ndassie aims for 10 days of operation per lamp (10 times 2,5 hour a day: 25 hours on maximum mode) and the Dockingstation can charge 20 lamps per day. Another risk is the capacity of the docking station: it can only charge a certain amount of lamps related to the amount of sunlight available.

The Docking station should be able to collect 600Wh per day under maximum load. A 150WP should be sufficient to supply the required amount of energy. The maximum current coming from a 150 Wp solar panel is 12,5 A. This value is theoretical, and above 10 A is considered to be acceptable.

2.1.4. Interesting Findings from BbiT Workshop from IPO HRO students

During the workshop Better Business in Technology IPO students from the HRO got the assignment to look for solutions for Ndassie: to make a design/adjustment for the Ndassie-Firefly Ledlamp. By participating in several interactive workshops they worked in groups and presented their solution in a report and a presentation. I have looked at the reports and gave them some comments on their ideas.

The first group came up with the idea, to replace the Lamp (which includes a battery) by a big battery with plug-sockets on which the people in Cameroon can provide all their machines with energy.

The second group came up with an idea how to reach the people in the rural areas and let them be introduced by the fire-fly lamp of Ndassie. The group focused their attention on the people in Cameroon living in the bigger cities. They are informed about the product of Ndassie through internet (facebook for example) and spread their knowledge via family and traders to rural areas.

To raise more money for the project, the group came up with the idea to launch a product for children in industrialized counties. The product is made for children who are afraid in the dark. They can put the glow-in-the-dark firefly on their ceiling so that they have safe light of their room. The packaging shows information about the Ndassie project and teaches children that light is important and a necessity for people. The profit of the product goes to Ndassie.

The third group looked at the European market to raise money for Ndassie. Their idea is for Ndassie to collaborate with a LED-producer that sells his products in Europe. On every LED-lamp sold, 50 cent will be donated by the company and 50 cent will be donated by the costumer. On the package a code is mentioned with which they can log in on the Ndassie website. There they can choose a village where they want to donate the 50 cent to. The customer and the company contribute in the social development goals of Ndassie.

fig. 6. Marketing Idea from the third group

Another group came up with the idea to improve the lead time of the lamps. The costumer goes to the docking station with his empty lamp and changes it by a fully charged lamp. In that way he does not have to wait for a few hours, or come back later.

The last group advised Jean to work with social media. Through people in Cameroon that live in bigger cities (that use social media) and have contact with people that are living in the rural areas, Ndassie can get information about their needs. This way the design of the lamp can match those needs.

2.2 Interesting findings from other BoP-lighting-projects

Unfortunately, I did not have the opportunity to go to Cameroon to investigate the requirements of the end-user. One of the possibilities to understand the needs of the end-user, is to examine the reports of students who did a similar project and went to the respective country. In that way I will have a better understanding in how to design for the BoP and what aspects to take into account.

2.2.1.Tim Gorter: Solar LED's in Cambodia

Gorter went to Cambodia to develop an affordable lighting product for rural population for Kamworks. This product needed to have LEDs and a solar panel. In comparison to the Ndassie-product, this product is designed for individual use; each lamp has its own solar panel. During his internship his research gradually focused more and more on the search for the ideal LED and the estimation of the costs for the owner. He executed a field research in which he performed a questionnaire with 21 households.

The list contained questions that were oriented towards the use of light. For example: Which light source do they currently use; what sort of light has their preference; for what activities will the lamp be used?

The major results with regarding to his questionnaire were:

- People want uniform lighting;
- People want white light;
- People use light mainly for dinner;
- People want to mount the light on the ceiling;
- Kerosene-light, candles, led lanterns, led flashlights, and self-made fluorescent tubes are currently used.

Gorter made a chart in which he compares the TCO (Total cost of ownership: all the cost of a product or service from purchase to operating and disposal) for different lighting methods. The carts present the cost of lighting per 1000-lumen hours.

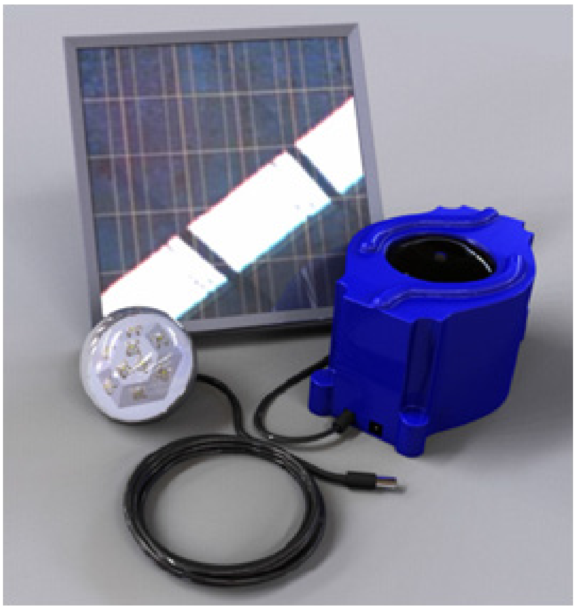


fig. 6. The end result of Tim.

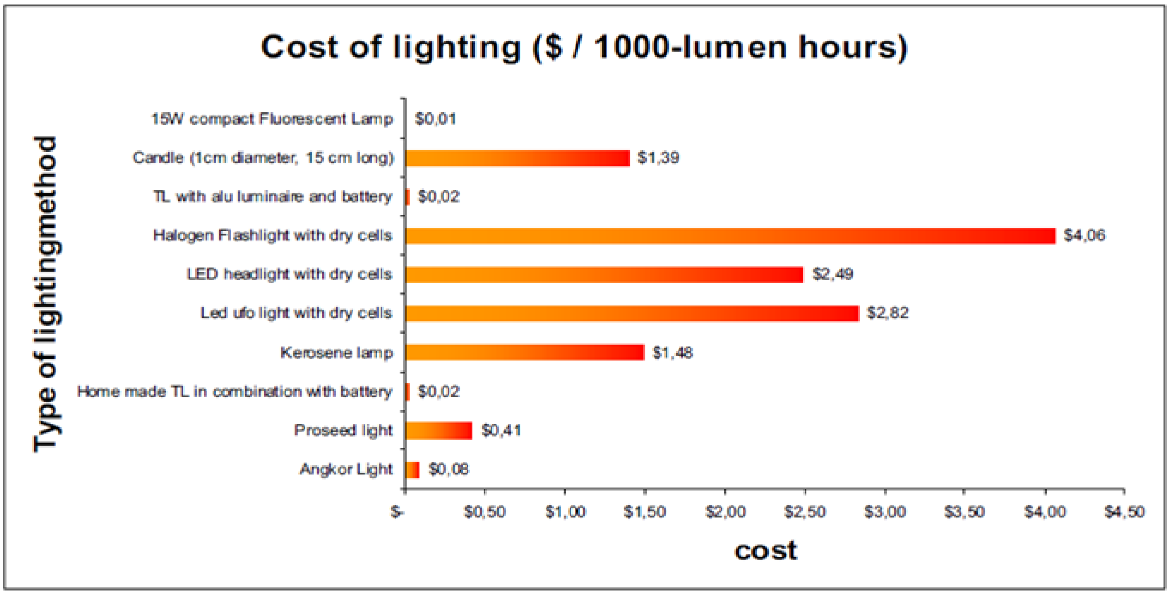


fig. 7. The Cost of Lighting graph by Igor

2.2.2. Steven Boom: Affordable lighting for people living in rural areas of Cambodia

The goal of Steven Boom, was to design a solar powered lighting product for the market of Cambodia. He did this in collaboration with Ecofys, Kamworks and TuDelft. Prior to the product development, he carried out a field research covering both the qualitative and quantitative aspects of the lighting needs of the end-user.

One part of his field- research was an interview in which he asked rural people their opinion of several available lighting products, which he showed by pictures of the products. People were asked to indicate which lighting product they liked and why. In general most respondents based their choice on functional reasons instead of aesthetic reasons. Products with common materials (like bamboo in Cambodia) were associated with poorness and dislike. Locals preferred modern plastic because they associate it with western quality.

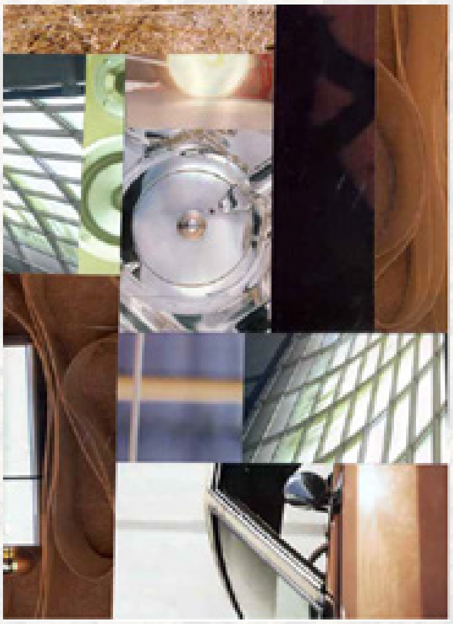


fig. 8. Moodboard by Steven

In the usage of the lamp, locals find it important that the light is evenly distributed. The lamp should be compact, light-weight and easy to handle. Furthermore the product should be able to hang from the ceiling and one should be able to walk with it.

Steven made a mood board to give an impression of what he thinks Cambodian people would like to see in the product. He thinks that they prefer massive, solid, round and geometric shapes in combination with transparent light materials.

Other requirements of the lighting product are:

- It should be able to stand on a rough underground like stones, mud or sand;

- The minimum illumination level should be at least 20 lux at a distance of 1 meter;

- Irreplaceable components should still function after a fall of 50 cm.

fig. 9. Pictures that are used during Field-research

2.2.3. Marcel Heist: Creating Rural Energy in India

Marcel Heist went to India twice to investigate and explore the energy situation of rural India. His approach in this research was very similar to the reflective transformative design process by

Hummels & Frens, which is not a linear process but rather a loop of iterations.

His assignment was to design a rural distributed energy network, in which the approach was very open. His observations in both rural and urban areas on small scale were based on four themes: local entrepreneurship, how people spend the day and how the villages interact with energy. He wanted to find out what the position of people in rural India is towards energy and their vision on how this might evolve. A co-reflection session with 9 participants and a brainstorm about energy with 20 participants was executed. He also consulted and interviewed a lot of people for their advice.

After this observations he came to realize that they indeed have needs to develop their own energy network. With his designer skills he wanted to design a product that could easily be fabricated by the local people. His idea was to build a lamp which can be charged by a solar panel and made with components bought in a nearby shop. A manual was designed to explain how to build the lamp.

Eventually he managed to design and build a business in a box which contains 10 lamps, a PV-solar panel and a buffer for just INR 6.767 (104 euro) .

fig. 10. Manual on how to build the lamp, made by Marcel

3. MARKET-RESEARCH

3.1 Market research on substitute products and other lighting solutions

When designing a new product, it is important to know which comparable products are already available on the market. By investigating the market it is possible to discover a unique window of opportunity. Components of several products can be copied and put together and therefore create a new product. New ideas can be generated by looking at products that do not directly have the same function (and therefore not a similar product). In this way "out of the box" ideas can be created. For example possible applications, components, materials, manufacturing-methods for the Ndassie-lamp can be considered. The market research is divided in 2 parts and can be found in the appendix. In the first part the comparable products were investigated and in the second part the non-comparable products.

The products in the first table (Appendix 3) are comparable to the Ndassie-product, under the condition that the product is a lighting device which can be charged by (or contains) a solar panel and that it can be used by rural people. The technical specifications and the price of the product were written down in the first column of the table. A picture of the product was added in the second colomn.

The second table presents products that are "non-comparable products". That means that the products does not have the same direct function as a portable solar lamp. All the products have something to do with lighting, but for different purposes.

Hereafter a first attempt was made in drawing up the list of requirements and wishes for the Ndassie-lamp. These requirements could now be compared with the products of the market research. In the first table (the "comparable products") there were three extra columns added: in the third column an enumeration was made of the equal aspects of the researched product and the Ndassie product. The advantages and disadvantages regarding to the Ndassie-lamp were described in the last two columns. The second table (the "non comparable"products) has the following colomns (in order): product, picture, differences/description, advantages to the Ndassie Product, features that can be used in the Ndassie Design.

For this research the advantages of the product to the Ndassie lamp were the most interesting. The advantages of the "comparable products" that can be taken into consideration for designing the concepts were:

- Sunny side up: simple and modern design. Has a build in solar panel that can be charged by sticking the product to the window.

- Solar Lantern: can be charged trough a communal solar panel (just as the Ndassie Lamp), but also has the option to be charged by a small solar panel for individual use.

– LuminAID: an inspiring product that can be folded into a very small package and can therefore be easily transported.

– Waka Waka light: succesfull dutch BOP product that has great marketing and is suitable as a reading light.

–IKEA Solvinden line: this lamp is powered by sun and wind (trough the blades on the lamp).

– N200 Solar Light: automatically switches off in bright light.

The advantages of the "non comparable" products:

– Bicycle Led Lamp: easy click system

– Headlight Moon: Bandage head system

– Iphone docking system: additional docking system with phone–charger and radio

– Majiscup: made of ecofriendly material

These qualities are great in developing "out of the box" idea's, but the most of them are not suitable for the Ndassie lamp, as many requirements has to be taken into consideration. The ones that are usefull are underlined.

3.2 Market research on the available basic components

The two components which predetermine the design of the lamp are the battery and the light source. One of the reasons is that the sizes of the batteries vary a lot. A SLA battery is much bigger than Li–ion. Also, the choice of which LED and how many LED's are used in the design are decisive. That is why the decision was made to choose the battery and the LED (and how many) before designing and choosing a concept.

3.2.1 The LED's

A LED can convert electrical energy into light energy. LED's offer a long service life and are high energy efficient, but initial costs are higher than those of fluorescent and incandescent lamps. The main functional part of LED is a semi–conductor chip. Like a normal diode, the current flows from the p–side to the n–side. When an electron meets a hole it falls into a lower energy level, and releases energy in the form of a photon. This is the principle of light emitting. The wavelength of the light emitted depends on the material forming the P–N Junction.

Regardless of type, color, size, or power, all LEDs work best when driven with a constant current. LED manufacturers specify the characteristics (such as lumens, beam pattern, color) of their devices at a specified forward current (IF), not at a specific forward voltage (VF). With an array of LEDs, the main challenge is to ensure every LED in the array is driven with the same current. Placing all the LEDs in a series string ensures that exactly the same current flows through each device. (National Semiconductor, 2011) If in parallel, every LED should be connected with a resistor whose resistance is much more than LED's, and the losses on

fig. 11. Wick lamp

resistors will be very high. If in parallel, every LED should be connected with a resistor whose resistance is much more than LED s, and the losses on resistors will be very high.

How much lumen is needed?

Lumens are a measure of the perceived power of light (the light that you can see). Waves of light that are beyond the spectrum visible to the human eye are not included in the lumen.

There are several types of kerosene lamps that people in rural areas in Cameroon use today. The poorest people in Cameroon use wick kerosene lamps which emits only 10 lumen a piece. The wick lamp has a life expectancy of a half year, if it is lighted for 4 hours a day.

The hurricane Kerosene lamp is the traditional lamp in Cameroon. It emits 30 lumen and the wick life is 2 years (if it is burned for 4 hours a day).

fig. 12. Kerosene lamp

The amount of lumen that the kerosene lamps produce is not enough for children to study with, or for mother to cook the food in a hygienic way. With brighter light, people will be more productive in studying and running their business. In the Netherlands there are lighting standards (NEN – EN 12464–1) with which the design of lighting-installations in workplaces has to comply.

Nature of the lighting	Type of space	Standard lighting performance (lux)
Orientation lighting	Storage rooms, parking lots, hotel entrees, elevators, bathrooms, lobbies, lounges.	50 to 100 100 to 200
Work lighting	Living rooms, fairs, exhibitions, **offices, class rooms, kitchens,** installation spaces, supermarkets, drawing rooms	200 to 375 **400 to 750** 800 to 1500
Specialty work lighting	Precision engineering with fine details, inspection rooms, operation rooms	1600 to 3000 3200 to 6000

fig. 13. NEN Lighting Standards

Now that it is clear how much light approximately is needed, it is useful to know how much lumen several regular "house" lamps generally emit:

Type of lamp	Lumen per Watt
The old-fashioned incandescent lamp	around 15 lumen per Watt
Halogen lamp	around 20 lumen per Watt
Modern CFL (15W)	55-60 lumen per Watt
Fluorescent lamp	around 50 -100 lumen per Watt

fig. 14. Lumen per lamp

Assuming a room in a rural area home of 12 m2 room needs a 40 watt incandescent lamp to light the room, 40*15 = around 600 lumen is needed.

On the internet there is a large quantity of LED's available to buy. In the technical specifications often the amount of micro-candela and a viewing angle is given. The formula to calculate mcd (microcandela) into lumen is:

$$I = \frac{\phi}{\omega}$$

ø = lumen

I = candela

ω = steradian in degrees

I used a website that calculates automatically the mcd and viewing angle into lumen: *http://photonics.intec.ugent.be/education/IVPV/res_handbook/v2ch24.pdf*

<u>The requirements of the LED's and Battery</u>

LED:

- the LED should have a minimum viewing angle of 90 degrees.
- the total amount of LED's should not be more than 10 LED's.
- the total price of the LED's per lamp should be less than 0.50 USD.
- the total amount of Lumen should be a minimum of 600 Lumen.
- the LED should emit white bright light.
- The LED's should not need a bigger battery than 6V 5.5 Ah
- The LED's should be adjustable onto the PCB
- maximum height of 1 cm

Battery:

- the battery should not be toxic
- Maximum voltage is 6V
- Maximum dimensions are: 75 mm wide, 50 mm high and 120 mm long
- Minimum capacity of the battery should be bigger than 4 Ah
- Maximum discharge rate of 60 percent after 1 year.
- Maximum price is 3 USD a piece.
- Rechargeable in the Docking-station within 5 hours.

<u>Different type of LED's:</u>

<u>Through whole LED:</u>

- Used for many decades in various applications. Fairly recently, started to be used in lighting
- Affordable Limited light- output
- Most common used LED
- Low price
- High temperature performance
- Low power consumption
- High reliability
- Broad range of shapes, colors and packages

fig. 15. Through Hole LED

Example: High Power 8mm LED Diode

73.6 lumens @ 20 mA, price:

€ 0,035

To emit 600 lumens of light: 8 LED's are needed (72.6 * 8 =): 589 lumen at a price of (8 * 0,035) =

€ 0,28.

Miniature LED's:

- Mostly used as indicator light in cell phones and calculators

- Very small: less than 3 mm in diameter, available from 1.5 to 3 mm.

- Low current

- Standard and ultrahigh output

fig. 16. Miniature LED

Example: Kingbright LED Transparent 3mm L-1334YT

0.009 lumens @ 20mA, price: £0.067

To emit 600 lumen of light: you need 667 LED's = 600 lumen at a price of £44666,70

High Power LEDs

(HPLED / Solid state lights) (Surface Mounted Device-technique (SMD))

- Produces strong light (1W): danger of overheating is high.

- Because of the heat, it must be mounted on heat-sink and/or thermal isolation sheet (which brings extra costs).

- Expensive

- Energy efficient

- exceptionally long life

fig. 17. HP Light

Example: Neutral White (4100K) Luxeon Rebel LED (Philips)

145 lm @ 700 mA, price: $4.69

To emit 600 lumen of light: 4 LED's (145 * 4) are needed = 580 lumen at a price of $18,76 .

Super Flux LED's

-Rectangular package of LED with 4 pins

-When based on PCB, it emits maximum lightless with less power cost than other transitional LED's.

-Low thermal resistance: temperature junction is 50 % less than traditional LED's.

fig. 18. Super FLux LED

-Mostly used in large panels (for example billboards)

- Designed for maximum light emission

- Viewing angle from 40 to 120 degrees

Example: 3mm SuperFlux LED 75° 5000mcd Wit

(4500 mcd) 6.5 lm @ 20 mA, price:E 0,29

Emit 600 lumen of light: you need around 92 LED's = 598 lumen at a price of 26,68 euro .

The choice of the LED

The choice of the LEDs (and the amount) is related to which battery is needed to provide these LEDs with energy. One of the requirements that was set from the beginning, is that the lamp should emit light for at least 25 hours in the highest setting, or 50 hours in the medium mode.

After evaluating the information about the different types of LED's (in which the aspects price, amount of lumen and amount of LED's are considered) there were two types of LED's that had the best specifications: the high power LED and the trough-hole LED.

The prices of LEDs were not easy to find on the internet. The technical specifications were also often incomplete. That is why the price-inquiries and the technical specifications had to be asked to the concerning companies. That took a lot of time because they don not respond immediately. In the appendix a table can be found in which 21 LEDS are compared in the following aspects: type LED, lumen, amount of LEDs to emit 600 lumen, price per LED and the total price.

