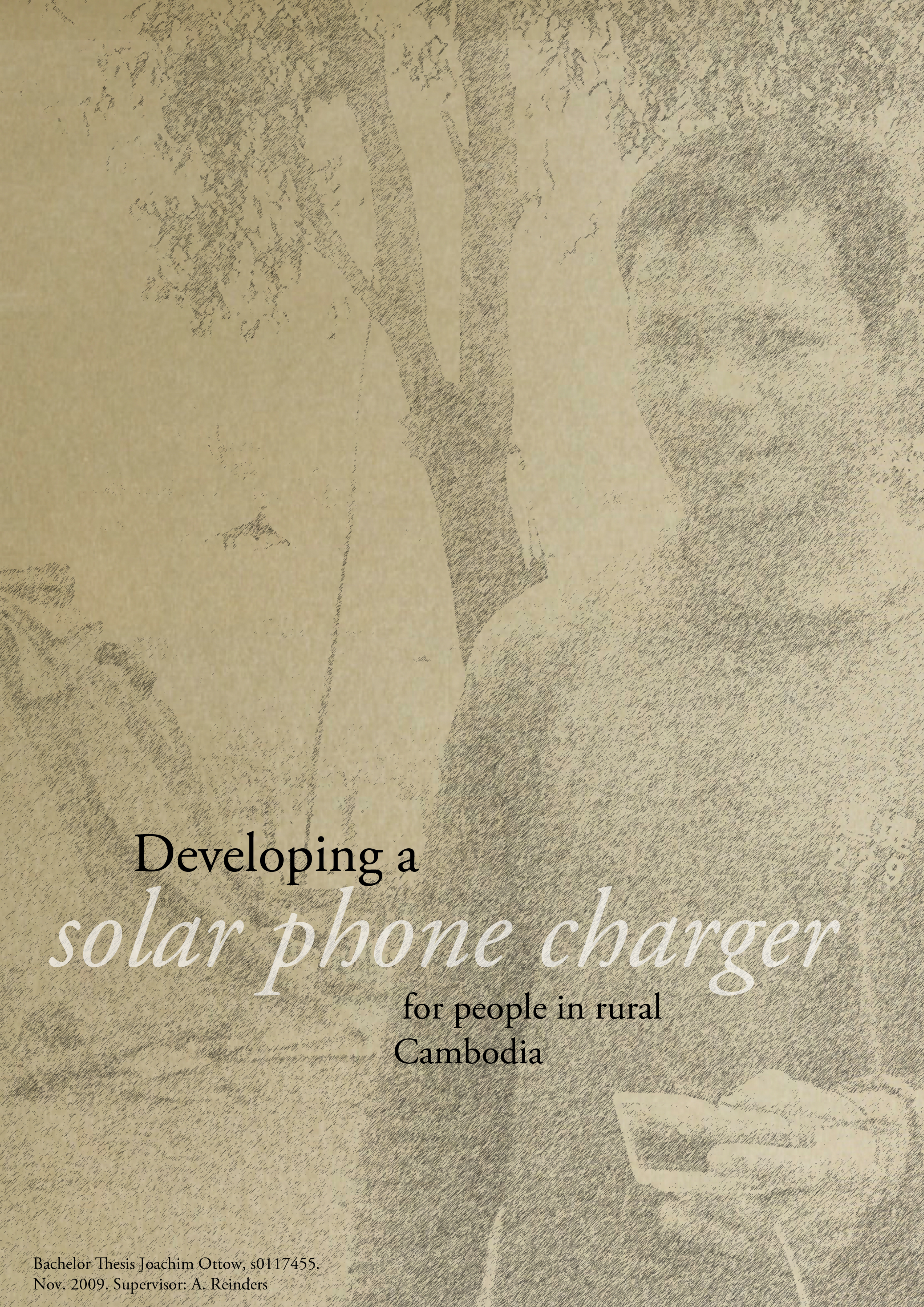

Developing a *solar phone charger* for people in rural Cambodia

Bachelor Thesis Joachim Ottow, s0117455.
Nov. 2009. Supervisor: A. Reinders

Preface

This document describes the process and results of my Bachelors Thesis. During the execution of the project and writing of this paper many people have been of great help, there for my appreciation:

Arjan Luxwolda & Jeroen Verschelling as supervisors from Kamworks,
Angele Reinders as a supervisor from Twente University,
Arie Paul van den Beukel from Twente University,
The employees and students at Kamworks and Picosol.

On a personal level I would like to thank
Hannah, my parents, family and friends.