Eventually the two LEDs were chosen which had a reasonable amount of LEDs (max 10) and the lowest total price. The amount of mAh (energy needed to emit the LEDs for 25 hours) had to be calculated to determine whether it was possible to charge these LEDs with a regular SLA or Li-ion battery:

Choice 1 High Power LED:

1w high power led with heatsink 140 , 105 lumen @ 350mA

6 * 105 lumen = 630 lumen

Max forward current = 350mA, 6 pieces (6*350) = 2100mA

Watt = V * A = 3.8 * 2.1 = 7,89 Watt

Minimum hours on maximum power = 25 hours

25* 2100mA = 52500 mAh battery (MUCH TO BIG!)

6 High power LED's are too heavy for Li-ion or SLA battery that suits the budget.

Choice 2 Trough hole LED:

Super Brightness Flat Top LED 90 degrees, 73,6 lumen @ 20 mA

The maximum average voltage trough the LED: 3.1V

The Power needed for 8 LED's: 20mA*3.1V*10=0.496W

Requirement is that the lamp should emit light for 50 hours on medium mode, or 25 hours on maximum mode-->

Energy for maximum mode= 0,496W*25h=12.4W/h

Estimated efficiency of the LED driving Circuit: 85 % --> 12.4W/h*0.85=10.54 Wh

Estimated discharge rate of battery: 50%

Energy of the battery: 10.54/0.5=21.08Wh

Voltage of the Battery: 6V

Minimum capacity needed from battery: 21.08Wh/6V= 3.5 Ah

8 * 73,6 lumen = 588.8 lumen

Super Brightness Flat Top LED 90 degrees, 73,6 lumen @ 20 mA

Max forward current = 20 mA, 8 pieces (8*20) = 160 mA = 0.16 A

Watt = V * A = 3.6 * 0,16 = 0.58 Watt

Minimum hours on max power= 25 hours

25 * 160mA = 4000 mAh battery

which Possible for an affordable SLA or Li-ion battery.

3.2.2 The batteries

There are four main types of rechargeable batteries that are available on the market: batteries based on the next combination of chemicals: Nickel-Cadmium (NiCd), Lithium ions (an anode, cathode + electrolyt), lead-acid (PbO _2 + HSO _4) and Nickel Metal hydride (NiMH) batteries.

Li-ion battery

In this Li-ion battery, the lithium ions move from the negative electrode to the positive electrode when it is charged (this happens when the battery is charging). When it is discharged, the ions move the opposite. There are different types of positive and negative electrodes. For example a positive electrode material can be LiCoO2 or LiMn2O4 with different specific capacity/energy and average potential difference. These characteristics also differ in the negative electrodes materials, which can be for example Graphite or Hard Carbon. The anode (negative electrode), cathode (positive electrode) and the electrolyte as the conductor, are packed in cells. The other components of the battery are: the PC board, external contacts, insulation and the outside plastic enclosure.

When the battery is charging the positive ions (cathode) move via the electrolyte to the negative ions (anode) as can be seen in figure 4. When discharging, the anode undergoes oxidation or loss of electrons and the negative ions move to the positive side. Li-ion batteries come in many varieties: Lithium Cobalt Oxide, Lithium Manganese Oxide, Lithium Iron Phosphate, Lithium Nickel Manganese Cobalt, Lithium Nickel Cobalt Aluminum Oxide (or NCA).

The advantage of the Li-ion battery is that the cycle life is longer than the other batteries (1000-1200 cycles). It also provides the largest energy density per weight and is a low maintenance battery because it does not have a memory. There is no periodic discharge needed and it has a relatively low self-discharge.

A big disadvantage is that there a certain regulations for transporting the batteries in big quantities. Other big disadvantages are that the Li-ion is still more expensive than the other batteries and the battery needs an extra protection in the circuit (extra cost of 1 USD) to limit the voltage and the current, otherwise it will explode .

Multiple Li-ion batteries can be packed in parallel or in series in a battery pack. Connected in series, there should not be too many cells, otherwise the performance will be decreased. Placing the cells in parallel is the only option to have a higher Ah rating. The voltage differs from 3.6V to 4.2V.

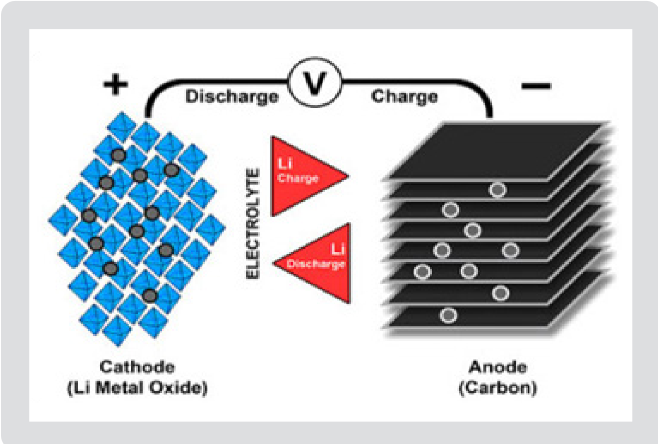


fig. 19. The way a Li-ion functions

Lead Acid battery

The lead-acid battery was the first rechargeable battery invented in 1859 by Gaston Planté. There can be a dozen of cells in each lead acid battery. Each cell has a nominal cell potential of 2.0 Volt. In each cell there a two solid bars that present the two electrodes: the negative pure Lead (Pb) and a bar of positive Lead Dioxide (PbO2), standing in the liquid Sulfuric Acid (H2SO4) which is mixes with water. The chemical reaction of discharging the battery is: $Pb(s) + PbO_2(s) + 2H_2SO_4(aq) \quad 2PbSO_4(s) + 2H_2O(l)$.

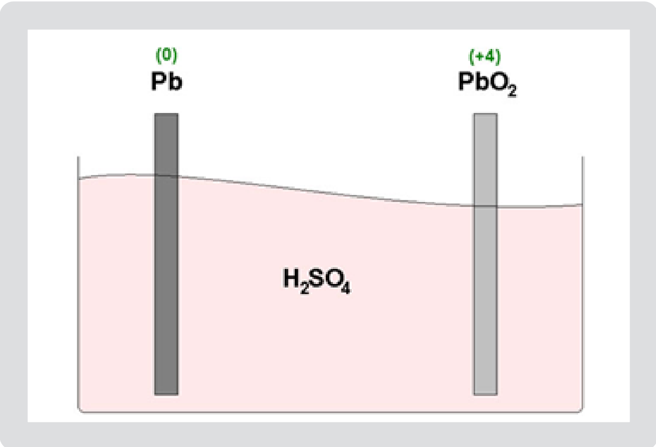


fig. 20. The way a LEAD ACID battery works

There are several types of lead acid batteries, including the Sealed Lead Acid (SLA), True Deep-Cycle batteries, Lead-Calcium and the unsealed lead acid "car battery".

Because the lamp is going to be a portable product the only possible lead acid battery is the Sealed Lead Acid (SLA) Battery. This maintenance-free battery, can be put in any angle, has no memory and the cells are carefully sealed. The most commonly used SLA's are: the VRLA (Valve-regulated lead acid) and the AGM (absorbent glass may) battery) which contains gels.

The VRLA is a regular lead acid battery. These batteries have a pressure relief valve which protects the battery from overcharging: the valve will be activated when the battery is recharged with a higher voltage than 2.30 volts per cell. They are often used as a back-up battery.

The AGM is contains gel (looks like petroleum jelly) instead of a liquid acid. The gel is trapped together in a sponge-like matted glass fiber separator material. The gel protects the plates during heavy discharging.

A big advantage of the SLA is that it is a dependable and cost-efficient battery in terms of cost per watt hour. It is a mature product, so the technology is well understood. Another advantage is that it has a large overcharge tolerance and a low self discharge: the low over-voltage potential prohibits the battery from reaching its gas-generating potential during charge. Consequently, it can never be charged to their full potential.

The disadvantage of a SLA is that it is always big, heavy and bulky and cannot be stores in a discharged condition. The cycle life is much shorter than of a Li-ion and the energy density is also much lower. Besides that the product the lead and electrolyte of the battery can cause environmental problems .

NickelCadmium

A NiCd battery contains Nickel (Ni) and Cadmium (Cd) and available in sealed and vented cells. The sealed Ni-Cd cells can be used individually or in packages of two or more cells. They can be produced in a cylinder shape or a button shape. It usually has a metal case with a sealing negative and positive plate equipped with a self sealing safety valve. The plates are rolled together in a "jelly roll' shape, isolated from each other by the separator. The reaction during discharging is $2NiO(OH) + Cd + 2H_2O \quad 2Ni(OH)_2 + Cd(OH)_2$. The nominal potential of a single cell is 1.2 Volt .

The advantages of the NiCd battery is that it is simple to charge, it delivers good performance, difficult to damage and it can be stored in a discharged state. The NiCd battery comes in a wide range of sizes (from AAA trough D) and performances, so it gives a design freedom.

The biggest disadvantage is that cadmium is a toxic material and cannot be disposed. That makes it a very environmental unfriendly material. Nickel and Cadmium are also more expensive than lead and acid, which makes the product more expensive than the SLA. Another disadvantage is the temperature coefficient. It has a negative temperature coefficient: as the temperature in the cell rises the internal resistance falls, which can cause charging problems.

Nickel-Metal-Hydrid

NiMh batteries are very common in the AA rechargeable batteries, operating at 1.2 V per cell. The NiMh is similar to the NiCd battery and is his biggest competitor. The NiMh is newer than the NiCd; it is less toxic and has higher capacity. The energy density approaches that of a lithion-ion battery. Nevertheless the biggest disadvantage of the NiMh battery is that it has a high self-discharge rate: in storage it loses 20 % on the first day and another 4 % in the first week. The battery is known as the practical application of a nickel hydrogen battery, because it uses hydrogen-absorbing alloy as a negative electrode.

The processing and mining of the various metals can be destructive to the environment. It is important that this happens in a environmental friendly way. The Nickel in the batteries are mostly recycled.

Comparing the batteries.

The information of the batteries had to be summarized in a table to get a clear overview for an easy comparison of the characteristics. In this table the positive aspects got a green frame and the negative a red frame. The aspects that were most important in the choice of the battery, were the fast charging time(estimation of the time to fully charge the battery) and the estimated price. Other aspects that were taken into account were: the energy by volume (the size),the self-discharge rate (the percentage per month in which the capacity declines), the cycle-life (how many cy-

Characteristics	Units	Li-ion battery	SLA	NiCD	NiMH
Operating Temperature	Degrees C˚	-20 to 50	20 to 50	-40 to 45	-20-50
Energy Density		Very High	Low	Medium	High
Self Discharge	% / Month	6-10	2-4	15-25	20-25
Cycle Life	Cycles	1000-1200	500-800	500-1000	500-1000
Energy by volume (Volumetric energy density)	Watt hr/ ltr	200-300	70-110	100-150	200-350
Energy by weight (gravimetric energy density)	Watt hr / kg	120-160	30-45	100-150	60-80
Average voltage per cell	Volts	3.6	2	1.2	1.2
Energy by weight	Watt hr/ kg	120-160	30-45	40-60	60-80
Storage		95	70-92	66	66
Overcharge tolerance		Very low	High	Medium	Low
		Environmental Friendly		Poisonous	

fig. 21. The Characteritics of different battery types

The most suitable battery

The NiCd battery can be rejected because it is too toxic and therefore too environmental unfriendly. The NiMh can also be rejected because of its too high self-discharge rate.

The only types of batteries that remain are the Li-ion and the SLA. The cost of the lamp should be around 7 USD, so the components need to be as cheap as possible, but still high quality. The Lion battery is almost twice as expensive as the SLA. For an acceptable quality Li-ion the price will be around 3 USD for one cell, which will make the total battery cost 7 USD (2 * 3 USD + 1 USD for the heat sink). An expectable quality SLA (5.5 Ah) will cost around 3,30 USD.

The lamp should emit 50 hours of light in a medium mode (25 hours in maximum mode) with 8 LED s, with a maximum forward current of 20 mA * 8 = 160 mA. To calculate the amount of watt, the voltage has to be multiplied by the current:

Li-ion battery Watt = V * A = 3.6V * 0,16A = 0.58 Watt.

SLA battery Watt = V * A = 6V * 0,16A = 0.96 Watt.

25 hours of light in maximum mode: 25 * 160mA = 4000 mAh battery.

In the search for the best Li-ion or SLA battery it was very difficult to find the prices (just as it was for the LEDs). A lot of companies were approached to get an inquiry for the price and specification. Just as with the LEDs, a list was made with available suitable batteries on the current market, which can be found in the appendix.

4. DEFINING THE REQUIREMENTS

4.1 Requirements of the client and end-user

The requirements from the end-user were based on the conclusions I made from the analysis phase, which are:

Price:

-The lower the price the better;

-Warranties are often not asked for;

-People think that the higher the price, the better the quality;

-Acceptable retail selling price between 8-14 USD.

The usage of the lamp:

-It should be possible to hang the lamp inside the house. The houses often have aluminum plated roofs, wood and stone walls;

-Use for studying, cooking, gathering, on a market booth, while fishing;

-The charging of the lamp should not be needed more often than once every five days.

Design of the lamp:

-Possible to hold with one hand;

-The weight should be less than 2 kg;

-Not easy to break (it should be possible to let the lamp drop from 1,5 meter high without breaking);

-The color of the lamp should not be white (= color of death);

-The red sand and dust should not be easily seen on the lamp;

-The lamp should have a standard so that it can be used to read.

Functions of the lamp:

-The Ndassie - lamp should be much brighter than a kerosene lamp: the minimum amount of lumen needed to light a workspace according to the Dutch lighting standards;

-Charge the mobile phone;

- Power the radio;
- The angle of light should be big enough to light an 12m2 room;
- Preference of white light.

Marketing aspects:

-Costumer service is important;

-Chinese products are not trusted;

-The more products a person owns, the higher the status;

-Poor people need to see the effect fast when the product is bought;

-Word-of-mouth is very important;

-It is important the salesman is known by the community: the costumer tend to trust a well-known salesman.

Jean Seraphin requirements:

-The lamp should be luxurious. Black in combination with gold is seen as luxurious colors;

-People prefer bigger products above small products. The lamp should not be too small;

-The lamp should fit in the Docking station;

-Maximum manufacturing price of 7 USD;

-The end-user should not be able to take the battery or other components out of the lamp (the risk exists that the parts are going to be used for other purposes;

-The lighting source of the lamp should be LED's

-The lamp should contain a maximum of 10 LEDs per lamp;

-4 lamps on each shelf, 5 shelves in the docking station.

4.2 Defining the performances

There are many aspects to take in consideration when designing the lamp. Therefore it is not easy to get an clear understanding of the most important characteristics. That is why a chart has been made to get a clear overview of this:

fig. 22. Chart of the Performances

4.3 List of requirements and wishes

Dimensions

According to the dimensions of the Docking station:

4 lamps on each shelf, 5 shelves in the docking station

-Maximum height of lamp: 142 mm;

-Maximum length of lamp: 316 mm;

-Maximum width of lamp: (386 /4=) 96,5 mm.

Functions

-Low / Medium / Full light- adjustment;

-Charging function for mobile phone;

-Energy function for radio;

-Display (indication) of the battery state;

-The lamp has to be able to hang;

-The lamp has to be able to stand.

Characteristics

- The light source of the lamp should be LED's

-The lamp should emit a minimum of 400 lumen, maximum 600 lumen;

-LED color: water clear white light;

-Minimum viewing angle of LED: 90 degree's;

-Viewing angle of all LEDs together must be at least 300 degrees;

-Maximum of 10 LED's in one lamp;

-A fully charged lamp (on medium power state) should emit light (on medium power) at least 50 hours ;

-Maximum weight of lamp: 2 kg;

-The charging connector of the lamp should fit with the components of the PCP of the drawer.

Battery:

-The battery should be environmental friendly;

-Rechargeable within 5 hours;

-Maximum 6V;

-Minimum 4Ah.

Design

-The lamp should have a luxurious appearance;

-The(charging) connecting part of the lamp (to the shelf)should match the PCB that is already designed;

-The colors of the company should be recognized in the design: Dark green, magenta, Fluor green, gold, white;

-Filth should not easily be seen on the lamp;

-The lamp should be easy to carry;

-Dust proof / water resistant;

-The cover of the lamp should be transparent.

Costs

-Recharging the lamp should be cheaper than refilling a Kerosene lamp (less than 3 USD a month);

-Cost of all LED's for one lamp: max 0,40 USD;

-Maximum cost price of lamp: 6 USD;

-Maximum retail selling price: between 8 and 14 USD (best for target-group with a salary of 35 USD;

-Maximum Battery costs less than 3,50 USD.

Manufacturability

-The casing should not have more 4 components that need to be produced. (as little as possible);

-The lamp should not have more than 20 components in total;

-As many components as possible should already be available on the market (buyable);

-The assembly should be done within X steps (as little proceedings as possi-ble).

Transport

-The total package of the end-product should have an as little volume as possible;

-The components of the end-product should come from one region, so eve-rything can be transported within one cargo;

-The transport-costs should not be more than X percent of the cost-price of the end-product.

5. CONCEPT GENERATION

5.1 Choosing the battery and the LED's

The most important requirement in the choice of the battery is the price (less than 3.5 USD), the time to charge the battery (maximum of 5 hours) and the right capacity to emit enough current for the LED's (minimum of 5000 mAh).

The prices of the batteries were not easy to find on the manufacturers website. For every price, quite a lot of email-conversation took place. Often the manufacturers had no price on their website, or offered different prices for different quantities. All the prices were collected in the tables found in the appendices.

Eventually after having had a lot of email-conversation, the discussion was made to go for the TELONG 6V5.5AH SLA battery. This battery had, in comparison to the rest a reasonable low price (2.99 USD a piece)and the company seemed well-trusted and has an good reputation. The characteristics can be found in the Appendix 8.

The prices of the LED s were also not easy to find. Besides that it was questionable whether the LED s emit the given amount of lumen (or the large viewing angle). It took a lot of time to get these inquiries and choose the right LED's. In the end the best two options (lowest total price and emitting 600 lumen) were the "1W high power led with heatsink" and the "Super Brightness Flat Top LED".

"The High power LED" needs a much too powerful battery to emit the 630 lumen for 25 hours on maximum mode . The "trough hole LEDs" can function with a reasonable battery and is the (relatively) cheapest option in comparison to the other LED's. The Shenzhen JinPuLi company in China can supply these LED's for 0.035 USD a piece. Every lamp would need 8 LED's, which makes the total price 0,28 USD per lamp. The exact characteristics can be found in the Appendix 6.

fig. 23. Sketches

5.3 Three Concepts

5.3.1 Concept 1

The first concept has a rounded square shape casing with the battery in the middle. This way the bottom-case does not have to be too high. The top-case is rounded and will cover the LED's + the battery. The shape is simple and easy to manufacturer.

The bottom of the case has a big hole in which you can put your fingers so you can carry the lamp to the docking station. This hole can also be used to hang the lamp on the wall. There are also 4 little holes in the bottom of the casing through which a cord can be put. By using this cord it is easy to hang the lamp around your neck or from the ceiling.

The size of the lamp is small enough to hold in one hand. The design is kept simple, so it will appeal to many people. All the buttons and wires are on one side of the lamp, to limit the width of the space needed on the shelf.

The lamp has a rectangular shape, with rounded corners. The shape is easy to pile up for transport.

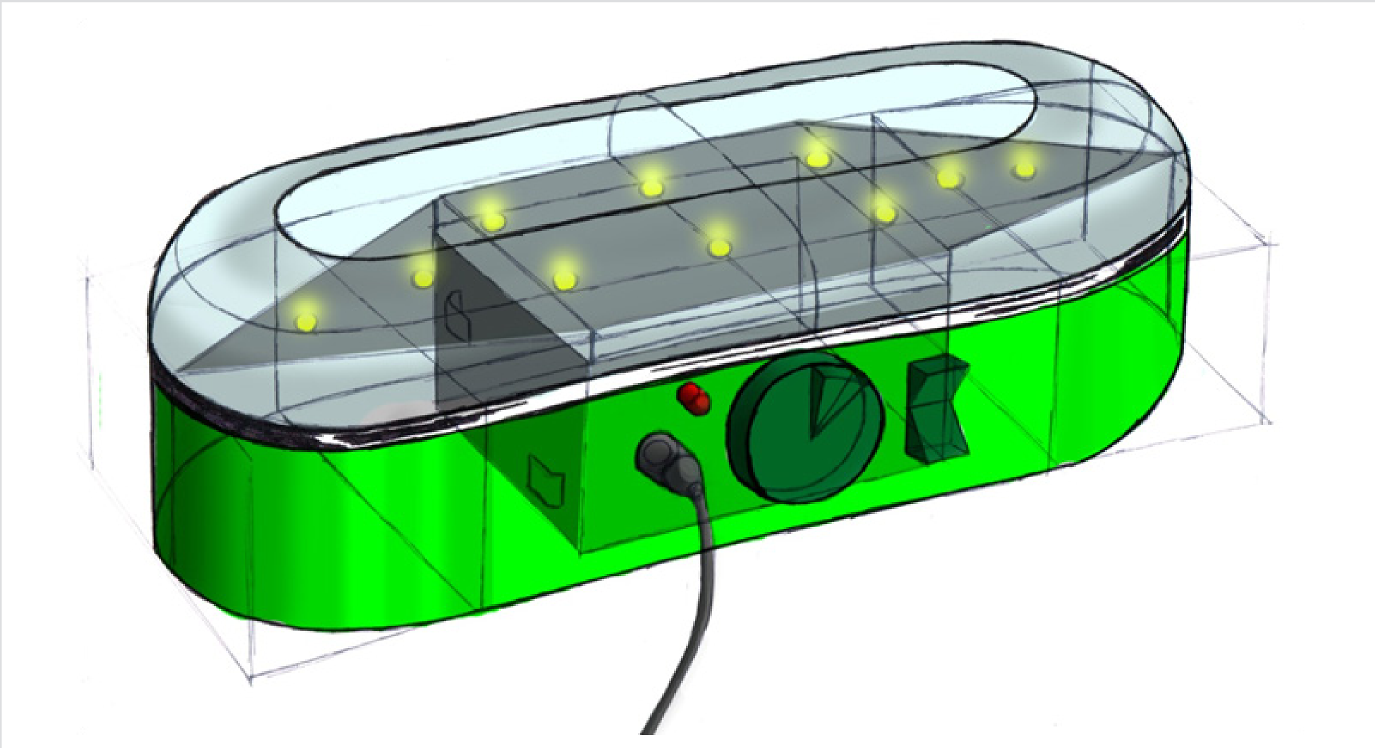


fig. 24. Concept 1

5.3.2 Concept 2

The second concept is based on the idea that the lamp should be as cheap and easy as possible to produce. That means that the lamp should have an easy shape and that is why I came up with a simple square shape. The lamp has an upper and bottom part, which are equally shaped: only one mould has to be produced and can be used for both parts. Therefore the production costs can be kept low. The middle part is connected to the bottom and the cover. On this part the buttons, USB port and possibly a signal lamp are going to be mounted. This part is made of metal and can be laser cut, bended and welded.

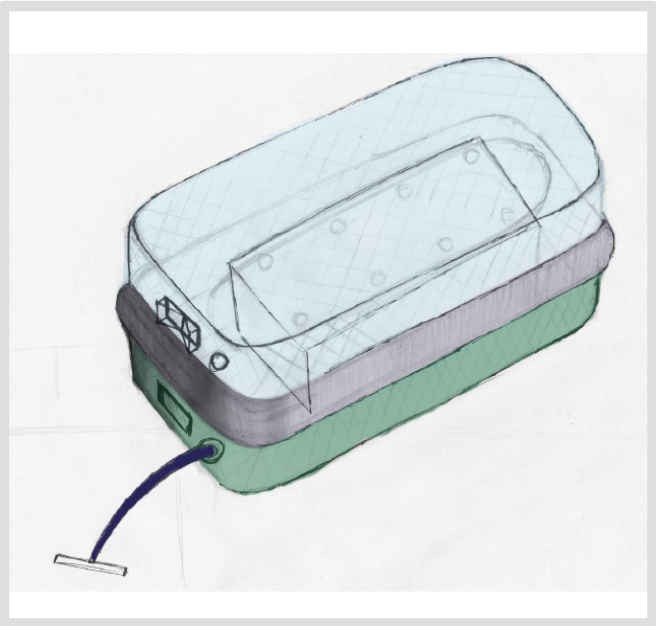


fig. 25. Concept 2

The battery can be placed in the left side of the bottom–casing, so it is in close proximity to the charging pins of the shelf. The only components that are going to be produced by Ndas–sie are the cover, the middle–part and the bottom part. The rest of the components are going to be bought. Between the two parts there is plate in the middle on which all the com–ponents are attached. The cover and the bottom parts will be screwd on the middle plate. The lamp brightness of the lamp can be adjusted by pul–ling a cord; it has 5 modes: on. off, low, medium, high setting. A rubber strip covers the projections.

5.3.3 Concept 3

The third concept is derived from the shape of a firefly: an insect with which many people in Cameroon have played in their child–hood. The design of the lamp has a "friendly" appea–rance, which will make people feel comfortable with it. The lamp could be released in two different versions: a stylish but simple version for adults and a playful edition with a multitude of colors for children.

De LEDs are attached to a globe–sha–ped plate, with on top of that an even more curved plastic cover that en–sures light is spread across a wide angle. The battery is not situated in a lying position, but is standing upright in the casing.

The lamp is meant to stand on the table or can also be hung from the ceiling. This can be realized by atta–ching a lever or handle to the lamp,

which also facilitates easier carrying of the unit. The amount of buttons on the lamp has been kept to minimum in order to minimize possible confu–sion. The user interface is equipped with one USB port, which allows the lamp to be connected to a mobi–

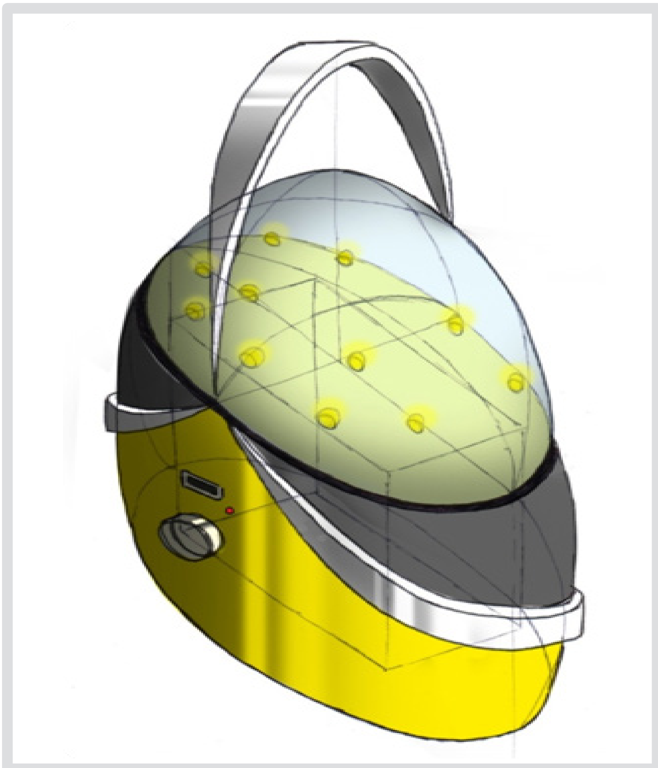


fig. 26. Concept 3

le phone or radio (the battery of the lamp can provide other small elec–trical appliances with electricity). A small LED located on the front of the unit, through color indication, notifies the user of the amount of power left in the battery.

5.4 Final Concept Choice

There are several ways of how to choose the concept. Firstly it is important to choose the concept that meets the most (important) requirements that are defined in an earlier chapter.

In the Appendix 9 an table can been found in which all the three concepts have been compared based on the listed requirements. A rating of maximum 10 points were giving to each requirement, for each concept. Eventually a general comparison was made by calculating the total amount of points per concept. The table gives an idea to which degree each concept meets the requirements, but of course this is just an general estimation.

According to the table, the best concepts were concept 1 and concept 2. Both concepts are quiet similar. The biggest advantage of the second concept, is that the main focus will lie on producing the lamp as cheap as possible and therefore design a lamp for the BOP-market. The focus will not lie on the appearance of the lamp that much, but mainly on functionality. From the 4 described goals in chapter 4.2, this concept satisfies both functionality and affordability.

The first concept is more focused on creating a lamp that is attractive and robust. The challenge is to not only concentrate on these two goals, but also on designing an affordable and functional product. It's a substantial challenge to design a lamp, suitable for the BOP that is functional, affordable, attractive and robust, but not unachievable. The first concept can satisfy all goals and is therefore the most suitable.

6. DETAILED DESIGN

6.1 The Morphological chart

The Bottom part (main housing)

The main housing was the most difficult part to design. This was a process in which the design changed again and again with the design of the individual parts. The parts that have to be placed onto (/ attached to) the bottom part are: the PCB, the battery, buttons, attachment of the cover and cover-led. In a later chapter the placement of all the components will be discussed.

In this concept a rectangular rounded shape is chosen for the bottom part. In detailing the bottom part, the dimensions had to be chosen based on the maximum dimensions given by the shelf. Also, the height of the bottom-part, the thickness and the angle of the rounding had to be defined.

Although many Cameroonian people think that the bigger the product is, the better, it was important that the design of the lamp would not become too bulky. For the transport of the lamps, limited size is also crucial. A right proportion between the length, width and the height had to be chosen. It was especially challenging to keep the height and the length as small as possible.

The SLA battery is the biggest component that has to be placed in the main part. This restricted the angle of the rounding: the larger the angle, the wider the bottom part had to become. That is why straight sides have been chosen with a small rounding of the bottom.

The Handle

One of the requirements is that the lamp should be able to hang from a ceiling or on a wall. One possible method is to make 4 holes in the bottom of the lamp trough which a string can be threaded. These 4 strings can be hung on a hook on the ceiling or on the wall.

Another option is to design a handle, which can be rotated in the right position (0 degrees for hanging on the wall and 90 degrees for hanging on the ceiling.

The third option is to cut a notch in the bottom of the lamp. In this notch the user can put his fingers to carry the lamp, or it can be used to hang the lamp on the wall (on the ceiling is not possible).

The main Cover

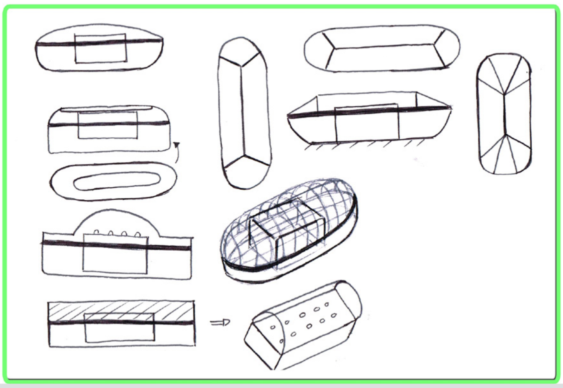


fig. 27. Sketches of the main cover

The cover of the lamp needs to have an easy shape to manufacture. It is also important that the light of the LED's can emit in an as wide as possible angle. The cover should not obstruct the light. Another requirement from the client is that the cover should have a luxurious appearance.

There are a lot of possibilities in shaping the cover:

-Rounded versus angular: a rounded shape looks softer;

-Smooth versus textured: a smooth surface differs more light.

Attachment of the cover to the main part.

The cover has to be connected to the bottom part. The two parts should be detachable from each other, as it should be possible to for example to replace the battery when needed. Therefore it is not an option to permanently attach the two parts. There are several option in attaching these two parts:

- Use of bolts

- Trough use of pins

It is difficult to use screws to attach the cover to the bottom-part; as there is little room to place the screws, as the Cover led is between the two parts. The bolts could be mounted with the bold inside of the lamp and the nut outside the lamp. The nut should not stick out, as an extra component should cover the connection (to avoid protruding sharp parts). The bolts are going to have a very short lenght as the thickness of the lamp is only 3 mm. That means that there should be a minimum of four screws. Besides that it takes a lot of precision to fix the little nuts, and is therefore more expensive than the use of pins.

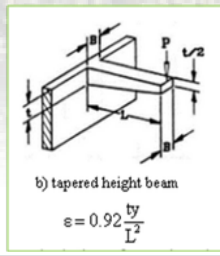


fig. 28. Snap fit

By using pins, there is not an extra component added to the list of components, it therefore saves money. The pin can be integrated in the design of the Cover en the Bottom-part. The main disadvantage of pins, is the question whether they will be strong enough and won't break. That is why it was important to do an stiffness analysis to investigate whether the pins will hold or not.

In this calculation the assumption was made that the cover is going to be made from PMMA, as the exact material has not be specified yet. The maximum allowable strain level (εrPMMA) of PMMA is 5 %. The deflection of a pin has been calculated by the "snap fit pin formula":

$\varepsilon = 0.92\frac{ty}{L^{\wedge}2}$ in which y is requested -->

y (deflection) = $\frac{\varepsilon * L^{\wedge}2}{0.92t}$ = $\frac{0.05*2.4^{\wedge}2}{0.92*2.6}$ = 1,20 mm

in which
t=2.6 mm
L= 2.4 mm

In comparison to the static analyze in Solidworks, the maximum displacement is 4.47*10^-7 m

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 1	4.47019e-007 mm Node: 40125
cover 2-Study 1-Displacement-Displacement1			

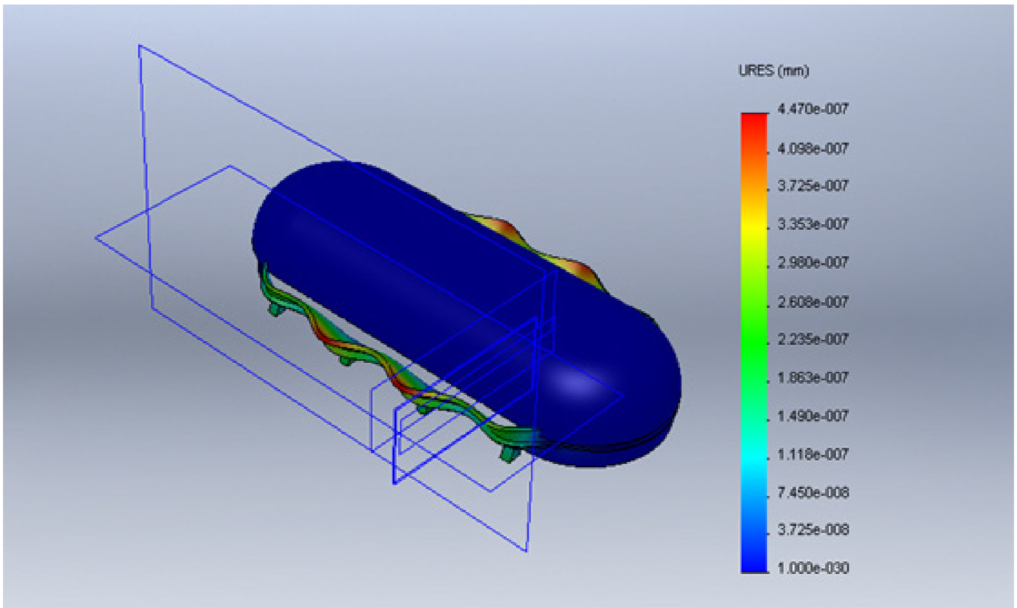


fig. 29. Displacement study of the main cover

Cover LED + position Led's

The LED's need to be placed on a separate PCB. The LED's do not tend to be placed on the main PCB as the heat of the LED's could influence the other components. This PCB of the LED's has to be placed above the battery and has to be fixed (in a way) to the bottom main part of the lamp. There are 3 challenges related to this component: how to place the PCB above the battery, how to fix the "cover" to the main bottom part and finding the best position of the LED's on the PCB.

The pair of arms of the LED's can be cut, so there needs to be a minimum space of 3 mm between the bottom of the PCB and the top of the battery.

The height of the battery is 47 mm and is 5 mm higher than the bottom main part. To meet this height difference, the "cover for the LED's" need to be rounded. The costs of rounded PCB are much higher than a flat PCB. A flat PCB has to be used, which means that it has to consist 2 parts: one plastic cover and one PCB. The two parts can be mounted to each other with little srews.

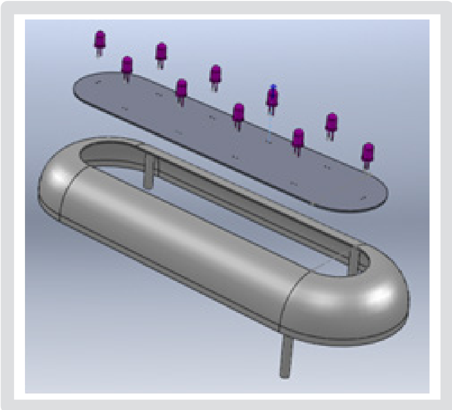


fig. 30. the cover LED

The second problem is, how to fix this "LED Cover". The cover can be mounted onto the (main) cover or onto the Bottom part. The possibility to mount it to the main cover is not very practical as the PCB of the LED's are wired to the main PCB (which will be mounted on the bottom part). Another option is to mount the edge of the Cover LED between the Main cover and the Bottom-part. The problem with this option, is that it might cause problems in the attachment of the main cover to the bottom. The final option is design two or four hollow (narrow) cylinders underneath the Cover LED, which connects the bottom-part with some screws to the LED Cover. This last option was chosen, as the Cover LED will be firmly secured to the bottom part and the cylinders can easily be integrated into the design.

The charge connector.

The charge connector connects the lamp to the shelf. This part is the most fragile part, as it is used every time the lamp needs to be charged. There should be some kind of charger pin and something that can be connected to this. The easiest solution is to design the charger pin on the shelf in stead of the lamp. The pin should have a shape, which makes it easy to put on and remove the lamp. Cilinder, Cone, hexagonal shapes are possible. The shape that is chosen, consists two cones with a flattened tip. The lamp has a hole in the same shape with a metal end.

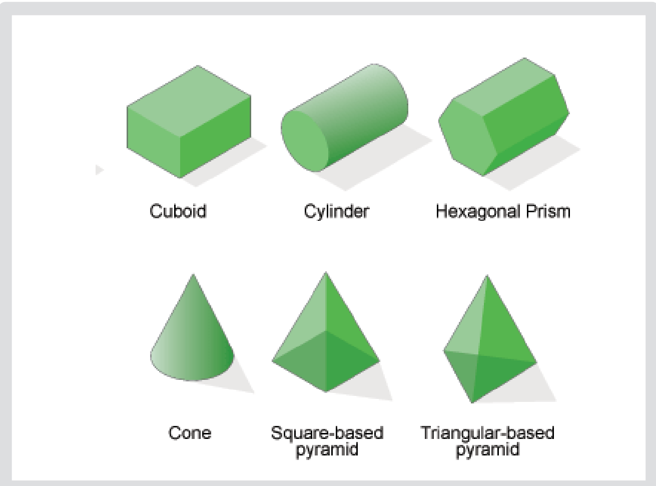


fig. 31. Possible shapes of connector

One of the requirements is that the brightness of the lamp should be adjustable in 3 modes: low, medium and high. There should also be an on/off button, so the user can also use the USB port. Another requirement is that the user should be able to see whether the battery is almost empty and needs to be recharged. These options can be realized as described below

Signal of an almost empty battery

The lamp is going to be used in the off-grid areas of Cameroon, where the distance between the home of the user and the location of docking station can be a few hours by foot. The end-user should be signaled in time if the battery is almost empty, so he or she can plan his trip to the docking station. There are three options to indicate that the battery is almost empty:

-Signal LED that will go on when the battery has less than 10% power left;

-A display with for example 5 stripes, which presents which percentage of the power of the battery is still left. Another option is a display which shows the percentage of the power that is still left.

-A warning sound which will go off when the lamp has less than (for example) 5 % of the power left.

The function of the lamp has nothing to do with music or sounds, so a warning sound is not desirable. The display and the signal light are the remaining options. A display is more expensive and has greater energy consumption than a signal light. I therefore opt for a signal light

On/off indication

There are two options to visually indicate to the end-user that the USB port and lights can be used:

-An off/on button;

-An off/on switch.

Another option is to keep the plug-in charger for mobile phones or radios permanently on. The LED's can be switched on by pressing (for example) the low, medium or high button.

In the off-grid areas of Cameroon there are many sand-drifts of dark red sand. It is important that dirt cannot easily enter inside the lamp. The switch is not an option because it has an open groove. There will be a loss of energy if the battery always needs to be ready to charge the mobile phone or radio. The sole option that remains eligible is an off/on button.

Low/Medium/High mode

For switching between different modes of intensity for the LED, different option exist:

-Three buttons for the three positions;

-Rotate switch with three positions;

-Horizontal or vertical switch with three positions;

-Pull a cord to adjust the brightness of the LED's in three modes.

The option to pull a cord is the cheapest option. The price of a cord is cheaper than the price of three buttons or a switch. It also reduces the amount of components to one. It is also very easy to control by the PCB. The problem with a cord is that the user needs to pull the cord carefully, which cannot be assured. It is also not possible to see on which mode the LED's are on. The conclusion is that the cord is not the best option. A rotate switch can have an attractive appearance and will decrease the amount of parts (in comparison to buttons). The height of the face on which the rotate switch should be mounted is only 2.9 cm high. Above and under the switch there should be some space to place the users' fingers. The diameter of the rotate switch can be maximum 2 cm. The small space between two lamps in the shelves restricts the length of the rotate switch to 2.0 cm. People with little fine motor skills should also be able to use the lamp; so a rotate switch is not an option. As mentioned in the choice of the on/off indication, a horizontal or vertical switch is also not an option because of the sand and dirt. The tree buttons with three positions remain. The advantage is that the user can easily see on which mode the lamp is on. Another advantage is, that if the buttons are big enough, the end user does not need very fine motor skills. In the design of the buttons it should be clear which button is for which mode, without using any words. The cheapest way to make the buttons is to make them from one piece (with or without the on/off button). In that way it is also not possible for dirt to enter the inside of the lamp between the buttons.