Abstract

The assignment was to develop a solar powered charger of mobile phones for use in Cambodian rural areas. The design phase was for the largest part executed at the Kamworks location in Sre Ampil, Kandal, Cambodia. Detailing and finishing was done at Twente University, Enschede.

Important aspects of the design process were the market survey, prototyping and the production preparations. Most important features of the design were: integration with the Kamworks Moonlight and creating a product with two devices, a charger and a solar panel, developing a single-mold design for the product shell, setting recommendations and constraints for the PCB and allow manufacturing for a maximum price of US$12,-. The project would focus on efficient production and pricing rather than usability and design. Time to market was considered to be more important than an aesthetically pleasing and refined design.

The final design is able to charge a Nokia mobile phone battery once with the electricity that is generated by the solar panel on the average Cambodian day. Because the average users charge their phone once every 3 days, the product should be able to support the batteries of a family with 3 mobile phones. When users leave for an extended period they can take the separate charger with them to charge their phone when it's batteries are empty, increasing total battery life.

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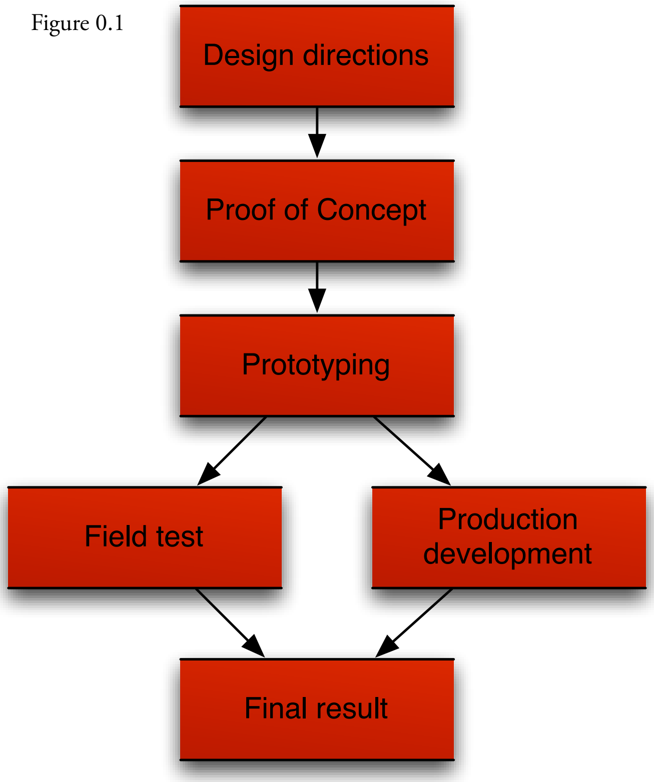
Layout of the Report

The basic lay-out of this report is derived from the design process, which is shown in the diagram, Figure 0.1. At first design directions were set out, these present guidelines for the rest of the project. Then a proof of concept is made, which consisted of a survey with the local population. Results provided feedback on the design and expectations of the end users, creating a prototype reflecting was the next step. The last stages of the process were a simultaneous field test and the production development.

Figure 0.1



1. Introduction

This chapter gives a brief introduction on the sectors of the country related to the development of the Solar Phone Charger and describes the framework of the assignment. A country study is in Appendix I.

Figure 1.1

1.1 Sectorial Background

The information on the sectorial background gives an impression of the state of Cambodia's solar and electricity development. The largest group suffering from problems on electricity issues is the rural population.

1.1.1 Country

Even though the government and (inter)national organizations have put effort in developing a stable environment for development the country is still struggling with many problems. Being the 7th poorest country of Asia's 32 countries Cambodia is ranked 109th on the 2008 GDP World rank with a GDP of $818,- a year (GPG, 2008). The amount of people below the poverty line is estimated on 35%, of which most live in rural areas. Inequality appears to be increasing and economic growth has only been benefiting a narrow urban base of the population. On the flip side the growth of 9.62% of the GDP per capita over the last 5 years has placed Cambodia just below China, Turkmenistan and Azerbaijan (World Bank, 2006). Unfortunately the meltdown of the global economy has slowed down this growth substantially during the last months.