USB port

A radio or a phone can be charged by connecting it to the lamp via the USB port. This is going to be a USB 2.0 port, because this is the most common. However, the problem is not which USB-port it has to be, but on which position. This will be discussed in the next paragraph.

6.2 The Components to be bought.

This paragraph discribes which components need to be bought and chosen next to the battery and the LED's.

- USB port : As mentioned in the previous paragraph a USB 2.0 was chosen. The part which I found on the internet is USB 2.0 Jack and costs $0.10.

- PCB LED: Regardless of type, color, size, or power, all LEDs work best when they are driven with a constant current. This constant current can be realized through a LED Driver IC or a" DC / DC converter or regulator". The differences between them are the BOM Count, BOM Footprint, the price and the efficiency. After discussing with Percy (the intern that is responsible for the electrical circuit) the best option is choose a DC/DC converter, in specific the LM2731X, a 0.6/1.6 MHz boost converter with 22V internal FET switch (1.17 USD). The PCB that Percy designed for the lamp can be found in the appendix. The total cost of the PCB LED, as well as the price of the main PCB is estimated on the price inquired of a PCB assembly company.

- Buttons Low/Medium/High and the On/Off button: will be bought at the same manufacturer. The On/off button will light up once it is on. The L/M/H buttons are one (rounded) rectanglar shape divided in three parts. The costs are approximately $0.20 and $0.30.

- Signal Light: A simple trough hole LED do. The main PCB controls this light and it doesnot have to be so bright. The chosen signal light costs $ 0.02 including a rubber band.

6.3. The Architecture of the lamp (positioning of the parts)

The positioning and design of the buttons, signal-lamp and the USB port can be done in many ways. Because the space between the lamps in the shelf is only 1,5 cm, it is important that the buttons, USB port and the signal light are on one side. The rounding of the bottom of the housing and the rubber strip leaves only a space of 29 * 160 mm left, to position the parts.

In placing the battery in the bottom part, it was important that there was a little space between the battery and the bottom part: otherwise the heat of the battery cannot go anywhere. Figure .. shows the architecture of the main part: the bottom part. Figure ... represents the exploded view of the lamp.

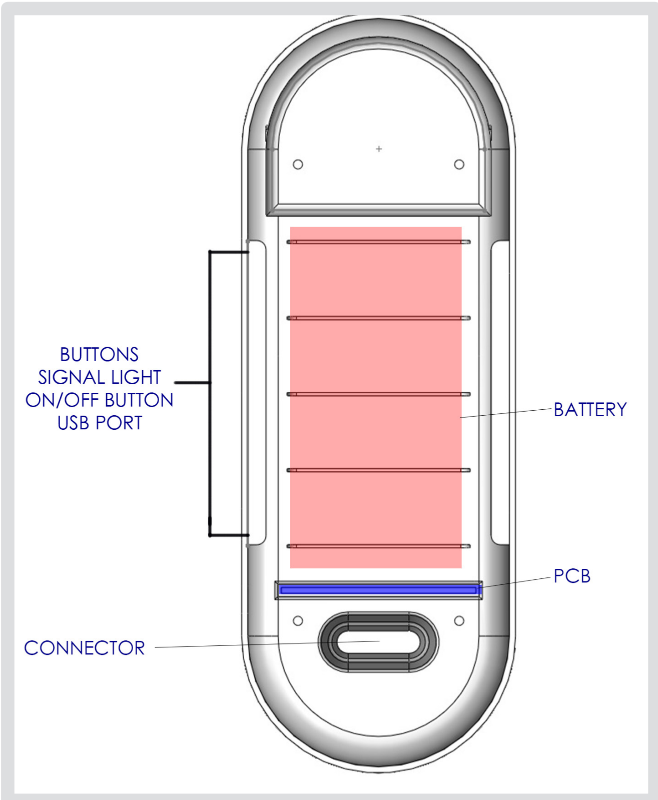


fig. 32. The architecture of the bottom part

fig. 32. Exploded view of the lamp

6.4. The SolidWorks model

fig. 31. Bottom Part

6.5. Material Choice

The materials used to produce the Ndassie lamp vary per product component. There are several general requirements that have to be fulfilled for all components, and specific requirements that differs per component.

6.5.1. General material requirements

The Material choice is dependent on the component shape and preferred production method. The materials of all the components have to meet some general requirements.

In choosing the right material for each component, many aspects have to be taken into consideration. All the components have different shapes and are therefore manufacturable by a limited amount of production-methods. These options are described in a later chapter. The most obvious way to produce the components is by using a mould in which a liquid material can be injected (injection molding). As this production-method will most likely be chosen, it is important that the material is liquid and suitable for different injection-molding-methods.

The components that need to be (custom) produced for Ndassie are: the bottom part, the cover LED, the main cover, the rubber strip and the rubber handle. The main PCB is going to be designed by another intern from Ndassie and is going to be produced by a specialized company. The Led-PCB is going to be designed and produced by a specialized company.

Each component has different requirements. The requirements that the material of each component has to meet are: lowest price per kg, lowest amount of material needed, luxurious appearance. The requirements for each component individually are discussed in the next paragraph.

6.5.2. Material requirements for the different components.

When choosing the material for the next parts, the next points has to be taken into consideration:

<u>The Bottom part:</u>

-The material has to be strong, meaning that it does not break just easily when it falls on the ground. In the mean time the material also should have a certain elasticity so it bounces back when touching the ground. (Fatigue strength and impact strength --> Yield strength), (Hookes law: Young's modulus)

-The chosen material has to be dust-proof, meaning the material should have a smooth finish so the dust will not stick to the surface.

-The chosen material should conduct the heath of the battery as much as possible in order to prevent overheating. Besides that the material should withstand the heat of the battery, meaning it should have a higher melting point than (TEMPERATUUR BATTERY).

- The chosen material should be available in bright colors.

-As the average thickness of the bottom-part is 3 mm, all the afore mentioned requirements should be met for this thickness.

<u>Cover LED</u>

-The material has to be strong, meaning that it does not break just easily when it falls on the ground. In the mean time the material also should have a certain elasticity so it bounces back when touching the ground. (Fatigue strength and impact strength --> Yield strength), (Hookes law: Young's modulus)

-Given that the Cover-LED has two cylinder tubes, the chosen material should be suitable for this shape and matching dimensions. Meaning that the material is strong enough when it is shaped in a long and thin cylinder.

- The material should have a certain brightness or shininess in order to reflect the light of the LED's to maximize the illumination.

Aan deze eisen moet worden voldaan indien gemiddelde dikte van the component 3 mm is.

Main Cover

-The material should be (clear) transparant.

-The material has to be strong: it should not break (or develop cracks) when it falls on the ground (from approximately 1,5 meter high) (Brittleness), (Fatique strength and impact strength --> Yield strength), (Hookes law: Young's modulus)

-The material should be smooth, so no dust or sand can stick to the cover.

Aan deze eisen moet worden voldaan indien gemiddelde dikte van the component 2 mm is.

Rubber strip:

Makes the lamp dust and water proof.

- The chosen material should have a certain stiffness and elasticity in order to hold all the components of the lamp together (especially the main cover and the bottom part). This two characteristics should bear a proper proportion to each other:

-The strip should be elastic enough to be (re)placed on the lamp without any cracks.

-The strip should be tough enough to withhold all the components together.

-The rubber should have a rough finish, in order to the antiskid function.

-The chosen material should be available in bright colors.

Rubber strip handle:

Same as rubber strip

-Elasticity --> Young's modulus

6.6. Final Material Choice

In the Appendix the characteristics of several thermoplastics can be found. The software which has been used to find the right material for each component is CES. This program enables you to set out different materials by certain characteristics. The graphs that are made in CES can also be found in the Appendix.

<u>The Bottom part:</u>

Two graphs has been plotted:

Graph 1: Density versus Price

Graph 2: Young Modulus versus Yield Strength.

After plotting the graphs, the following limits have been set: the material should be moldable and it should be a Polymer, based on the aforementioned requirements/needs.

The best three options according to two graphs were: PVC-vinyl, PP and ABS. PolyPropeen will not be suitable, as this material is to inaccurate for the bottom-part. Both Acrylonitril-butadieen-styreen and Poly-Vinyl-Chloride are appropriate materials. The perfect material can be created by choosing the right proportion of each sub-material (which is possible with both materials), which should be determined by a material-expert. Eventually (thermoplastic-)PVC is chosen for the bottom part, as this material is cheaper per kg and scores better in the second graph. It is easy to color and can be blended with other polymers for the best result.

<u>The main cover:</u>

Two graphs has been plotted:

Graph 1: Density versus Price

Graph 2: Young Modulus versus Yield Strength.

After the 2 limits were set: the material should be moldable and it should be transparent.

According to both graphs the best options were: PET, PLA and Polyester. PET and PLA are commonly used for packaging, in which the products are made by vacuum-forming. PLA is biodegradable and therefore very interesting, but unfortunately to expensive. The most suitable material for the main cover is Polyester, as this material can be mixed with other materials to optimize the characteristics. Polyester is versatile, widely used and can be purchased for a low price.

<u>Rubber Strip:</u>

Two graphs has been plotted:

Graph 1: Density versus Price

Graph 2: Yield Strength versus Elongation

The limits that has been set, are the limits moldable and Elastomers.

The best options are: EVA, IIR and Silicone elastomers.

6.7. Stiffness Analysis

One of the requirements is, that the lamp should withstand a (free) fall from 1,5 meter onto a hard rigid floor. By the use of Solidworks a droptest has been done, to determine whether the lamp will survive the fall. The study has been made with the Bottom part, as this part is the most complex. The results of this test can be found in the appendix. The conclusion of the test, is that the bottom part can survive the droptest.

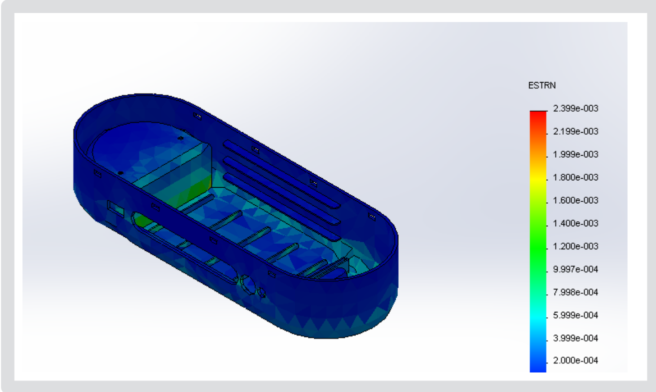


fig. 32. Droptest Simulation

6.8. The Design of the shelves

The first design of the docking station was made by Igor Schouten. The redesign of the docking station was the responsibility of another intern and was executed simultaneously as this bachelor research. This was the graduation project of Mey for her master's degree in Integral Product Design at the TUDelft. As the Docking station is closely linked to the lamp, we decided that we both do a part of the design of the drawer, on which the lamps are going to be recharged.

Mey's part was the design of the sliding out and in of the shelf (including the problem of the wiring) and my part was to design the shape of the drawer. I only did a rough basic design after which Mey did the further detailing (including the material choice, manufacture etc).

The requirements of this shelf are:

–The shelf should have place for 4 Ndassie lamp (in total there should be 5 shelves in the docking station, so in total 20 lamps.

–When the lamps are fully charged, there should be a signal that shows that they are ready.

–The dimensions of the shelf should be .. by .. cm

–The PCB for the charging of the lamps should be on the shelf.

–The PCB of the shelf should be close to the shelf: maximum distance is 2 cm.

–It should be possible to take the lamp of the shelf with one hand.

–The placing of the lamp on the shelf should be fixed in order to prevent sideling movement of the lamps.

In figure 34 the rendering of the shelf is presented.

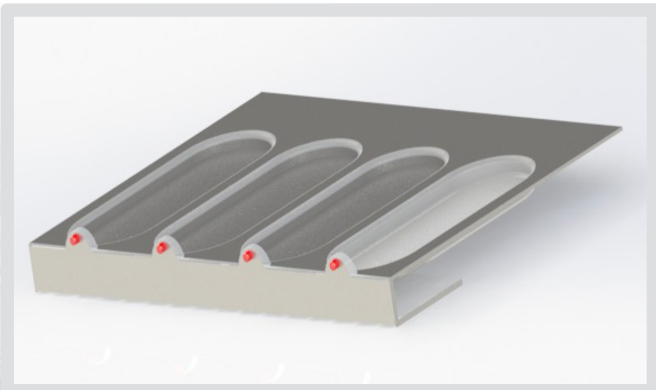


fig. 32. Basic shelf design

7. PRODUCTION OF THE LAMP

The list of components that is going to be bought:

-The battery : TELONG COMPANY)

-LED's: Shenzhen JinPuLi electronic technology Co)

-Wiring

-USB port

-Signal light

The PCB for the LED's and the main PCB are going to be designed by Percy (of course with the given requirements of the lamp). The PCB's are going to be made by a well-established European company.

The remaining components that need to by manufactured are the bottom-part, cover, coverLED and rubber strip. The best possible way to manufacture these parts is by using a mould, as all the components have a specific design.

7.1. Manufacture the lamp

7.1.1. Possible manufacture methods

The bottom part and the cover parts have several projections, which excludes many shaping methods. Some methods like for example carving or bending might be possible, but they are too intractable, time consuming and expensive. Possible shaping methods for all parts are:

-Injection molding: A thermoplastic material (in a granulate form), is brought in a heated cylinder, which melts the plastic. By a moving plunger, the material is pushed with a great force (pressure) trough a narrow injection opening in the hollow mould. After the thermoplastic is cooled down and taken his vast form, the moulds open and the product is done. Suitable for thermoplastics with a relative low melting temperature for large quantities;

-Blow Molding: similar technique to glass blowing, adapted to polymers. (bottles and containers);

-Compression Molding: pre-measured

Possible Production Methods / Parts	Bottom-part	Cover	Cover-LED	Rubber strip
Injection Molding	X	X	X	X
Blow molding				X
Compression Molding		X		
Rotaional Molding		X		
Thermoforming		X		

fig. 33. Bottom Part

quality of polymer (granules) in a preformed tablet, where a pre-heated mold presses the granules in the right shape. Simple shapes without undercuts;

-Rotational Molding: Hollow products, no fine details and difficult shapes;

-Thermoforming: for example vacuum forming or pressure forming. A thermoplastic sheet will be pressed under a high temperature on a (wooden) mold (with vacuum pressure or force). No fine details possible.

As can be seen in figure 26 the most obvious production method is Injection Molding, as this method is suitable for all parts. Especially when Ndassie is deciding to produce large quantities of the lamp

injection molding is the cheapest and easiest method.

There are several design guidelines which must be restricted. The design must be reconsidered to make it possible to injection mould the parts. The design guidelines which are already fulfilled by the current design are:

- Uniform thickness trough out the part

- Generous radious at all the corners

- Use ribs to improve stiffness (the current design has some ribs, but there could be more)

Rules that still needs to be changed in the design are:

- Minimum draft for an easy removing from the mould: important in the bottom- and cover-parts.

7.2. Assembly

The assembly of the lamp will be carried out in 4 steps. In the first step the outer parts will be placed on the bottom part, eg the bottons, signal lamp, the connector, the rubber handle strip and the switch. The wiring of these parts will be placed next. The second step will be the placement of the main PCB, after which the wiring of the previous components will be attached to this PCB. The next step is the placement of the battery that will be connected to the connector and the PCB. During this first three steps the LED's can be placed on the LED-PCB after which the PCB with the LED's can be placed on the Cover LED. Once all the components are well connected to the main PCB, the next step is to connect the PCB of the LEDS, to the main PCB, after which the Cover-LED can be placed on the Bottom part. This will be fastened by placing the screws from the bottom-part into the cylinders of the Cover LED. The last two steps of the assembly are the positioning of the Cover and as last the rubber strip.

7.3. Transport

Although it is not 100 percent certain where the components are going to be bought, it will most likely be from China, in the surrounding of Hong Kong. Trough the website Alibaba several company's are found that can provide several parts that are situated in this region. Between Hong Kong and Cameroon there needs to be a stop-over in a civilized, stable and safe county where the components can be assembled , tested and packed. There are 2 possibilities in transporting the components from China to Africa: by airplane or by ship. The Business in a box model are too big and heavy to transport via plane, so the most obvious and therefore best option is to transport the products by ship. All the parts are going to be bought or manufactured in China.

The three possibilities in transporting the parts of the lamp and the final product are: transporting by truck, train, plain or ship. The final destination of the end-product is Cameroon, which has a large coastal line. There are 5 harbors in Cameroon, of which Douala (the Capital city) has the biggest. Since Doula has the biggest harbor, it will probably be the cheapest and easiest option.

It is very difficult to estimate the transportation costs of the lamp, because it is not determined yet where all the parts are coming from. That is why a global estimation is needed to get an idea of what the transportation costs are going to be. These costs can be found in the Chapter Cost Estimation.

8. COST ESTIMATION

In calculating the total cost price there are many costs to take in consideration. These costs are divided between the direct costs and the indirect costs. The direct costs are the costs that directly belong to the product: like production costs, development-costs, the purchase costs of the components, transport-costs, distribution-cost, duties (like import-duty) etc.

Next to the direct cost, the indirect cost should also be counted to the total cost price. These include fixed overheads, promotion costs, salary of the employees, travel-costs and other (unexpected) costs.

Because there are many costs to take in consideration, it was only possible to make an (very) rough cost estimation. The prices that are determined by the supplier are based on a price inquiry of a small amount. When larger amounts are going to be produces, the costs of the parts will drop. In this calculation the indirect costs are not taken in consideration. Because this whole project is

9. CONCLUSION

The overall conclusion of this project, is that the lamp is too expensive and therefore not suitable for the people of the BoP. This is due to the too ambitious requirements formulated in the starting phase by the client (Jean). These requirements led to a too expensive architecture that is not financially feasible. Some requirements are very contradictory: the lamp should have a luxurious design, as the production cost should be less than 7,50$ (which was not based on a cost break down).

Altough the lamp turned out to be too expensive for the target group, many other requirements were met by this design. Besides that a large amount of suitable information was gathered to use

10. RECOMMENDATIONS

The recommendations I made are related to the company Ndassie and at the end of the paragraph to improve the design of the lamp.

The first recommendation that I would like to do to Ndassie, is that I think that they should invest more money and time to investigate for which target group they want to develop a product. Field research should be done in Cameroon in which the focus point should be to invest the requirements of the prospective end-user.

Ndassie is a company with mainly interns employed. I would recommend to hire some professional people who are experienced in designing, producing and launching a new product. As Ndassie is a company with little finance it could be a possibly to start a cooperation with a big company that is experienced with LED's, such as Philips or OSRAM. In this way Ndassie could take advantage out of the expertise of that company and could therefore develop an innovative and more advanced product.

In the current business model of Ndassie there are at least two links (??) between the company and the end-user. Because of these extra links, the retail price will end up higher, My recommendation would be to maintain the distribution-chain as short as possible. In this way there is less risk of corruption and the retail price can be protected. This can be realized trough hiring local people who are educated by Ndassie and sell the Business in a box franchise to local entrepreneurs.

The Ndassie lamp contains 10 trough hole LEDs, in which each LED should emit 73 lumen at 20mA. I talked to someone who used to work for Philips lighting and he mentioned that the characteristics of the LED's I chose might be impossible. I calculated the amount of lumen with an angle of 90° what is probably too big for this LED. In the calculation I made, 8 * 73 lumen is emitted at just 0.42 W. Another point he mentioned is that this type of LED is not dimmable. That means it needs three LED driving circuits, for three modes. One with 8 LED's, one with 4 LED's and one with 2 LED's, which will be a total of 14 LED's (and 3 LED PCB's). That will increase the total costs per lamp. It would be more sufficient to use dimmable LED's. I would recommend to use the LED 5630, as this LED is dimmable, widely available and supply up to 85lm/W at 120mA for $0.10 per piece.

In this project an SLA was chosen as battery. This was done as a group, in which the main reason was, that the SLA was twice as cheap as the Li-ion and therefore the most suitable. The choice of this battery resulted in somewhat bulky (and heavy) design. That was not seen as a problem, because Jean opted that Cameroonians think that the bigger the better. I think that an SLA battery is old-fashioned and insufficient as it has a large discharge rate. Although the Li-ion battery is more expensive, I think that the battery should not be a component to save money on. Once the lamp is succesfull, larger amounts of lamps can be produced, which will reduce the cost price.

Supposing Ndassie will redesign the lamp and focuses on the BOP market, I suggest to invest in a good quality battery and LED and restrict the costs on the housing by not trying to make an luxurious lamp. I would suggest to design a lamp, that is an advanced torch (/flashlight) and can be used inside and outside the house. In that way the lamp will be more portable. I would also suggest to build in the PV-cells, so they are not dependent on anyone else.