1.1.2. Rural population

Cambodia has a large rural population, an estimated 85 to 90% of it's total inhabitants. Of these rural people most primarily make their living with agricultural activities like farming, fishing, keeping livestock and harvesting other natural resources. People in these areas, like in most rural areas, exhibit at least some of the following characteristics, as defined by Focus Group 7 of the International Telecommunication Union (Focus Group 7, 2000, page 1):

- "scarcity or absence of public facilities; reliable electricity; reliable electricity supply, water access, roads and regular transport
- scarcity of technical personal
- difficult topographical conditions, e.g. lakes, rivers, hills, mountains or deserts, which render the construction of wire telecommunication networks very costly
- severe climatic conditions that make critical demands on the equipment
- low level of economic activity mainly based on agriculture, fishing, handicrafts, etc.
- low per capita income
- underdeveloped social infrastructures (health, education, etc.)
- low population density
- very high calling rates per telephone line, reflecting the scarcity of telephone service and the fact that large numbers of people rely on a single telephone line"

Many of these characteristics are applicable to Cambodia's rural territories, and all of these influence the availability and spread of electrical power supply. According to statistics only 8.6% of the rural population is connected to the grid while in contrast 53.6% of the urban population has electricity available by this mean. To use electrical equipment 70% of the households make use of batteries, which can be charged at a price in shops or by neighbors who happen to have an electrical generator. This has several disadvantages, prices are high, batteries have to be transported, availability of electricity is limited and batteries often have a bad impact on the environment after disposal. This illustrates the need people have for independent, affordable and locally available power supply.

1.1.3 Solar energy

Cambodia is a country with good solar potential with an average low of 4.11 kWh/m2 in the north-west of the country and an average high of 5.23 kWh/m2 in the south. The average amount of solar radiation on the entire country is 4.67 kWh/m2. As a mobile phone uses an average of 2.5 W per charge and they are estimated to be charged twice a week they would use 260W per year, one square meter would thus theoretically be sufficient to power 18 mobile phones for a year.

1.1.4 Solar technology and prices

Although solar energy is abundant, the availability of photovoltaic cells to turn this potential energy into electricity is lacking. Because the technology is relatively new, prices are high and the availability is low. But as prices of small solar panels have started to drop in the last couple of years, many new applications have been found. A lot of small chargers based on solar technology have been introduced and sold in Western countries, unfortunately prices often range from $59,- to $150,-. As the people in rural areas earn less then $120 a month on average, these products are not affordable for them.

1.1.5 Governmental involvement

As a resource for electrical energy, solar technology is very new to Cambodia. But as the website of Rural Electrification Fund Cambodia shows, active promotion and application of solar energy technology is at a rise. The Cambodian government has set up a Renewable Electricity Action Plan which consists of five guiding principles:

1. Renewable energy technologies will be used when they are economically most cost effective
2. The RGC will serve the role of market enabler
3. Private sector firms will serve as market developers and suppliers

4. Decision on renewable electricity development for the needs of the poor
5. Subsidies and credit will be used carefully

Additionally the Action Plan's long-term goals are:

1. 5% of all new installed capacity, or about 6MW of mini hydro and 850 kW of village hydro, will be supplied by renewable electricity technologies and delivered to rural households or businesses
2. 50 000 new households connected by Rural Electricity Enterprises (REE) off-grid extension
3. 12,000 households will be served by solar photovoltaic energy
4. A sustainable market for renewable electricity system should be developed

1.1.6 NGO's and organizations

Not only the government is actively involved in the production and distribution of solar technology, in fact the government tries to include many private organizations and NGO's to reach the goals set in their Action Plan. This includes the World Bank, UNDP, Rural Electrification Fund Cambodia, Renewable Energy Private Sector Association (REPSA), Rural Electricity Entrepreneurs (REE) and some other small organizations.

1.1.7 Mobile telecommunications

While it might be surprising, the mobile telecommunications sector is relatively well developed in Cambodia, many people have phones that provide basic connectivity to improve businesses and to stay in touch with family and friends. Many households already have mobile phones there are some initiatives to improve the availability of these. One example is the 'Cambodia Village Phone Company'. Their goal is to connect rural communities through mobile phone technology and create socially responsible and sustainable business in Cambodia. This also involves education about phone usage and sharing knowledge on telecommunications to benefit these people.

In the last couple of years the growth of mobile telecommunications has grown significantly, from 1 million users in 2005 to 2.6 million at the start of 2009 (Asiaecon, 2009). Considering a family to be 3 people, taking in account some households have multiple phones, at least 54% of the population has access to mobile communications, of which the largest amount is settled in the urban areas. In rural areas surrounding Phnom Penh and other large urban centers the penetration of mobile communication is also high. These areas often lack a grid connection and therefor rely on expensive charge services. Many households use a car battery that powers most of their electronics. A major problem with using these is the inability to use or charge any electric devices when there is no money to charge an empty car battery. As mobile communication starts to become much more essential for people to stay in contact and gives them opportunities to enter in the available markets of dealers and traders, an empty phone battery can be a problem. Providing affordable electrical power to these impoverished people would in the first place improve their standard of living by for example providing safe lighting but also empower them to make better use of modern communication tools.

1.2 Framework of the assignment

Combining both my technical background, Industrial Design, and the minor 'As the World Turns' into one field study has had my preference for a long time. As turned out to be a combination of the minor and bachelor thesis could be made. Via the Industrial Design Bachelor coordinator I got introduced to Kamworks in Cambodia, a small solar company located in the village Sre Ampil, at about 24 km east of the capital Phnom Penh. The companies primary business is the development and application of energy services in rural Cambodia. The mission according to their website is:

To provide affordable energy systems in order to contribute to sustainable development.

A study by Kamworks revealed that the average costs of charging a mobile phone are $0,4 per charge with an average of three days between charges. This would result in an annual expenditure of $48,- and is a lot on an average budget of $1000.- a year, of which most is spend on housing and food. The study furthermore revealed that the price most people would want to pay for a solar charger ranged to $10,-, less then 20% was willing to pay $11,- or more.

Bringing the majority of the Cambodian population in contact with solar energy could also open up the market for more of their current and future offerings. Kamworks has imported some solar chargers but they were not of very good quality. Therefore the company would like to develop a new solar charger that does comply with expected standards.

1.3 Problem definition

The goal of the assignment is to design a solar charger for mobile phones that is going to be manufactured and sold by Kamworks in Cambodia. This project will primarily focus on the manufacturing and use of this product. Knowledge gathered in earlier products made by the company will be used in the market and target group analysis which will lead to a set of product guidelines compiled in the list of requirements. A number of concepts will be sketched that will result in a visual prototype and if possible a completely working test product. For manufacturing a 3D model will also be produced. To sustain the product for future upgrades a list of recommendations will be made that can be of use for Kamworks in future updates to the product. The design process will be an elaborative process with Tim van Steen who will design the circuit board. A total time of 4 months will be spent on this project.

Methodology

To support the design process the following questions have been used. These questions acted as guidelines to prevent neglecting important aspects of the design process and outline the assignment strategy.

1. What does the market for phone chargers look like?
    1.1. What are current (solar) solutions for charging mobile phones?
    1.2. What are benefits and disadvantages of these current solutions?
    1.3. In what way can current solutions be improved?

2. What defines the target group?
    2.1. How much knowledge does the target group have of solar electricity?
    2.2. What do the living conditions of the target group look like?
    2.3. What does the target group consider to be esthetically pleasing in a design?
    2.4. What does the target group consider to be important in the functionality of a solar phone charger?

3. What are design requirements from the client?
    3.1. What are legal requirements considering the product?
    3.2. What are requirements considering functionality?
    3.3. What are requirements considering the esthetics?
    3.4. What requirements does the environment put to the design?
    3.5. To what extend does the charger need to be repairable/serviceable?

4. How can the charger be manufactured?
    4.1. What are the components in the product?
    4.2. From what material will the product be manufactured?
    4.3. What machines are necessary for production?
    4.4. Where will the components be manufactured?
    4.5. Which partners have to be found for production?

2. Design Directions

The first design phase was started after a series of interesting conversations with Jeroen Verschelling, Director of Kamworks, Tim van Steen of the electronics, Mariska Rooijakkers, a student working on the Moonlight at that time, and reading the report of Team Lumen who developed the Moonlight, an earlier solar product by Kamworks. It seemed to be a good approach to make some preliminary designs and see how people would respond in a field test. But first some directions were mapped considering potential product features, existing products and the Kamworks product line. Eventually a preliminary List of Requirements (LoR) was compiled.

2.1 Electronics

The electronics student Tim van Steen worked on the project from February till June. At my arrival in Cambodia, in April, several choices on the design of the electronic system were already made. Tim developed the charger to work with Nokia phones only and used an official Nokia NHM-5NX manual to develop the electronics to its specification. Tim did measurements on the behavior of batteries available form Kamworks, and also used in the Moonlight, as well as the solar panels that would be used. The batteries could only provide a voltage of 2 x 1.2V together, which is too little as the charge voltage of a Nokia battery is 5.5V~6V. Therefor Tim had to design a voltage booster. This is a electronic circuit that boosts a low voltage to a higher one. Tim developed two versions of this booster circuit; one with an ATtiny13V 8-bit micro-controller and one with a ZXSC voltage mode boost converter. The ATtiny13V version would be a programmable circuit that could later easily be expanded with additional functionality while the ZXSC circuit would need additional hardware to add functionality but have the benefit of being easier to manufacture and cheaper as well.