In a later stage, when the Ndassie lamp will be improved, I would advise the future designer to have a look at my market-research table, as there are some features, when combined, will create a unique innovative product. For example adding the wind energy charging system from IKEA Solvinden to the Ndassie-lamp. In that way the BoP people can not only take advantage of the sun, but also combined from the wind.

11. DISCUSSION

During this project, as a designer, I have listened to much to what the client wanted. Although I tried to change his thoughts about some things, it was hard because he was very persistent. As some (important) decisions were made as a group, not always my preference was chosen. After framing the requirements, I should have realized that some of them are very conflicting and therefore unrealistic. After this conclusion, I should have changed some requirements, which my design can be met.

I could have done this be changing the target group. In this case I could have changed the target group to people in Cameroon that have a higher income and mainly use the lamp as a back-up in case there is a power failure (what happens a lot in many African countries). Or for example independent entrepreneurs that can use their Ndassie lamp to sell from their market booth at night.

My preference would be to maintain the people of the BoP as the target group and focus on replacing the Kerosine lamp, what should have been the priority. I could have done a detailed investigation in the use of the Kerosine lamp and his characteristics. With this information I could have designed a functional, for the BoP affordable lamp which emits a similar amount of lumen as a kerosene lamp.

This bachelor didn't have a clear enough framework for me. The project frame work was to big in my opinion. This was the case, as Jean wanted me to focus on the manufacturability of the Ndassie lamp (which was far too many steps ahead) and the University of Twente wanted me to make a well-considered design. It took me a lot of time to do the analysis phase as I wanted to do this thorough.

In a very early stage, I already had contact with Chinese manufactures from which components could be bought or components could be manufactured.

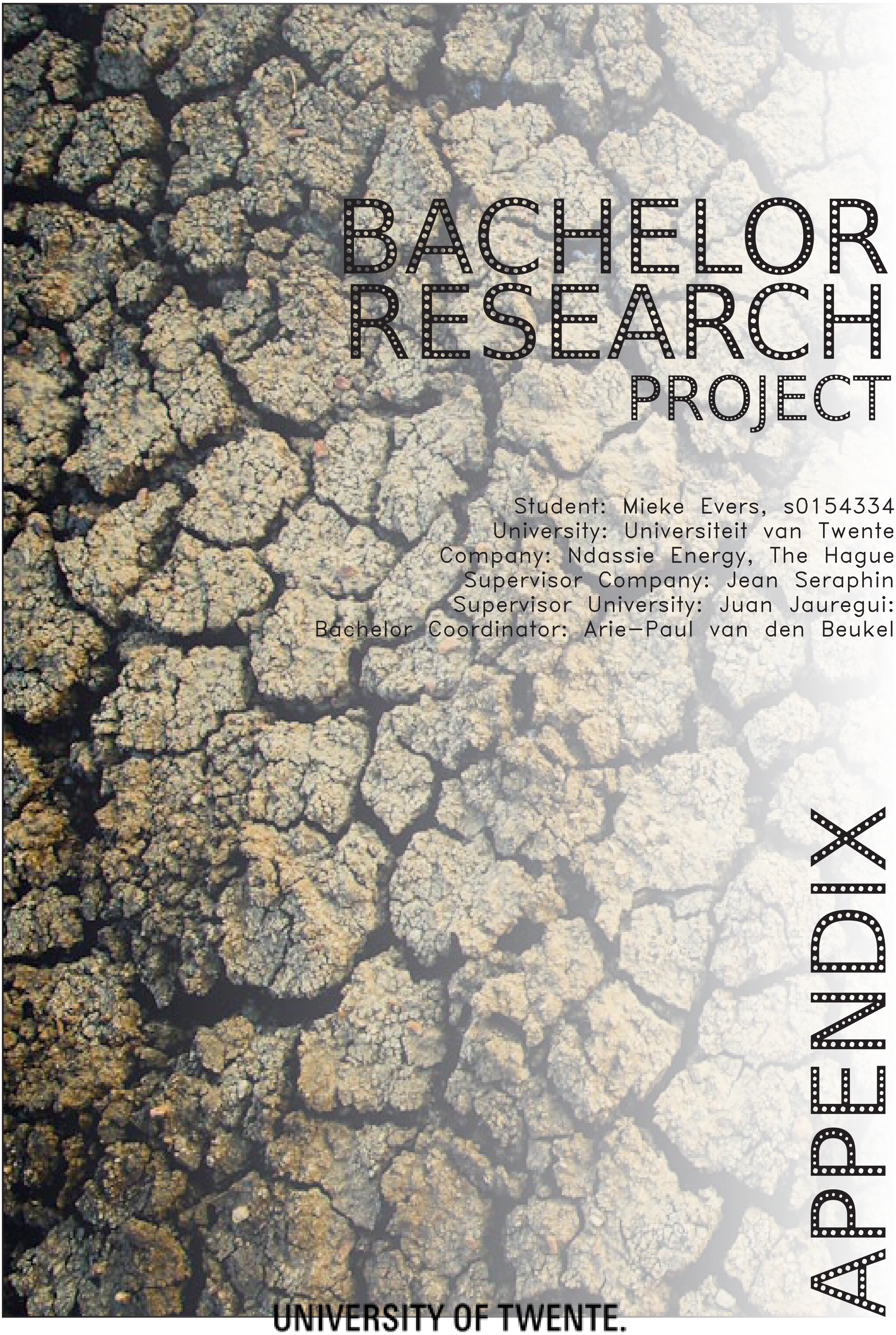
In my report I mainly did recommendations towards the producing, assembling and transporting the Ndassie lamp. Specifying this, would have been too time consuming as I only had three months to complete this research.

During the last few months I have read a lot about developing aid and micro financing and was wondering to what extend this is effective to prevent poverty. I still have a lot of unanswered questions. Would people be happier if they have a higher life standard? To what extent is it sensible plan to provide the entire world population in energy. Can the earth handle this?

My biggest question during this project was, whether the Cameroonians will profit from a lamp that they have to charge in a docking station owned by a local entrepreneur. The docking station has several benefits, as the people don't have to watch their own solar panel, extra jobs are created and the recharged is similar to buying the Kerosene once every two weeks, as they are use to. The biggest problem with the system is, that they are reliable to the man who owns the docking station and have to pay money every time they want to re-charge it. There is a big risk that the entrepeneur will overcharge, once the Ndassie lamp is bought. It is therefore very likely that they reach back to their Kerosene lamp, as the costs of the Ndassie lamp, don't weigh up against the costs of Kerosene.

A replacement (with a build in solar panel) for a Kerosene lamp (as mentioned before) will be more successful in my opinion. I think that in order to improve their living standards, they need to have electricity for the whole town (not only light). This can be provided through a "solar-panel-park", which will work similar as electricity grid.

Ken Meister did research in eight remote villages in Cameroon for the Athabasca University . His main research question was whether solar energy is improving the life of the people living in these off-grid villages. He also investigated whether solar energy could improve the socio-economic effects of these villages. His conclusion was that companies that produce solar lamps for remote villages, often don't satisfy the needs of the end-user; as their real needs are very different from the needs that are thought of by the designer. The solar-lamps are not used in the right way and often the goal of the lamp (replacing the Kerosine lamp) is not reached and people still use their Kerosene lamp next to their solar lamp. Although the particular examples that Meister found in this villages he believes that solar power can change the lives of the poor people, if only the needs of the end-users are well defined and if the usage of the product is well educated.



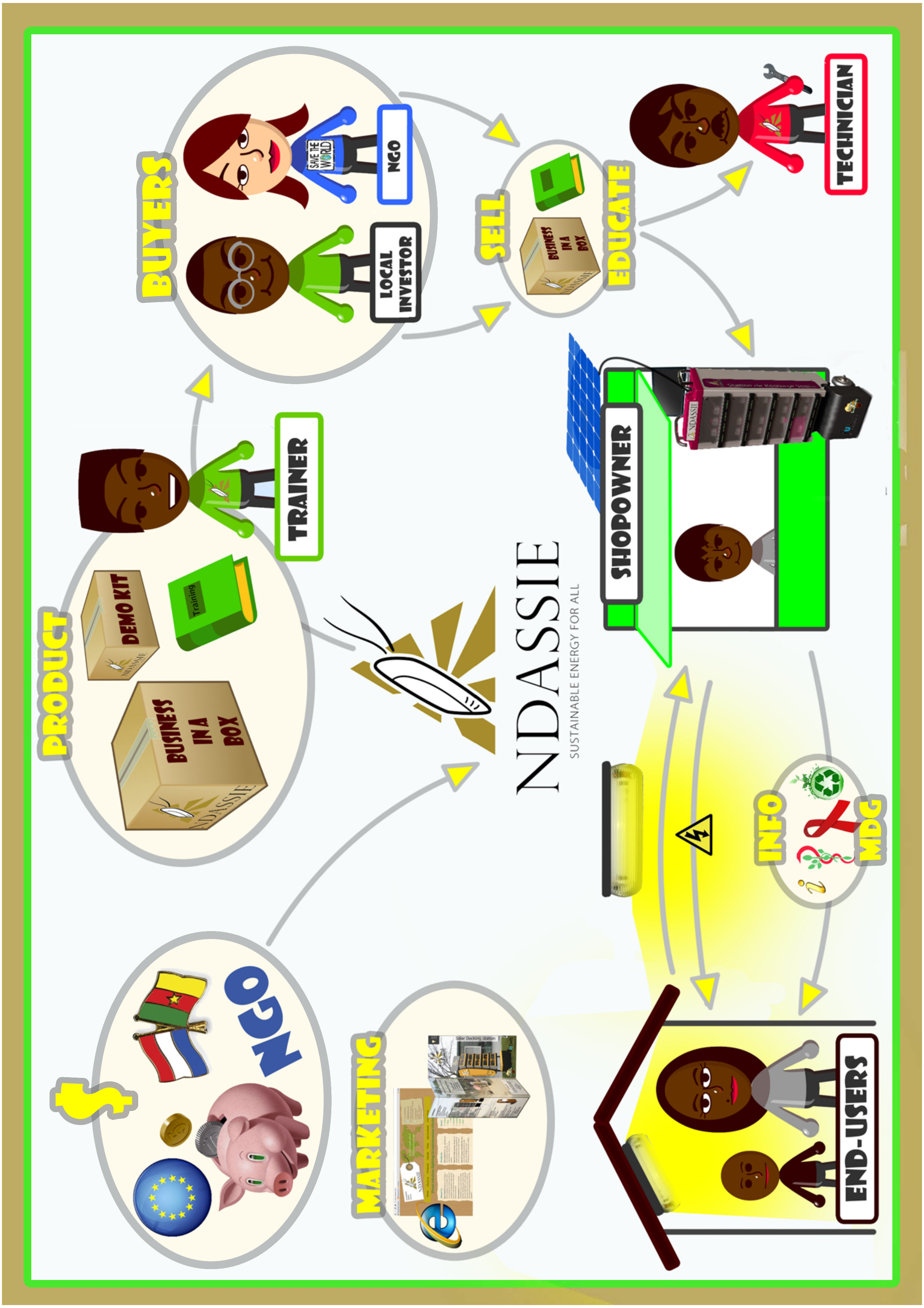
BACHELOR RESEARCH PROJECT

Student: Mieke Evers, s0154334
University: Universiteit van Twente
Company: Ndassie Energy, The Hague
Supervisor Company: Jean Seraphin
Supervisor University: Juan Jauregui:
Bachelor Coordinator: Arie-Paul van den Beukel

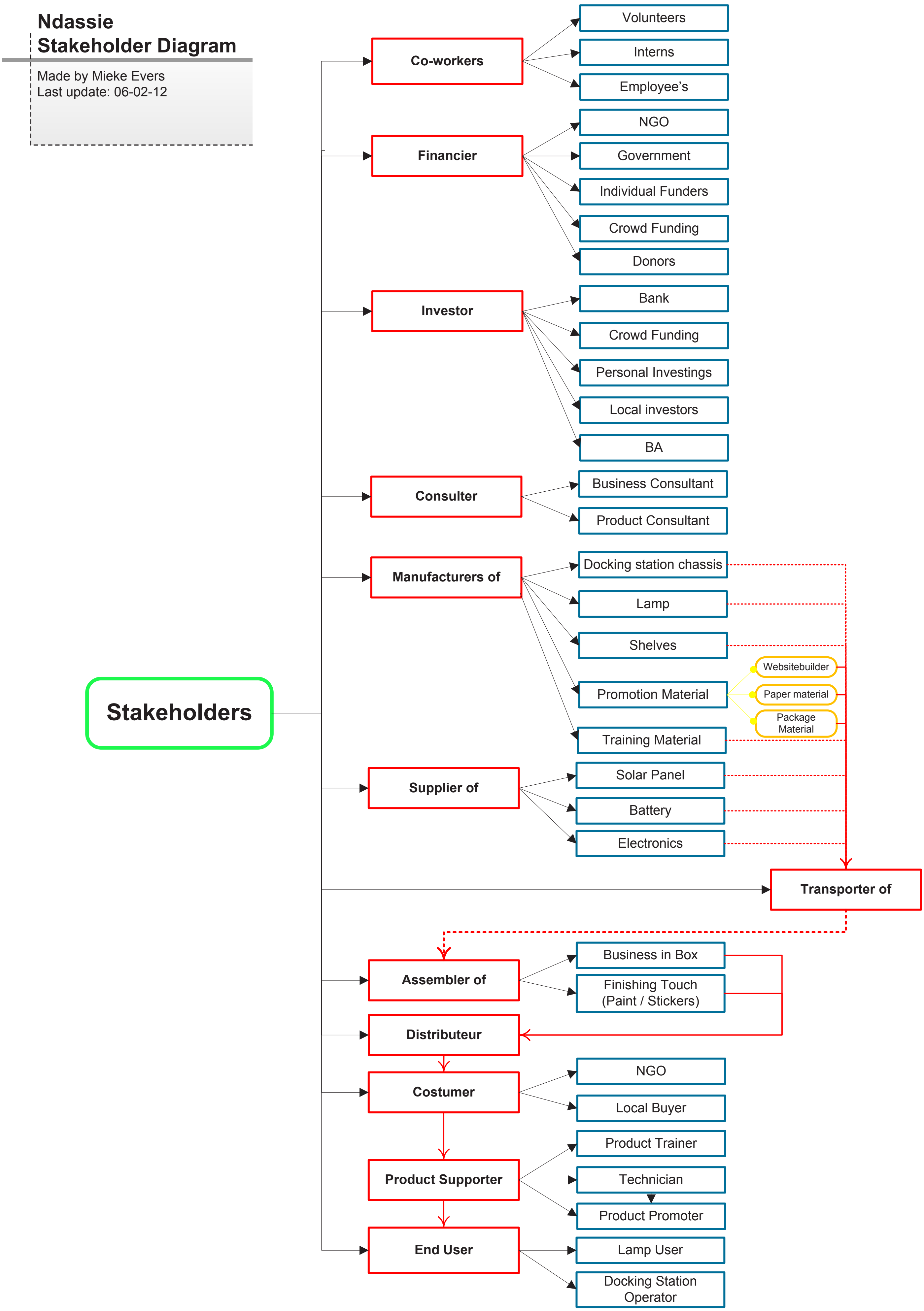
APPENDIX

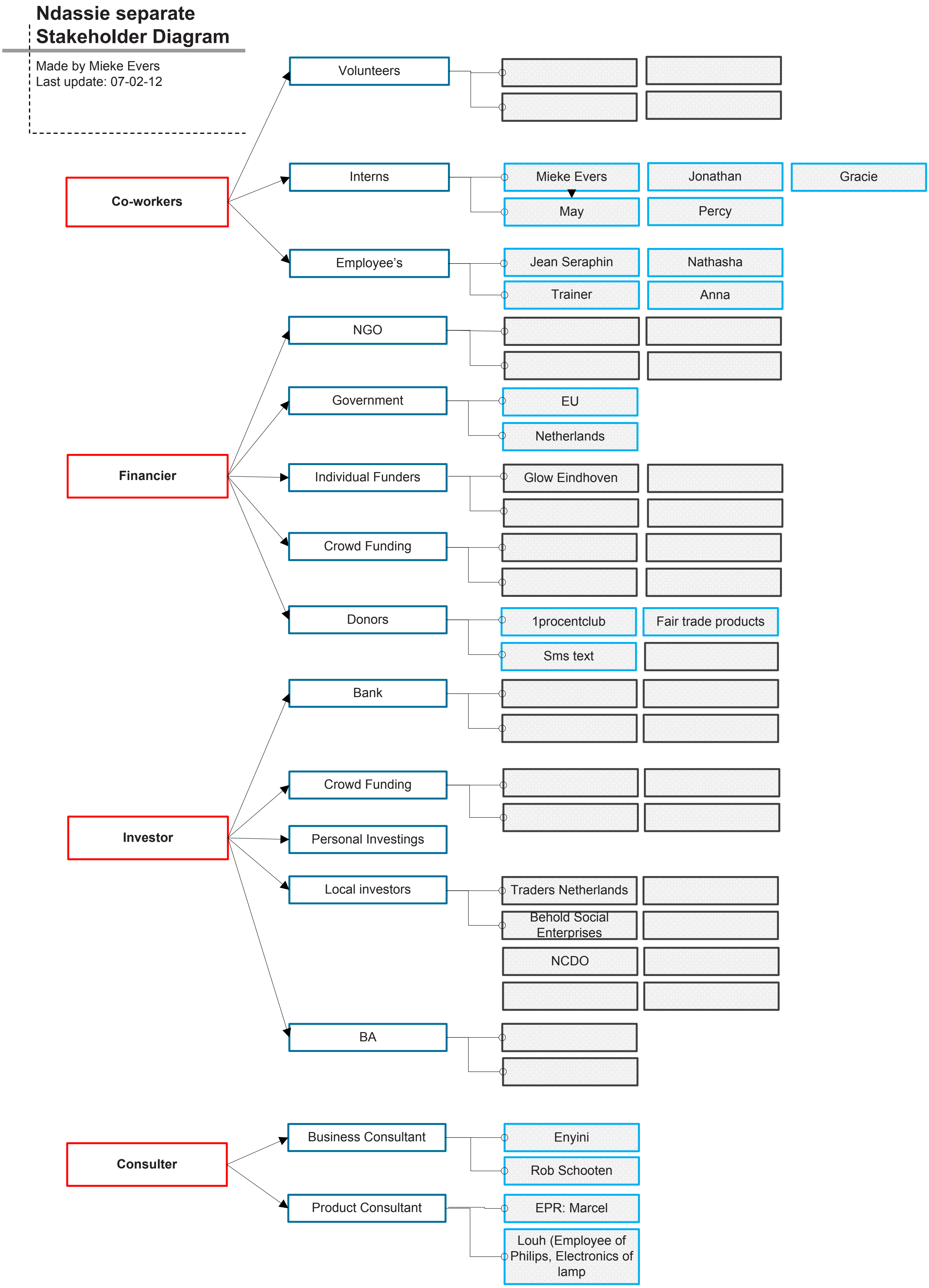
UNIVERSITY OF TWENTE.