2.2 Kamworks Products

The company basically has two low-cost consumer products, the first is the *Angkor Light* that has been in development since 2006 and is scheduled for a release in 2010. It holds a CFL lamp and powered by a solar panel that can be put on a roof or supporting pole. This lamp is aimed at richer rural households and will have a price of about $60.-. The other product, the *Moonlight*, has more affinity with the Solar Phone Charger. It is aimed at poor rural people and should cost about $18.-. The target group for this lantern are people that still depend on fire prone or expensive energy sources like kerosine and car batteries. To retain similarity in the product line-up of Kamworks and to reduce development and production cost, the Solar Phone Charger was to use a solar panel, batteries and connectors similar to the Moonlight.

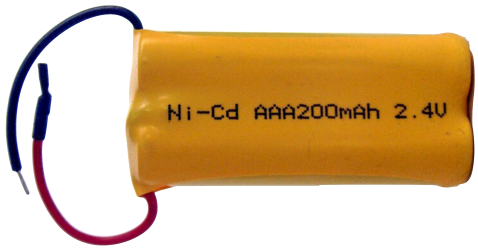
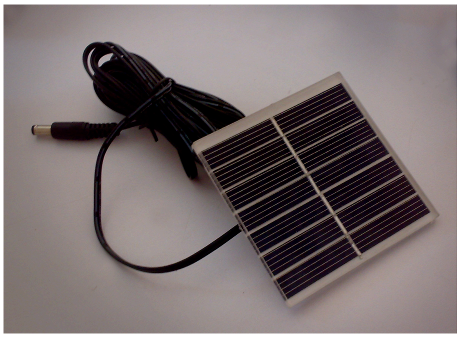
Figure 2.1

Angkor Light	Moonlight	Solar Phone Charger

2.3 Solar Phone Charger & Moonlight integration

The field test conducted by Mariska revealed people had very little knowledge of solar energy and solar products. The most common mistake of the participants was to place the solar panels inside, vertically or aimed at the North. Mariska's recommendation was to make use of a horizontal solar panel to increase the ease of use and probability of proper installation, which will increase efficiency and make satisfied customers. The downside of this solution would be a lower power yield. Tomas Jansen, an electronics student, did research into this and showed the solar panel would still deliver sufficient energy to charge the batteries. Making a new design for the panel support, as it will be called from now, would become part of this assignment as well. As the panel support had high priority, it had to be finished for the Moonlight product launch in summer, the design of this part went before the design of the charger itself. Even though the products were not developed simultaneous for this report the design stages of both projects will be discussed in the same chapters.

Figure 2.2

	
Kamworks Batteries	Solar Panel with wire

2.4 Mapping of directions

By first looking at possible directions for the charger that could be useful, the project focus would narrow. Keeping in mind the work of the Electrical Engineer, Tim van Steen, who had been developing two electric circuits; one basic circuit comprised of necessary "blind" elements and a sophisticated micro-controller version. As a guide in this process a gradation of households was used which shows 4 different classes of household according to material used for building. This is useful in the identification of target groups. The groups can be seen in Figure 2.3.

Figure 2.3

1 2 3 4

1. The cheapest possible product with a price of $10.- at the most. This would be a simple charger, a casing with batteries and separate solar panel housing (based on the Moonlight). This device would be aimed at the poorest part of the people, but could of course also be useful for families with a higher income. The simplest electronic circuit would be used and only be able to charge Nokia phones, the most common brand in Cambodia. Simple LED feedback could be achieved but adaptation of this feature is questionable because of the targeted price range.

2. A midrange product aimed at all but the poorest people with a price of $20.-. This product would be similar to concept 1, but would differ in terms of functionality and components. As the Electrical Engineer developed two circuits, the second, micro-controller, version would be used. This would give extended opportunities for a feedback LED that indicates charging and

capacity of the product. Functionality could later easily be expanded using new soft and hardware. Additionally different connectors can be provided making it possible to charge a more devices using the USB standard. Optionally would be the addition of a battery compartment, this could be used to recharge AA-batteries that can be used in other products like radios, lanterns and headlamps. As this functionality is not per se necessary this feature is considered to be premium. A product with such functionality would primarily be aimed at richer rural people without grid connection

3. An all-in one portable device aimed at people that need mobility with a price of more than $15.-. This would provide farmers and common travelers with the possibility to charge where ever they are and feature connection possibilities to fasten the product in a variety of ways.

4. An product featuring expandability, using multiple solar panels or batteries will for example increase capacity. This gives people the possibility to buy modular and expand the product to their wishes. This can be a combination of earlier mentioned features. Pricing would depend on the choice of the customer.

2.5 Existing mobile chargers

After defining these groups the next phase, the market analysis, was started. This mainly involved looking at competing products that are sold in Europe and America. Small cheap solar products of bad quality are already entering the market of Cambodia. Therefor these products will also be taken into consideration. Aspects of interest are: Design, Material, Price, User Interface and Functionality. In the following table, Figure 2.4, a selection of products from the international market is shown. These images portray a series of different functions and shapes current products have.

Figure 2.4

		
single AA battery, small and easy, no solar power	many connectors, 2 AA batteries, cheap, Chinese quality	can charge with USB, LED feedback, modern shape
		
battery charger (AA/AAA) via USB and AC, small form factor	two solar cells for more power, foldable, pricy construction	simple all-in-one design, very large, robust and bulky

		
small panel, connect 4 panels together, external battery	various attachment possibilities, use on a (motor)bike	small solar hanger, gadget, small capacity, cheap

2.6 Function Analysis

Possible functions of the Solar Phone Charger were graded from 1 to 5 to give an indication of the importance of a function. This gradation gives an indication of the primary and secondary functions.

Function	Grade
Produce electricity from solar energy	5
Supply one battery charge for a mobile phone	5
Stop charging when the devices internal batteries are nearly empty	4
Show charging of the internal battery	3
Show when the internal battery is full	3
Automatically start charging when a mobile phone is connected	2
Show state of internal battery while charging	2
Provide a possibility to to hang the device	1
Charge AA and AAA penlight batteries	1
Allow several brands of mobile phones to be charged	1
Charge non-phone electric devices, for example MP3 players	1

2.7 Preliminary List of Requirements

Using the information gathered a preliminary List of Requirements was made as a basis for the next part of the design phase. Four distinct categories were made wherein functionality, pricing and usage was gathered and specified. During the entire project this formed a blueprint of the final product design.

1. General
   1.1. The design should fulfill in the needs of the local population to charge their phone.
   1.2. The price should be a maximum of $15.-

1.3. The product will exist of two separate battery and solar panel devices.

2. The device
   2.1. Users will have to be able to use the device intuitively.
   2.2. Charging of the device by the solar panel should be sufficient.
   2.3. The ability to charge Nokia phones.
   2.4. The device should endure usage in the Cambodian environment.

3. The solar panel
   3.1. The solar panel is compatible with the Moonlight system.
   3.2. The panel support should protect the solar panel from UV radiation, water and other exterior threats to the functioning of the solar cells.
   3.3. The panel support will have to be mounted on a bamboo pole.
   3.4. The solar panel will be mounted horizontally.

4. Safety
   4.1. Installing and using the product should in no way endanger the users safety.
   4.2. The device should not damage mobile phones during charging.

3. Proof of Concept

The second stage of the development process consisted of closing and defining he borders wherein the product would be developed, this was done with a concept design. People in Cambodia have little or no experience with solar products, therefor it was decided to make a working prototype to show the people what the products functionality and use. The first step was concept generation, making of a first prototype and the testing of concepts in a combined market survey and target group analysis. The result was a preliminary List of Requirements.

3.1 Concept Generation: *Panel support*

Based on Mariskas advice it was decided to make the panel support horizontal. This would prevent foul installation which increases the efficiency and thus reduces the time for charging. In earlier projects several other designs were made for the panel support. In Figure 3.1 a short overview of the panels used earlier for the Moonlight. All these designs had to cope with a change in solar panel, the last version (3rd) was designed to use the same solar panel as the final panel support. This third design was found to be too bulky and use too much material. Therefor Kamworks asked for a simpler design.

Figure 3.1

Original Panel & Support	Second Panel & Support	Third Panel & Support

Production possibilities were thermoforming and injection molding, therefor designs would be made for both techniques. A note on this regard would be slight preference of Kamworks for thermoforming. This would allow local production, which is one of the key points in Kamworks mission statement. But this point would be valued under the cost of production when comparing options.

3.1.1 The solar panel

As the panel support is based on components of the Moonlight the solar panel that was going to be used was already defined. The panels are produced in China and have a glass top layer. Glass based solar panels are produced in large plates and then cut into smaller pieces. These pieces can be custom made, Kamworks decided to use 80x85mm panels. These provide enough energy to charge two AA-batteries completely on 80% of the days of the year. On the remaining days the product will function, but not be able to supply a complete charge. Calculations on this part have been done by Tomas Jansen.