TABLE OF CONTENT


BUYERS
SAVE THE WORLD
NGO
LOCAL INVESTOR
SELL
EDUCATE
BUSINESS IN A BOX
TECHNICIAN
TRAINER
PRODUCT
DEMO KIT
Training
BUSINESS IN A BOX
NDASSIE
NDASSIE
SUSTAINABLE ENERGY FOR ALL
SHOPOWNER
INFO
MDG
NGO
MARKETING
END-USERS

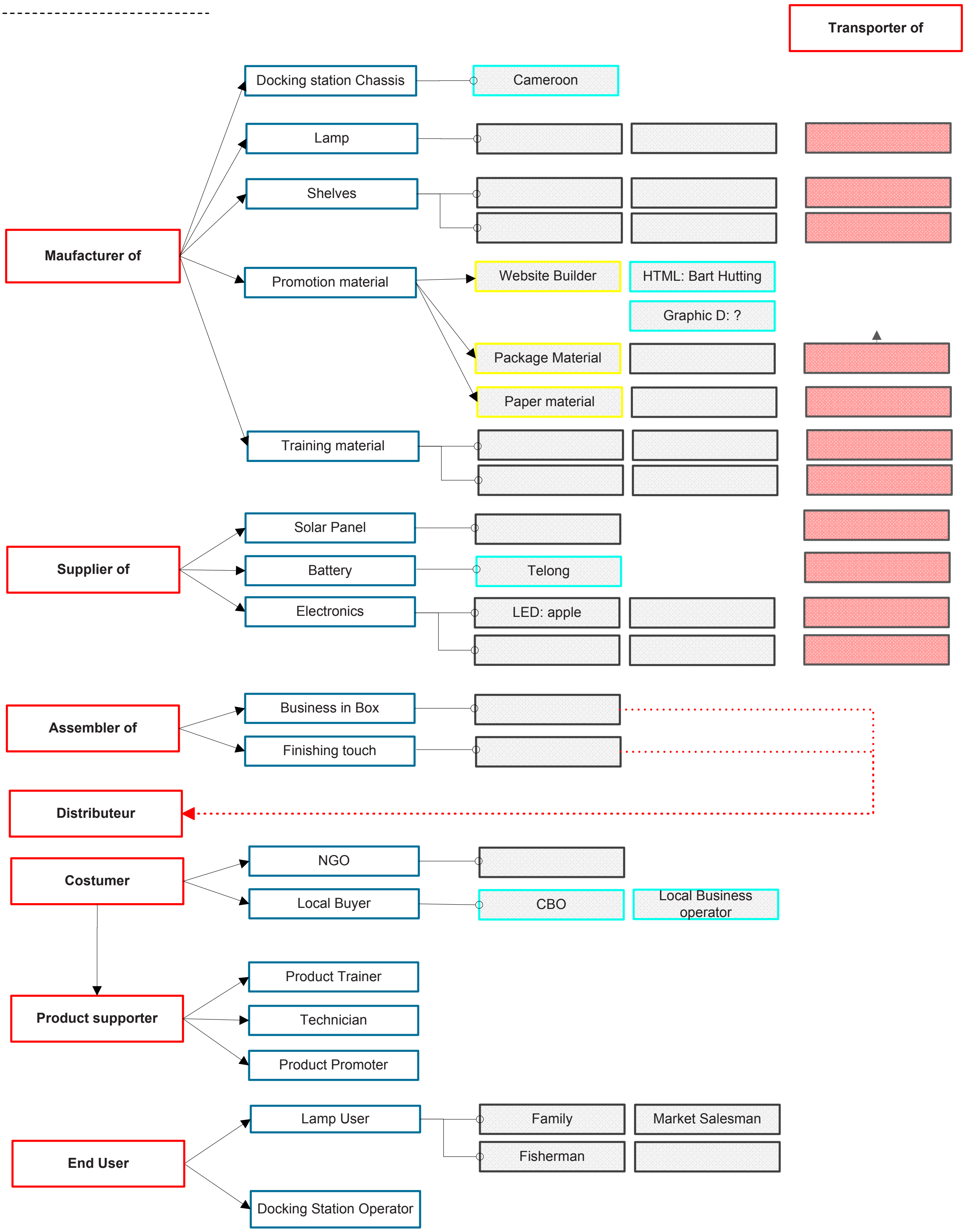
Appendix 2. Stakeholderdiagram




Ndassie separate
Stakeholder Diagram
Made by Mieke Evers
Last update: 07-02-12
Co-workers
Volunteers
Interns
Mieke Evers
Jonathan
Gracie
May
Percy
Employee's
Jean Seraphin
Nathasha
Trainer
Anna
Financier
NGO
Government
EU
Netherlands
Individual Funders
Glow Eindhoven
Crowd Funding
Donors
1procentclub
Fair trade products
Sms text
Investor
Bank
Crowd Funding
Personal Investings
Local investors
Traders Netherlands
Behold Social Enterprises
NCDO
BA
Consulter
Business Consultant
Enyini
Rob Schooten
Product Consultant
EPR: Marcel
Louh (Employee of Philips, Electronics of lamp

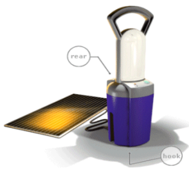
Ndassie separate Stakeholder Diagram

Made by Mieke Evers
Last update: 07-02-12

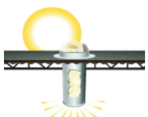



Separate Solar Panel
Solux Led-105-komplett
$47,50
SunlaBob Thailand
Solar Latern
Soyo Systems
Solar Latern
D-Light S 250 $ 44,95
Accendo LED Portable
Home Light
Build in Solar Panel
IKEA Solvinden line
$29,99
Sunny side up $35,-
LimunAID
NDASSIE
SUSTAINABLE ENERGY FOR ALL
Shenzhen Osea Sunjar
Nokero N200 Solar Light
$20,-
Waka Waka light
The Solar Muscle $8,-

Appendix 4: Marketresearch

Product	Picture	Simularity	Advantages to the Ndassie product	Disadvantages to the Ndassie product
Name: **D-light S-250 C:** Company: D.light (USA and Canada) Price: $ 44,95 USD Technical specifications: LED: lasts 50.000 hours		• Portable • Charged by solar panel • uses efficient LED • mobile charge connector • Different light settings	• Robust and housing • Rain resistant • Charged by single (private) solar panel	• No wide light angle • Provides only up to 12 hours of light (on low setting) • No radio input • Bulky design • Private solar panel (gets easily stolen)
Name: **Solux Led-105-komplett** Company: SOLUX e.V. (Germany) Price: € 39,50- 54,50 Technical Specifications Battery: Nmh - Max power: 2,5W - Max voltage: 6,0V - Max lum: 110 lm		• Portable • Charged by solar panel • mobile charge connector	• Charged by single (private) solar panel • Small and easy to carry • Lightweight	• Provides only 4 hours light (when fully charged) • Because of the single LED: the lamp cannot light up an entire room. • Bulky design • Private solar panel (gets easily stolen)
Name: **Accendo LED Portable Home Light** Company: Thrive Energy Technologies Private Limited (India) Price: unknown Technical specifications - Max vol: 6-Volt - 4.5 Amp - SLA battery - 2.5 W Solar Panel - 1W white-LED		• Portable • The specifications are similar • Different light settings • SLA Battery	• Charged through single (private) solar panel (it comes with AC charger too) • Robust design	• Not a wide enough light angle • Bulky design
Name: **Sunny side up** Company: Price: 32-38 USD Technical specifications 2 rechargable AA-batteries Fully charged: 7 hours of light		• Portable • Different light settings	• Auto lighting (switches on when it is dark) • Build in Solar Panel • Very modern and simple design • Stick to the window to recharge the lamp	• For people in Cameroon it's not easy to place the lamp in front of the window, because not everybody has one • Big housing for amount of light.
Name: **Solar Latern** Company: SunlaBob Thailand Price: unknown Technical specifications NiMH batteries NiMH AA batteries		• Different light settings (3levels) • Lightweight, durable polymer casing • Mobile charge connector • USB port	• The USB port and charging socket are protected by a rubber flap • Optional large solar (communial) panel (for 2-4 households) • Optional small solar panel for individual use	• Full-charge-time: 5-6h with a 5 Wp solar panel
Name: **Sunjar** Company: Shenzhen Osea Technology Co., Ltd. Price: unknown Technical specifications - Charging Time: 6-8 hours (direct sunlight) - Illumination Time: 5-6 hours of light on one charge		• Portable • Design inspired from Fireflies.	• Build in solar panel • Small, light, compact product • 360 ˚ light • Trustworthy shape • All in one product	• Put it outside in the sun to recharge (chance of theft)
Name: **Glowstar** Company: Price: 85 USD Technical specifications - 5 W lamp - 4.4 Ahr Battery - recharges within 8.5 hours - lamp life: 10.000 hours		• Portable • Lights up entire room	• 360 ˚ light • Charge it from sun, mobile phone, car, AC • Private solar panel	• Private solar panel (gets easily stolen) • Big product
Name: **LimunAID** Company: Price: unknown Technical specifications: - Fully charges within 5 hours - 4 hours of light on high setting - Battery will last untill 800 charges		• Portable	• Can be wrapped up as a very small package • Little material needed • Suitable for refugee camps • Great marketing: clear attractive goals ▯	• Doesn't give enough light to light up an entire room
Name: **Waka Waka light** Company: Off-grid Solutions (Haarlem NL) Price: Technical specifications: - 8 hours of bright light - 16 hours of reading light		• - Useful as reading light	• Build in solar panel • Very small: it fits on a bottle	• Won't give enough light • Have to put it outside to charge
Name: **Solvinden line** Company: IKEA Price: 29,99 USD Technical specifications: - Sun-charge-time: 9-12 h with sunlight, when clouded: 12h - Wind- charge-time: ci. 24 h at a windspeed of 4 m/s .		• Lights up entire room • Charged by solar panel • Modern design	- Powered by sun and wind! - (Shades) Made of recyclable material: polypropylene - Simple and chique design	• Meant for outside use • Replace battery after 2 years • Not meant for carrying (not portable)

Name: **Solar Latern** Company: Soyo Systems Price: unknown <u>Technical specifications:</u> - Battery: 12 V/7 Ah (S.M.F.) - lightsource: CFL 7 W - Usage per day: 3-4 h - Light output: 370 J - Solar Panel: 10 WP		• Portable • Charged by external solar panel	- Looks like Kerosene Lamp - 360 ˚ light	• No possibility to charge mobile phone and radio • Oldfashioned and boring design
Name: **The Solar Muscle** Company: Flexiway Solar Solutions Price: 6-10 USD <u>Technical specifications:</u> - 12 Leds: 2300 -3000 mcd per LED - Total lm per product: 33 lm - Viewing angle per LED: 100 degrees The Solar Panel: - Working voltage: 6 V - Working current: 100 mA - Max output: 0.6W - Time to charge: 15hrs			• Easy to connect to walls and roofs using screws, wires or even sticks. • Connectable • Weather- & shockproof • Bright & affordable • Small and light-weight product • All in one-product • Easy transport (low transport costs)	- Only switch on / off button - Solar panel at the back (so you have to place it outdoors or in front of a window. - Easy to connect to walls, but uncomfortable to reconnect everytime you have to recharge the product.
Name: **N200 Solar Light** Company: Nokero (Denver, Calorado) PriceL 20 USD <u>Technical specifications:</u> - Light output: 13.5 lm (high), 5 lm (low) - Recharge: DBT 1.9 h (high setting), 6.6 h (low setting) - AA rechargable battery		• Portable • Different light settings (2levels)	• Very small product, looks like regular light bulb • All-in-one-product • Automatically switches off in bright light to save charge	• Hangs outdoor for recharging • Replace batteries after 1,5 years (2 * AA bat) • Not waterproof • Easy to hang on ceiling • Good Marketing: nice website

Product	Picture	Differences / Description	Advantages to the Ndassie product	Features that can be used in the Ndassie- design
Product: **Street Latern** - Light source: 1W LED - Beam angle: 120° - Luminous flux: 950lm - LED total power: 30W - LED operating current: 350mA - Peak Watt of Solar Module: 110Wp - Battery: LA,100AH/24V		Street Latern, which is charged by a solar latern - Has a big capacity - LEAD-acid BATTERY - works autonomous	- Big capacity - Weather proof	- Use of LEAD-acid Battery - autonomous
Product: **SolaTube Lichtkoep**el Company: Techcomlight B.V Price: €385 – €833 		The daylight is received by the light-dome, in which 99,7% of the light will be refelected to the desired room. Light has been created inside the house without any use of electricity!	The system can be assembled on almost every roof en can be adjusted with different kind of lenses for the desired color of light.	Something can be done with reflecting the light, and with that the light intensity of the lamp can be increased (use of the patent Spectralight® Infinity reflection-material?).
Product: **Smart Polaris Led lamp** Back light for on the bike Price: €6,95		Bicycle lamp to click on your bike	Easy click system	Design of click-system so that the lamp can be adjusted to the ceiling (or for example on a market booth): it will be easier to hang the Ndassie Lamp (for example the use of magnets?)
Product: **Headlight Moon** Company: Caperlan Price: €19,95		Light with a bandage to put on your head.	Bandage system so your hands are free to work.	Design of head-system so the Ndassie can easily be used during fishing etc (Use of fluorescent colours for safety?)
Product: **GlowMark™** Charges within 8 minutes Glows for 48 hours. Price: £4,5 – £5,5 per Unit		Doesn't use electricity, solar power or batteries The product contains a chemical active substance (Crystal Glow Compound, SGCMkII™) that glows in the dark.	No use of electronic components	Use of chemical active substance. For example the lighting: even when the lamp is off, it emits light
Product: **Iphone Docking station** (with Wake up Light) Company: Philips Price:		Docking station for the Iphone with a integrated Wake Up Light (which has a build in radio)	Easy to charge your phone in a dockingstation	On a dockingstation the lamp and the mobile phone can be intergrated.
Product: **Majiscup** made of Corn Plastic or PLA (polylactic acid)		The product is ecofriendly an will be composted Disadvantage: possible that material can not be made as strong and as clear as plastic (not used in current lamps already)	Ecofriendly housing material	Use of Corm plastic in the housing of the Ndassie lamp.

Name Li-ion	Type	capacity	Voltage	Size	Temp. Range	Self-discharge Rate in %	Price a piece	Total Price in €	link
ER18505H High capacity Li-ion Battery	Li-SOCL2 Battery	3500mAh	3.3V	A	-40°C~+80°C	<1	$ 2.2 - 2.5	$4.40	http://www.alibaba.com/product-gs/522484172/Capacity_3500mAh_ER18505H_High_capacity_Li.html
li ion 32650 3.5ah rechargeable battery	LiFePO4	3500mAh	3.2V	A			$4.36	$8.72	http://www.alibaba.com/product-gs/280520871/li_ion_32650_3_5ah_rechargeable.html
Li ion Sanyo 18650		3000mAh	3.7V				RMB 20 - 30	50 RMB = 7.95 $	http://www.alibaba.com/product-gs/500639974/Li_ion_Sanyo_18650_3000mAh_Battery.html
Rechargable Cap-Lamp Battery		6500mAh	3.6V		-20--+60°C			$7.32	http://www.alibaba.com/product-gs/486236893/3_6V_6_5Ah_Rechargable_Cap.html
Li ion 18650 3.1Ah Panasonic NCR18650A		3100mAh	3.6V				(above order of 10.000)$ 4,8	$9,6	http://www.alibaba.com/product-gs/447790270/Li_ion_18650_3_1Ah_Panasonic.html
Er26500m Lisocl2 Power Type Primary Lithium		6500 mAh	3.2V		-55 to 85deg. C		?	?	http://www.alibaba.com/product-gs/535526964/3_6V_6500mAh_Er26500m_Lisocl2_Power.html
R20		650 mAh	3.7V				$1	X	http://www.alibaba.com/product-gs/533953176/R20_battery.html
li-ion 26650		3000mAh	3.2V				$2	$4	http://www.alibaba.com/product-gs/466965550/3000mAh_li_ion_26650_rechargeable_battery.html
26650 Li-ion Battery with UN38.3 UL and CE		3000 - 3300 mAh	3.2V		0 to 45 deg C		$2,64	?	http://www.alibaba.com/product-gs/378834448/26650_3_2V_3000mAh_Li_ion.html
High Quality 2 x 3.7V 3000mAh 18650 Rechargeable Li-ion Battery		2* 3000mAh	3.6 V				$ 2.38 - 4.62	$4,76	http://www.alibaba.com/product-gs/498309226/High_Quality_2_x_3_7V.html
high power lifepo4 battery	lifepo4	3500mAh	3.2 V				$ 1 - 5	$6	http://www.alibaba.com/product-gs/432267698/high_power_lifepo4_battery_3500mAh_32600.html

Name SLA	Type	capacity	Voltage	Size	Temp. Range	Self-discharge Rate in %	Price a piece	Total Price in €	link
6V 6AH AGM lead acid battery		6000mAH	6V	85X49X112X120mm					http://www.alibaba.com/product-gs/208838027/6V_6AH_AGM_lead_acid_battery.html
LP6-5.4 (6V5.4AH)		5400mAh	6V	70X47X100X110	(charge) 0-40 C		$ 3,27	3,27	http://www.leoch.com/en/product_view.aspx?tid=4&id=50
LP6-6.0		6000mAh	6V	70X47X100X111			$ 3,45	3,45	http://www.leoch.com/en/product_view.aspx?tid=4&id=51
SB6-6		6000mAh	6V	70X47X101X107			$ 3.48		http://www.powergorbattery.com/product/pr_lea.asp
EA660		6000mAh	6V	70X47X101X108					http://www.eastarbattery.com/products_show.asp?cateid=113&id=473
PS5.5-6		5500Ah	6V	70X47X101X109					http://www.powerkingdom.com.cn/product_view.asp#PS
TL655		5500Ah	6V	70X47X101X110			$ 2,99		http://www.sztlg.com/en/products_info.asp?list=15&id=18
		5500Ah	6V	70X47X101X111			$ 3,2		http://kldbattery.en.alibaba.com/productgrouplist-212048469-2/6v_battery.html
6v5.5ah		5500Ah	6V	70X47X101X111			$ 3,15		http://kldbattery.en.alibaba.com/product/560909633-212048396/SLA_VRLA_rechargeable_batteries.

Name	Type	mcd	angle	lumen	Amount of led's to produce 600 lumen	Price per LED	Total Price in €	link
Super Brightness Flat Top LED	Trough hole LED	40.000	90	73,6	8	0,035	0,28	http://www.alibaba.com/product-gs/540842800/Super_Brightness_Flat_Top_LED_Diode.html
SGS Approval 8 mm Photo diode LED	Trough hole LED	40.000	45	19,13	28	0,035	0,98	http://www.alibaba.com/product-gs/538736348/SGS_Approval_8mm_Round_Photo_Diode.html
High Power 8 mm LED Diode	Trough hole LED	40.000	90	73,6	8	0,035	0,28	http://www.alibaba.com/product-gs/540858764/High_Power_8mm_LED_Diode.html
Neutral White (4100K) Luxeon Rebel LED (Philips)	High Power LED		120	145 lm @ 700mA	4	3,57	14,28	http://www.alibaba.com/product-gs/539117031/3W_1w_High_power_LED_Chips.html
3W 1w High power LED Chips (Diodes Epistar)	High Power LED		140	180 @ 700mA	4	0,65	2,6	http://www.alibaba.com/product-gs/539890424/1w_3w_5w_high_power_led.html
1w 120lm high power led Epiled 38 mil	High Power LED			120 @ 350 mA	5	0,11	0,55	http://www.alibaba.com/product-gs/502094631/1w_120lm_high_power_led.html
1W high power LED,Tekcore Chips, 110-120lm	High Power LED		90-120	115 @ 350 mA	6	?		http://www.alibaba.com/product-gs/536356741/1W_high_power_LED_Tekcore_Chips.html
1w high power led with heatsink	High Power LED+ heat sink		140	105 @ 350mA	6	0,08	0,48	http://www.alibaba.com/product-gs/502083579/1w_high_power_led_with_heatsink.html
3W high power led with heatsink,warm white color	High Power LED + heatsink			165 @ 750mA	4	0,79	3,16	http://www.alibaba.com/product-gs/435393439/3W_high_power_led_with_heatsink.html
1W pure white Epistar super bright led high power with star heatsink	High Power LED + heatsink		120-140	110-120 @ 300-320 mA	5	0,7	3,5	http://www.alibaba.com/product-gs/541414519/1W_pure_white_Epistar_super_bright.html
superflux LED	superflux LED	18000 @ 20mA	160	93	7	0,04	0,28	http://www.alibaba.com/product-gs/294662621/superflux_LED.html
WHITE superflux LED	superflux LED	800-18000	60-160	93 @ 20Ma	7	0,08	0,56	http://www.alibaba.com/product-gs/339003966/WHITE_superflux_LED.html
PLCC2 3528 Series White Surface High Brightness White type SMD LED	SMD LED	800-2800	120	8,8 @ 25 mA	68	0,035	2,38	http://dglenstar.en.alibaba.com/product/308965292-210069310/PLCC2_series_3528_1Chip_white_type_TOP_SMD_LED.html
0.5w smd high power with 35-45lm for LED lamps	SMD LED		120	45 @ 150 mA	13		0	http://www.alibaba.com/product-gs/512153369/0_5w_smd_high_power_with.html

深圳市金普利电子科技有限公司

Shenzhen JinPuLi electronic technology Co., LTD

Straight insert LED product specification

Part Number：5MM　Round head white light

File Numbers：JPL-PZ-WI-005

Version Numbers：A/0

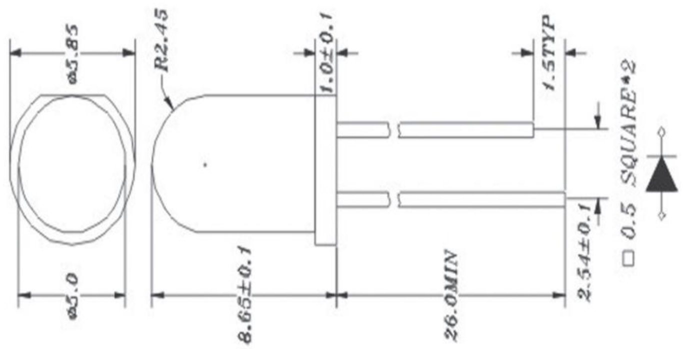
Product description：

Lens Type:water clear

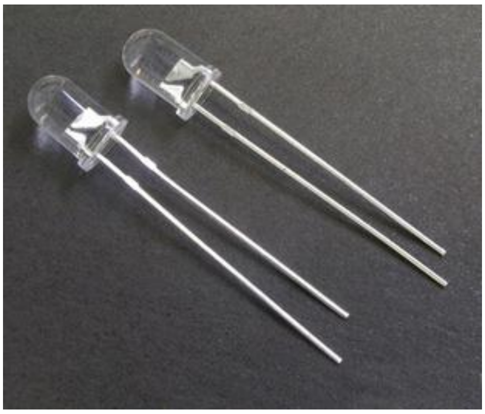
Size:Dia5mm

Emitting color:white

Structure：



physical:



Limit parameters（Ta=25℃）:

project	symbols	maximum	unit
Positive current	IF	20	MA
Positive current peak	IFP	80	MA
Reverse voltage	VR	5	V
Power consumption	PD	70	MW
Working temperature	TOPR	-40~+95	℃
Working temperature	TSTG	-40~+100	℃
Soldering temperature	TSOL	Max 260℃ Within five (5) seconds	

Product characteristics of light intensity:

project	symbols	conditions	min	average	max	unit
Positive voltage	VF	IF=20mA	3.0	3.1	3.2	V
Reverse current	IR	VR=5V	/	/	5	μA
Color Temperature	TC	IF=20mA	6000	6250	6500	K
Luminous intensity	IV	IF=20mA	25000	27500	30000	MCD

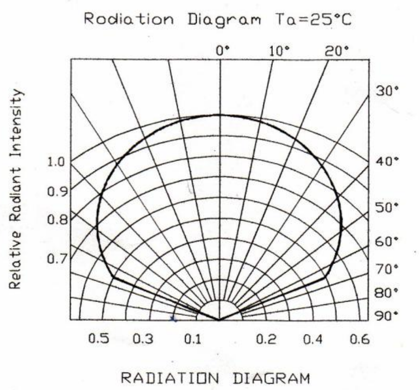
Announcements:

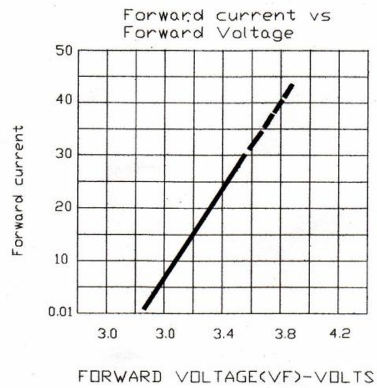
1、Product performance level I company by photoelectric themselves, different levels of product performance differences, please photoelectric customer requirement according to oneself decided to use methods。

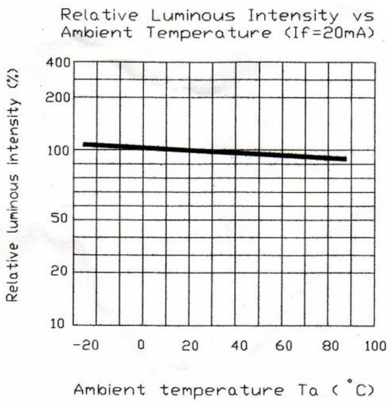
2、The luminous intensity test tolerance is plus or minus 15%。

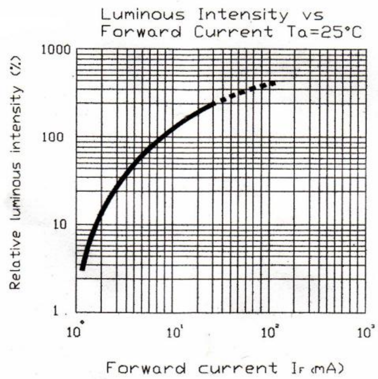
3、The voltage of the testing tolerance is plus or minus 0.05%。

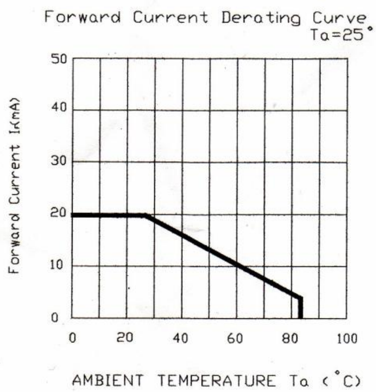
Performance test figure:

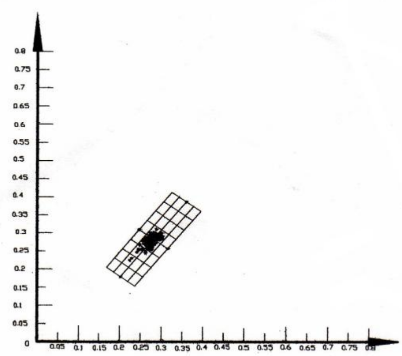

Rodiation Diagram Ta=25°C
0° 10° 20° 30° 40° 50° 60° 70° 80° 90°
Relative Radiant Intensity
1.0 0.9 0.8 0.7
0.5 0.3 0.1 0.2 0.4 0.6
RADIATION DIAGRAM


Forward current vs
Forward Voltage
50 40 30 20 10 0.01
Forward current
3.0 3.0 3.4 3.8 4.2
FORWARD VOLTAGE(VF)-VOLTS


Relative Luminous Intensity vs
Ambient Temperature (If=20mA)
400 200 100 50 20 10
Relative luminous intensity (%)
-20 0 20 40 60 80 100
Ambient temperature Ta (°C)


Luminous Intensity vs
Forward Current Ta=25°C
1000 100 10 1
Relative luminous intensity (%)
Forward current If (mA)

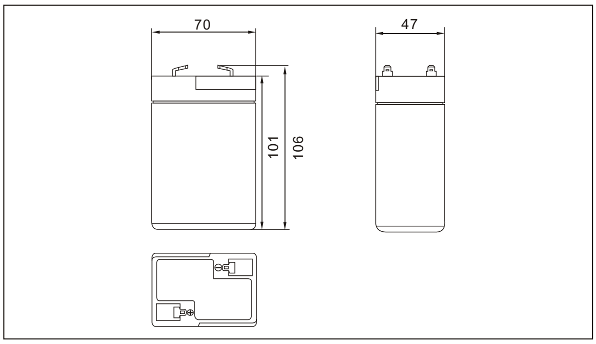

Forward Current Derating Curve
Ta=25°
50 40 30 20 10 0
Forward Current If(mA)
0 20 40 60 80 100
AMBIENT TEMPERATURE Ta (°C)



Shenzhen Telong Energy Technology Co.,Ltd

TL6-5.5(6V5.5AH/20HR)

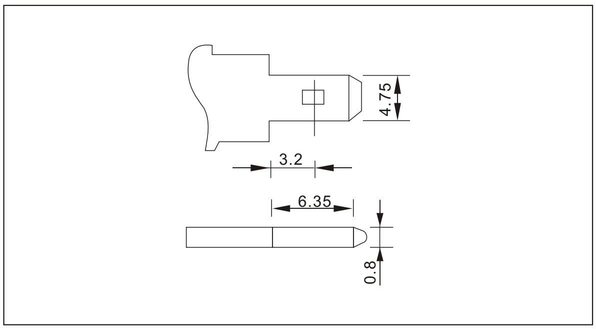
Outer dimensions (mm)



Specifications

Nominal Voltage		6 V
Rated capacity (20hour rate)		6.0 Ah
Dimensions	Total Height	106 mm(4.17 inches)
	Height	101 mm(3.98 inches)
	Length	70 mm(2.76 inches)
	Width	47 mm(1.85 inches)
Weight Approx		0.83 Kg(1.83lbs)

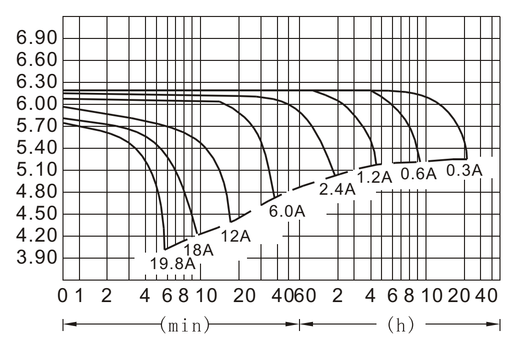
Terminal Type (mm)



Characteristics

Capacity 25℃(77℉)	20 hour rate(0.30A)	6.00 AH
	10 hour rate(0.55A)	5.50 AH
	5 hour rate(1.02A)	5.10 AH
	1 hour rate(3.60A)	3.60 AH
	1.5 hour discharge to 5.25 V	2.4 A
Internal Resistance	Full charged Battery at 25℃(77℉)	19 mΩ
Capacity affected by Temperature (20hour rate)	40℃(104℉)	102%
	25℃(77℉)	100%
	0℃(32℉)	85%
	-15℃(5℉)	65%
Self-Discharge at 25℃(77℉)	Capacity after 3 month storage	91%
	Capacity after 6 month storage	82%
	Capacity after 12 month storage	64%
Terminal	T1	
Charge (constant Voltage) Cycle	Initial Charging Current less than 2.40A	
	Voltage 7.20-7.35 V	
Charge (constant Voltage) Float	Voltage 6.75-6.90 V	

Discharge Curves 25℃(77℉)



Constant Current(Amp) and Constant Power(Watt) Discharge Table at 25℃(77℉)

Time		5min	10min	15min	30min	1h	2h	3h	4h	5h	8h	10h	20h
4.80V	A	19.8	12.4	9.63	6.33	3.60	2.10	1.55	1.24	1.05	0.69	0.57	0.31
	W	116.8	73.3	55.5	33.6	20.8	12.2	8.94	7.18	6.09	4.01	3.29	1.80
5.10V	A	18.2	12.1	8.85	6.00	3.38	2.01	1.50	1.20	1.03	0.68	0.56	0.30
	W	109.9	72.2	52.1	33.3	19.5	11.7	8.69	6.95	5.98	3.95	3.23	1.75
5.25V	A	16.8	11.6	8.25	5.82	3.27	1.98	1.47	1.14	1.02	0.68	0.55	0.30
	W	106.1	67.4	49.8	33.0	18.9	11.4	8.54	6.60	5.94	3.91	3.20	1.74
5.40V	A	15.3	11.1	7.70	5.56	3.16	1.92	1.45	1.12	0.98	0.66	0.54	0.29
	W	101.3	65.3	48.0	32.9	18.4	11.2	8.44	6.52	5.68	3.75	3.13	1.70
5.55V	A	13.3	10.5	7.15	5.17	3.05	1.88	1.38	1.10	0.93	0.64	0.53	0.29
	W	78.9	63.1	45.7	32.7	18.1	11.1	8.19	6.50	5.55	3.62	3.06	1.69

Shenzhen Telong Energy Technology Co., Ltd
ADD: FuKang Industrial Zone, GuanLan Town, Shenzhen City, Guangdong Province. China
TEL; 0086-755-27981420 FAX;0086-755-27981742
Http:www.telongbattery.cn E-mail:apple@telongbattery.com

PROFORMA INVOICE

Invoice No.:20120517 **Date:** May 17th 2012

The Seller: **The Buyer:**

Shenzhen Telong Energy Technology Co., Ltd — Ndassie

Add: FuKang Industrial Zone, GuanLan Town, Shenzhen City, Guangdong Province. China — Netherlands

Tel:+ 0086-755-2798142 **Fax:**+ 0086-755-27981742 **Tel:**

The undersigned Seller and Buyer Have agreed to close the following transactions according to the terms and conditions stipulated below:

Item No.	Unit Price （USD）	Description of Goods	Quantity(PCS)	Total Amount(USD)	Remarks
TL6-5.5	2.99	Valve regulated lead acid battery Size;70*47*100 Warranty：1year Weight:0.82kg+/-50G Capacity: 6AH/20HR	1	2.99	Total 1pcs sample express fee 87USD
		TOTAL:	1	89.99 USD	
TOTAL	Say U.S. Dollars eighty-nine point ninety-nine only.				
From shenzhen to Netherlands need 5days by express delivery. 1pcs total express fee 87USD.					

1. Delivery time: 7days after receipt of 89.99USD

2. Packing: common Packing

3.Port of Loading：shenzhen

4.Destination:

4.Terms of payment: T/T : 100% Payment before shipment.

5.BENEFICIARY:

董铁钢(Dong Tie Gang)

USD ACCOUNT NO.:

764053524172

BANK: BANK OF CHINA, Shenzhen Guanlan Branch

SWIFT CODE: BKCHCNBJ45A

6.Country of Origin：China

7.The above price is base on:

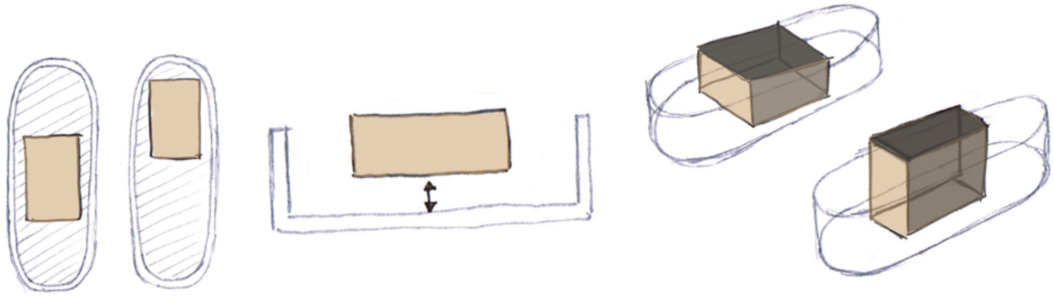
The Seller（卖方）: Shenzhen Telong Energy Technology Co., Ltd The Buyer（买方）:

Appendix 9: Choice of Concept

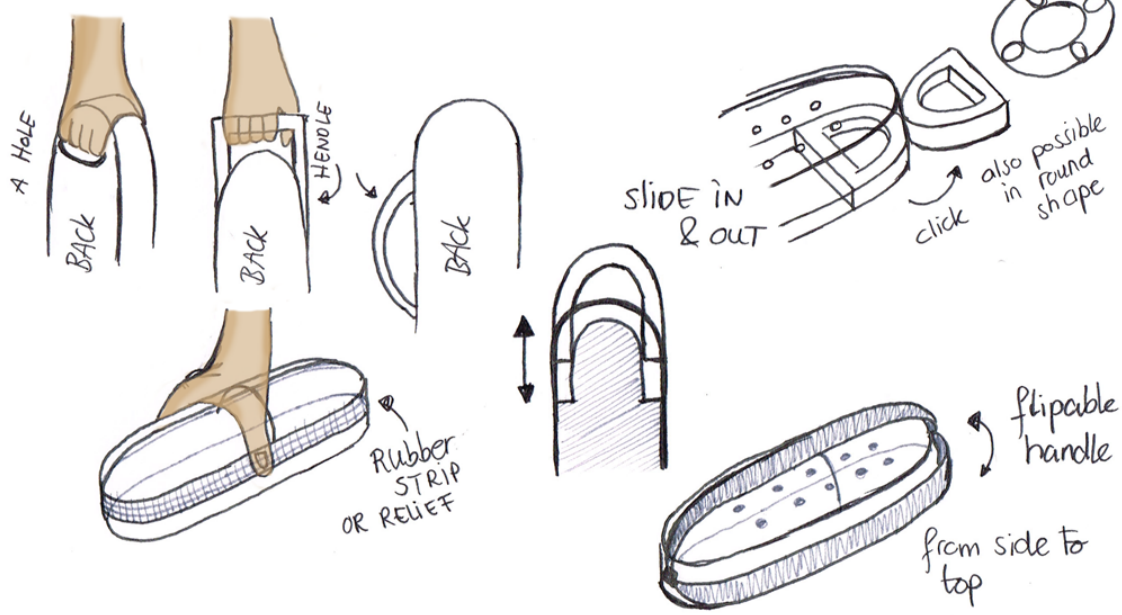
List of requirements	Concept 1	Concept 2	Concept 3	Points possible
Dimensions	10	10	9	10
Functions				
· Low / Medium / Full light- adjustment	same	same	same	
· Charging function for mobile phone	same	same	same	
· Energy function for radio	same	same	same	
· Display (indication) of the battery state	same	same	same	
· The lamp has to be able to hang	9,00	6,00	10,00	10,00
· The lamp has to be able to stand	10,00	10,00	10,00	10,00
Characteristics				
· The lamp should emit a minimum of 400 lumen, maximum 600 lumen	same	same	same	
· LED color: water clear white light	same	same	same	
· Minimum viewing angle of LED: 90 degree’s	same	same	same	
· Viewing angle of all LED’s together must be at least 300 degrees	10,00	9,00	4,00	10,00
· Maximum of 10 LED’s in one lamp	same	same	same	
· A fully charged lamp (on medium power state) should emit light (on medium power) at least 50 hours	same	same	same	
· Maximum weight of lamp: 2 kg	unknown	unknown	unknown	
· The charging connector of the lamp should fit with the components of the PCP of the drawer.	same	same	same	
Battery:				
· The battery should be environmental friendly	unknown	unknown	unknown	
· Rechargeable within 5 hours	same	same	same	
· Maximum 6V	same	same	same	
· Maximum 6Ah	same	same	same	
Design				
· The lamp should have a luxurious appearance	10,00	8,00	10,00	10,00
· The(charging) connecting part of the lamp (to the shelf)should match the PCB that’s already designed	same	same	same	
· The colors of the company should be recognized in the design: Dark green, magenta, Fluor green, gold, white	same	same	same	
· Filth should not easily be seen on the lamp.	same	same	same	
· The lamp should be easy to carry	8,00	7,00	10,00	10,00
· Dust proof / water resistant	same	same	same	
· The cover of the lamp should be transparent.	same	same	same	
Costs				
· Recharging the lamp should be cheaper than refilling a Kerosene lamp (less than 3 USD a month)	same	same	same	
· Cost of all LED’s for one lamp: max 0,40 USD	same	same	same	
· Maximum cost price of lamp: 6 USD	8,00	10,00	7,00	10,00
· Maximum retail selling price: between 8 and 14 USD (best for target-group with a salary of 35 USD	8,00	10,00	7,00	10,00
· Maximum Battery costs less than 3,50 USD	same	same	same	

Manufacturability				
· The casing should not have more 4 components that need to be produced. (as little as possible)	9,00	10,00	8,00	10,00
· The lamp should not have more than 20 components in total.	9,00	10,00	9,00	10,00
· As many components as possible should already be available on the market (buyable).	9,00	10,00	9,00	10,00
· The assembly should be done within X steps (as little proceedings as possible)	9,00	10,00	9,00	10,00
Transport				
· The total package of the end-product should have an as little volume as possible	10,00	10,00	8,00	10,00
· The components of the end-product should come from one region, so everything can be transported within one cargo.	same	same	same	
· The transport-costs should not be more than X procent of the cost-price of the end-product.	unknown	unknown	unknown	
TOTAL	**110,00**	**110,00**	**81,00**	**120,00**

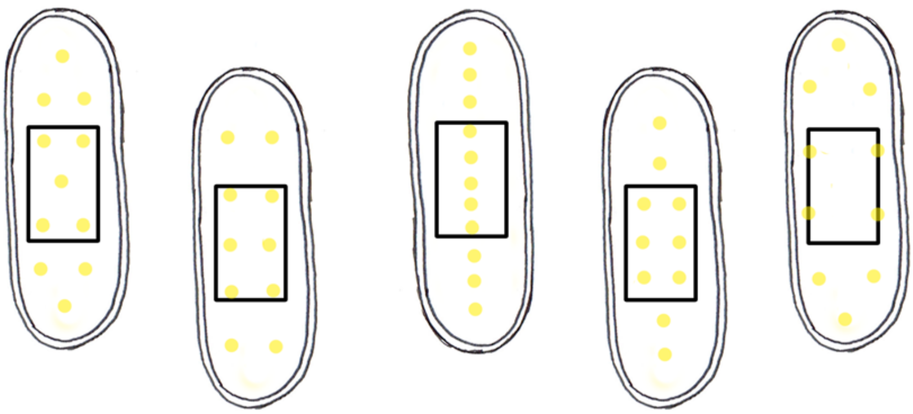
Position Battery_



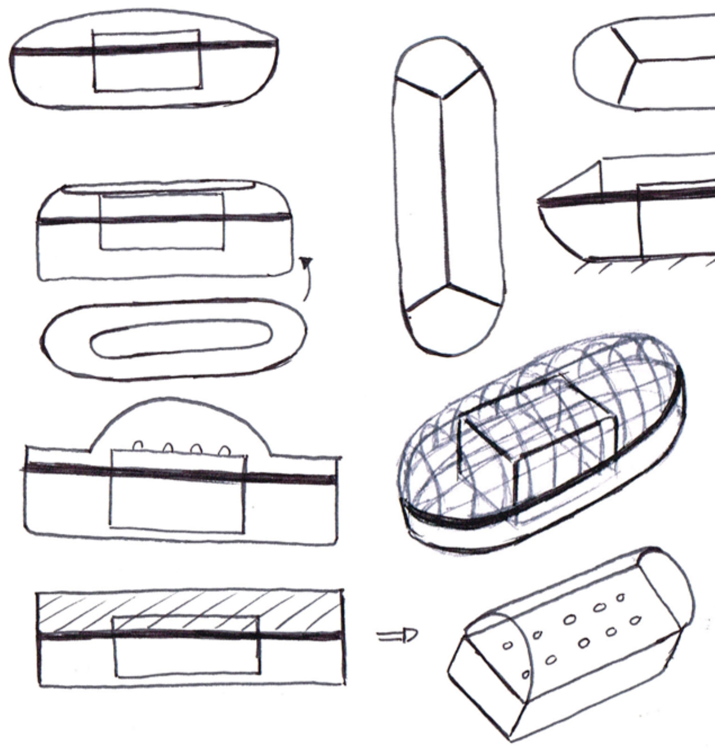
Ways to carry the lamp_



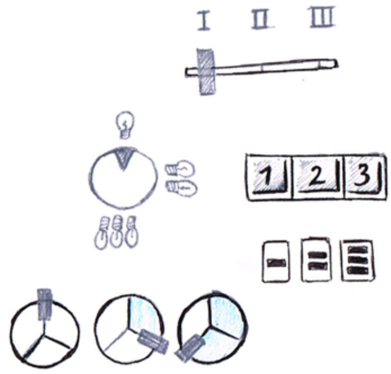
Position of LED´s



Shape of cover_



Low / Medium / High_



Important material characteristics:

What are the properties to take in consideration? (http://www.tpub.com/steelworker1/2.htm) :

Mechanical Properties

- ***Strength***: property that enables the material to resist deformation under load (permanent deformation).
  - Fatigue strength: ability to resist various kinds of rapidly changing stresses. (Fatigue strength at 10^7 cycles measured in MPA).
  - Impact strength: ability to resist sudden applied loads

  Measurement-->
  Yield strength: σ_y, the larger the σ_y, the stronger the material.
  The limit is the tensile strength, in which the material fails.
  Shear modulus: describes the material's response to shearing strains. (symbol: G, SI unit: pascal). G = $\frac{F/A}{\Delta x/l}$
- ***Plasticity***: the ability of a material to deform permanently without breaking or rupturing. This property is the opposite of strength.
  Measurement-->
  Hooke's law : σ=ε*E
  Or use a shear/stress rate diagram
- ***Hardness***: property that enables the material to resist permanent indentation. (symbol H, Vickers hardness test, unit: HV). HV = $\frac{F}{A}$ = $\frac{0.1891F}{d^2}$. The basic principle, as with all common measures of hardness, is to observe the questioned material's ability to resist plastic deformation from a standard source.
- ***Toughness***: the property that enables a material to withstand shock and to be deformed without rupturing: the amount of energy per volume that a material can absorb before rupturing (J/m^2). Toughness may be considered as a combination of strength and plasticity.
  Measurement--> $\frac{\text{energy}}{\text{volume}} = \int_0^{\epsilon_f} \sigma \, d\epsilon$
- ***Density***: Mass per unit volume (Symbol ρ)
- ***Elasticity***: the elastic limit of a material is the limit to which a material can be loaded and still recover its original shape after the load is removed.
  Measurement--> (Hooke's law →) Young's modulus: the measure of toughness of an elastic material. (symbol: E, SI unit: Pascal). E= $\frac{\sigma}{\varepsilon}$ (tensile stress / tensile strain).
- ***Brittleness:*** the opposite of the property of elasticity. A brittle metal is one that breaks or shatters before it deforms.
  Measurement-->
  Fracture toughness: (symbol K_{Ic} (stress intensity factor), SI unit: MPA * $m^{1/2}$): the resistance of materials to cracking and fracture.