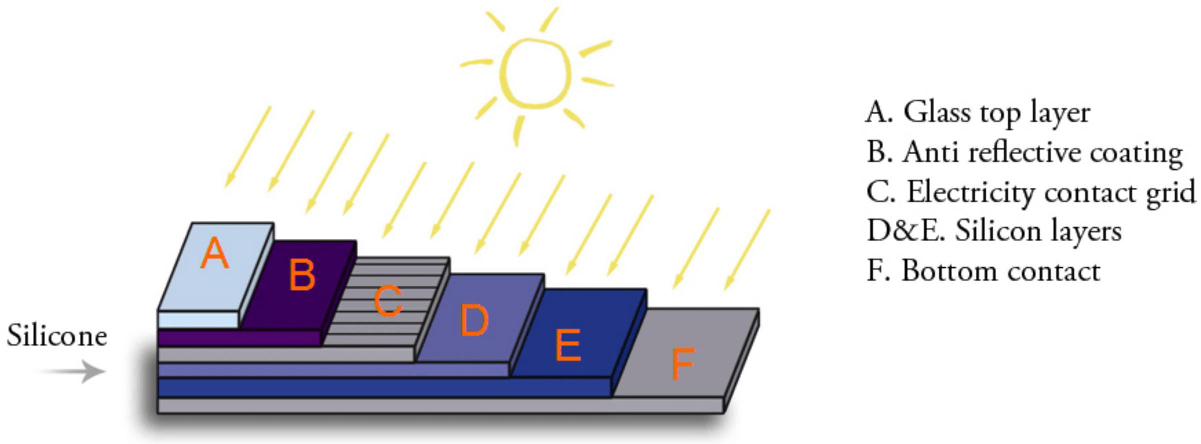
3.1.2 Solar radiation

Important considerations with the design of the panel support was water penetration and material degradation by solar radiation. As Cambodia has an average of 4.67 kWh/m^2 this is an important issue to keep in mind. The decision for a glass top layer instead of one from resin has to do with the lifespan of resin with such high solar radiation. Resin is mainly used in cheap solar products because of the easy manufacturing, but exposure to sunlight will slowly degrade the material and turn it white. As a result the resin layer will no longer allow light to pass through and reach the solar cells. This makes the product useless. Glass is thus the only option for a reliable, durable product.

3.1.3. Water penetration

The decision for glass based solar panels does bring one problem, glass based panels are built up from single flat layers (as seen in Figure 3.2) and then cut into smaller pieces. This leaves the sides of the panel open for liquids to enter. When water enters through these sides it will damage the solar cells and reduce the yield of the product. It is therefor necessary to make sure the sides of the product are closed properly. A common solution to do this is the use of silicone.

Figure 3.2



3.1.4. Thermoforming

Trying to thermoform the panel support out of one single piece was quickly found impossible because of several design problems: the larger the product gets the thinner the wall thickness becomes, to maintain enough strength this wall thickness is necessary. Too little material will lead to cracks in the product during manufacturing or after stress in usage, eventually destroying the product. Therefor a design with a separate connection frame was made to fasten the panel support to a pole. This frame would be made of metal to support the panel and could be fixed using two nails. The panel could be mounted in several different ways to a pole. The options tested at Kamworks are shown below. The most viable option was chosen eventually chosen, this is shown in Figure 3.3.