Thermal Properties

- Melting point: temperature in which the plastic transforms from solid into liquid
- Melt Index: (important when using thermoplastics) used to determine which viscosity the thermoplast has.
- **Thermal diffusivity**: used to calculate heat transfer:

$\alpha = \frac{k}{\rho c_p}$ in which:

α : Thermal diffusivity (m^2/s)

k : Thermal conductivity

ρ: Density

c_p: Specific heat

- Thermal conductivity: how much heat the material can conduct.

  $k = \frac{W}{m*K}$

- Specific heat: The specific heat is the amount of heat per unit mass required to raise the temperature by one degree Celsius

  $c_p = \frac{J}{kg*K}$

Relevant Electrical, magnetic and optical properties

- Electrical Conductivity κ versus resistivity ρ
- Reflect-refract-absorb wavelength colors (light)
- Water absorption

and of course The Price per kilogram!

Useable Thermoplastics

- Acrylonitrile (15-35%) Butadiene (5-30%) Styrene (40-60%) (ABS) →

  Acrylonitrile : gives the thermal and chemical resistance.
  Butadiene: (rubber-like) gives ductility and strength
  Styrene: glossy surface, ease of machining and lower cost.

  The processing behaviour of ABS plastics is largely predictable from their chemical nature, in particular their amorphous nature and the somewhat unpleasant degradation products. (boek)

  Tough, resilient and easily molded material. Usually Opaque, although some grades can now be transparent. Non toxic.

- Polycarbonate (PC): is a group of thermoplastics (PA, POM, PTFE) that can be easily molded and thermoformed used in many applications. The material is durable, low scratch resistance, and has a high impact-resistantance. The characteristics are similar to PMMA, stronger but more expensive.

- POM: the characteristics of this material are similar to nylon, but stiffer. It is rarely used without an additive. The high price of POM, is because of the good moldability, fatigue resistance and stiffness.

- Polymethylmethacrylaat (PMMA): also known as acrylic glass or Plexiglas. It is a safer, lighter and shatter-resistant alternative to glass. PMMA is a amorphous, transparent hard plastic.

- Cellulose polymers (CA): the natural fibers of the cellulose can be combined with acetate, butyrate or propionate. The combination Cellulose acetate combines toughness, transparency and a natural surface texture.

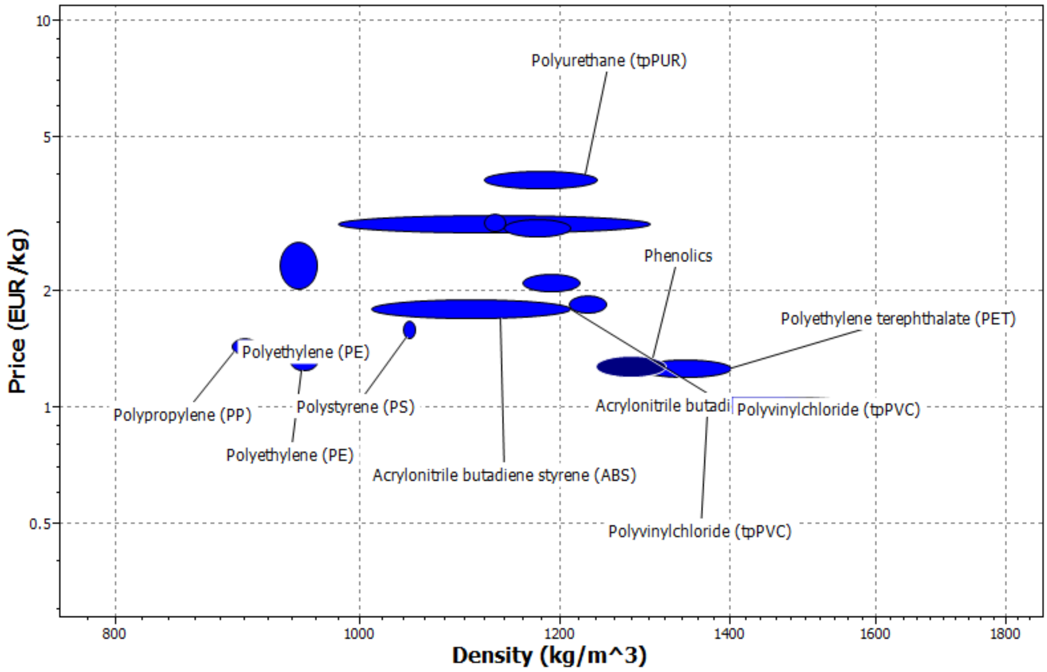
- Polyamide (PA) → Nylon
  Used today in: garment design, tires, product design for tough casings, frames and handles. Nylons are tough, strong and have a low coefficient of friction. Easy to injection mold.

- Polyvinylchloride (PVC): a hard amorphous material, that softens at around 85˚C. It is widely used in construction, because the material is durable, has good corrosion properties, is affordable and easy to color and assemble. Plasticizers can make the material softer and more flexible. The toxic aspect makes the product environmentally unfriendly.

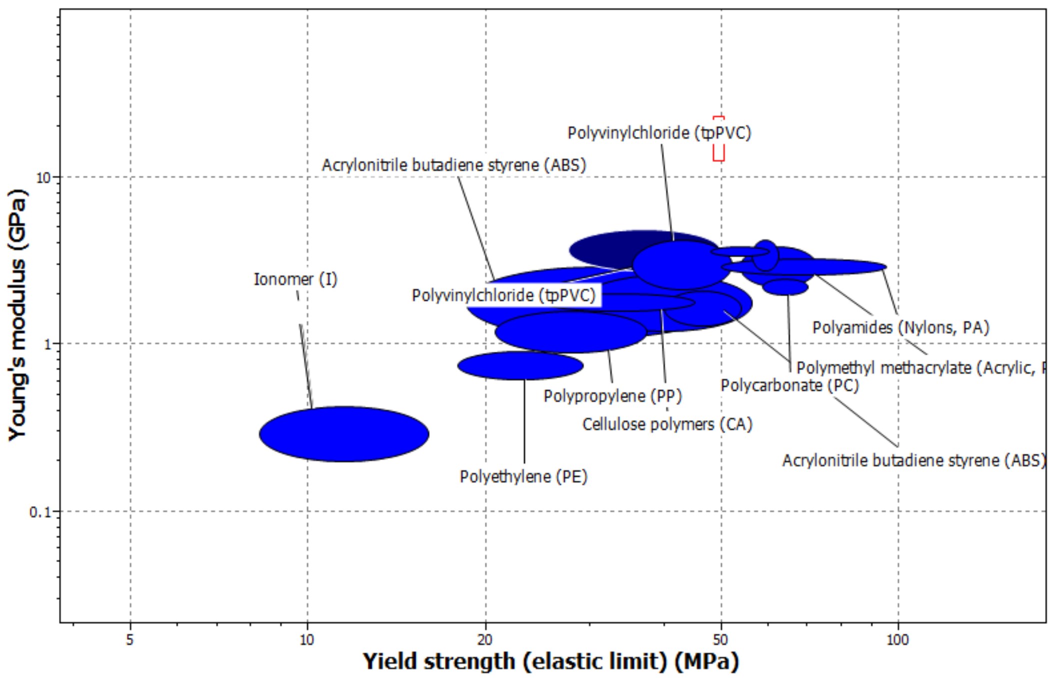
- Styreen-acrylonitril (SAN): has the same stiffness as High Impact Polystyreen, with a better temperature resistance and impact strength. The material is mainly applied in house hold products.

Bottom & CoverLED Part CES studie

Graph 1:

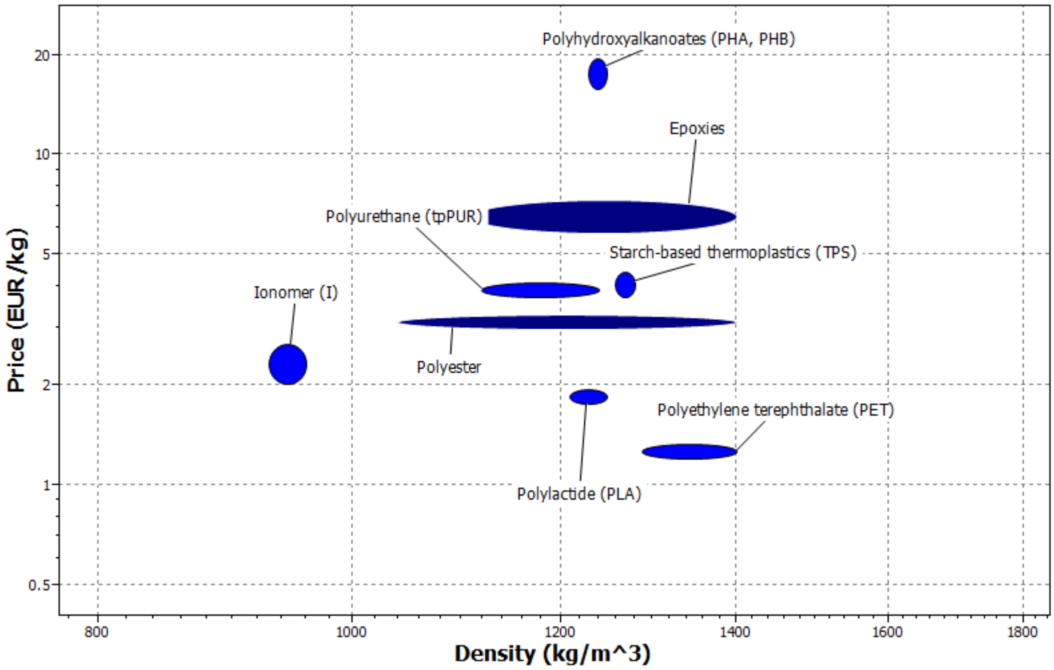


Graph 2:

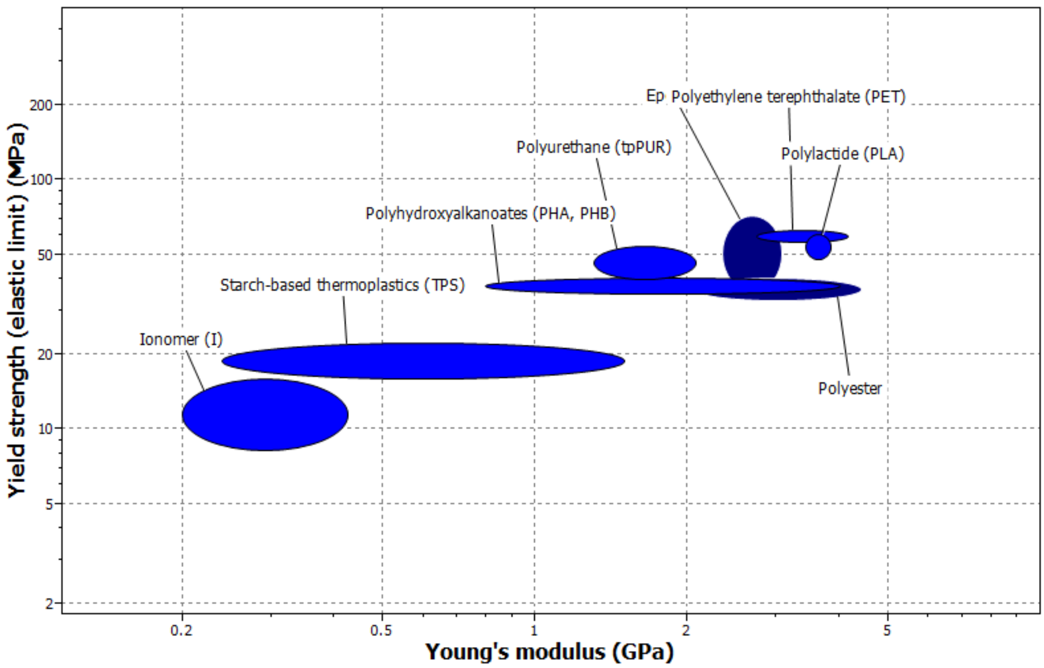


Main Cover Part CES studie

Graph 1:

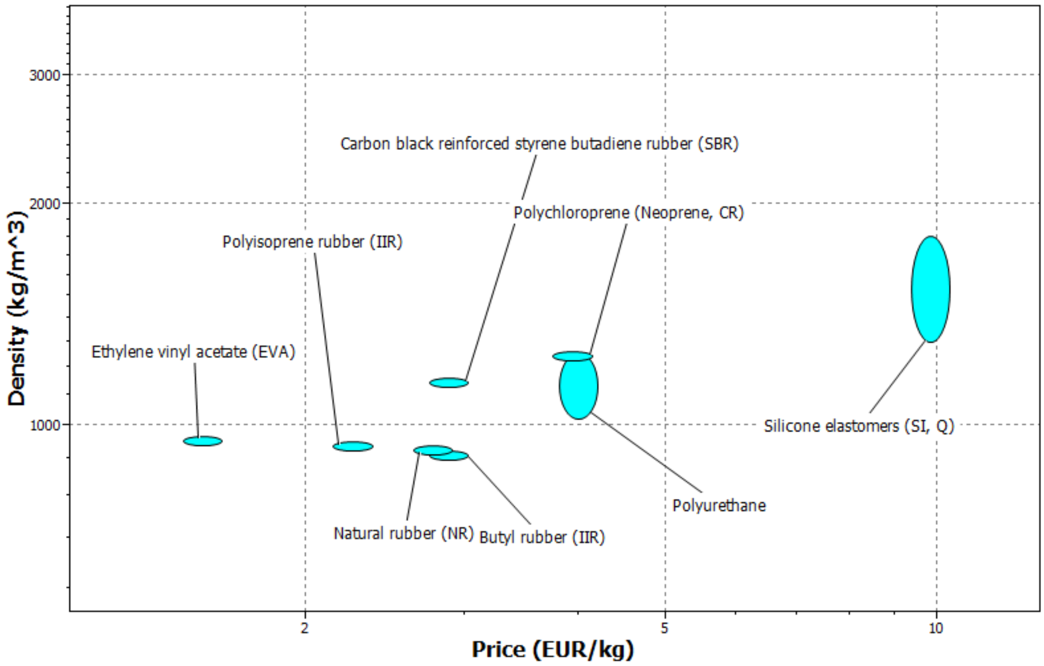


Graph 2:

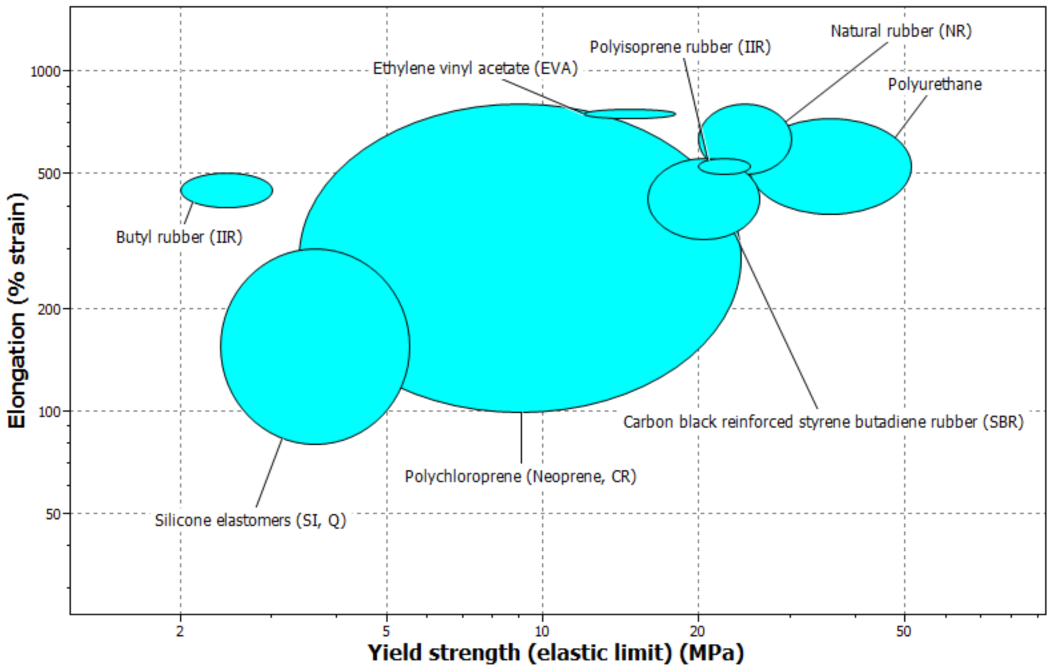


Rubber Part CES studie

Graph 1:



Graph 2:



Appendix 13: Cost Estimation Table

Part	Amount	R=real price E=estimation	M=Manufactured B=bought	Price a piece	Price	Remark
TELONG 6V5.5AH SLA battery	1	R	B	$2,99	$2,99	Telong Company
Trough Hole LED	10	R	B	$0,04	$0,35	Shenzhen JinPuLi electronic technology Co., LTD
USB Port	1	R	B	$0,30	$0,30	Shenzhen N-South Electronics Co., Ltd.
DC/DC Converter	1	R	B	$1,17	$1,17	Shenzhen Tosen Trade Limited
PCB (main)	1	E	M	$9,00	$9,00	Not Known
Wiring	1	E	B	$0,02	$0,02	Not Known
Buttons	1	R	B	$0,20	$0,20	Yueqing Toowei Electronic Switch Factory
On/off button	1	R	B	$0,10	$0,10	Yueqing Toowei Electronic Switch Factory
Signal light	1	R	B	$0,02	$0,02	Shenzhen JinPuLi electronic technology Co., LTD
Bottom part	1	E	M	$1,50	$1,50	Not Known
Cover LED	1	E	M	$0,50	$0,50	Not Known
Cover (main)	1	E	M	$0,65	$0,65	Not Known
Rubber Strip	1	E	M	$0,05	$0,05	Not Known
Screws	10	R	B	$0,02	$0,20	Not Known
Total					$17,05	