Figure 3.3

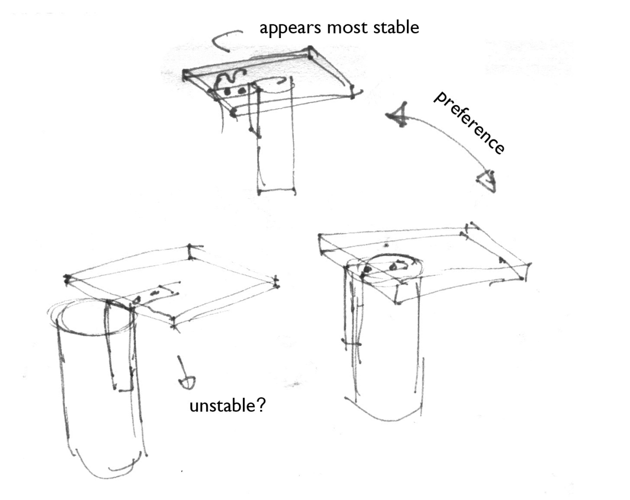
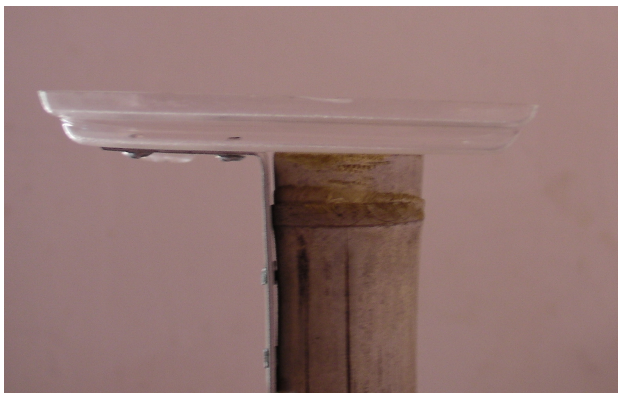
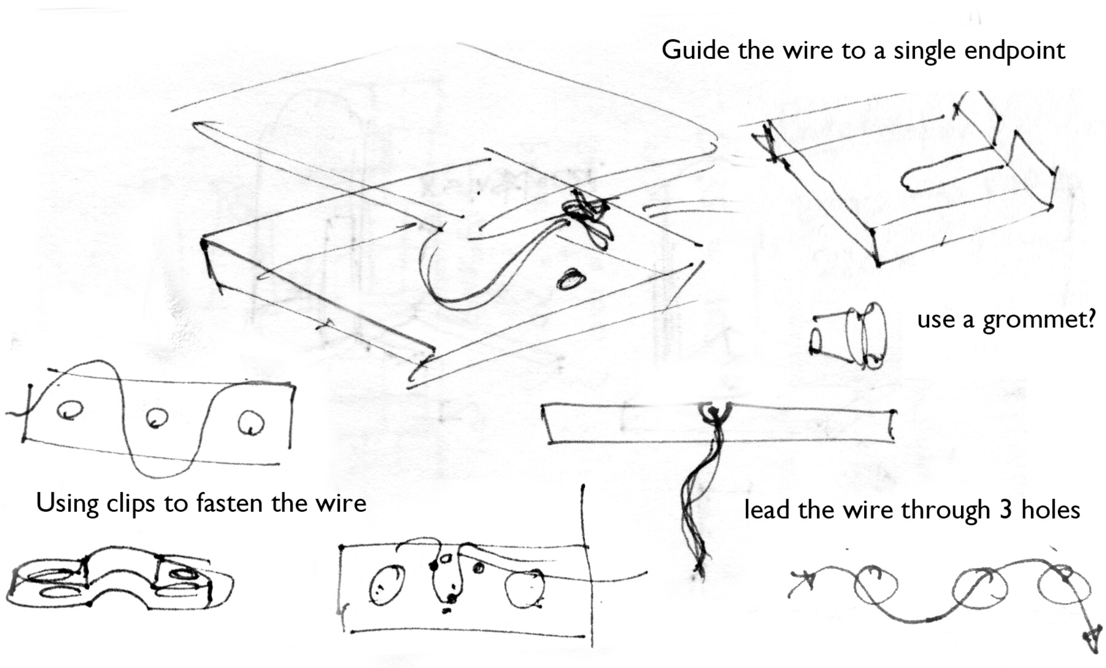
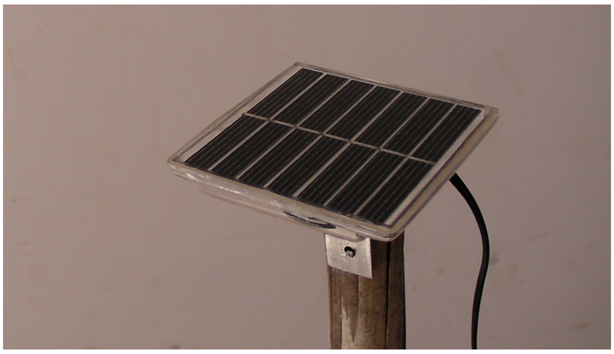
	
Sketches	Model

Figure 3.4



To make sure that the electricity cable would not come loose from the panel a pull-protection was introduced. The electricity cable would be tied into a knot twice and form an obstacle for the hole of the wire in the panel support. Even though other solutions were also considered and are shown in Figure 3.4, these would require additional operations or components, like for example adding a metal strip, using a grommet or adapt the thermoforming product. The knot would only require a simple hole to be drilled in the bottom of the support. The entire product would then be finalized with silicone which both fastens the solar panel in the support and prevents water to penetrate the solar panel. The finished model is show in Figure 3.5.

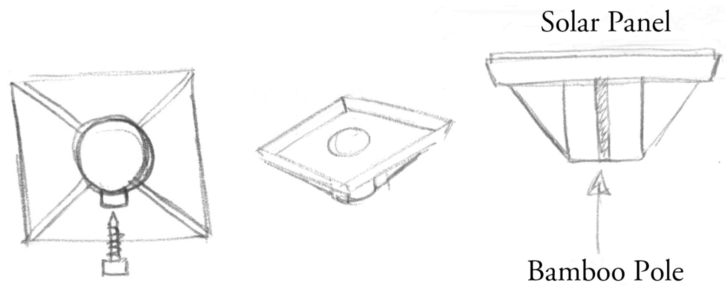
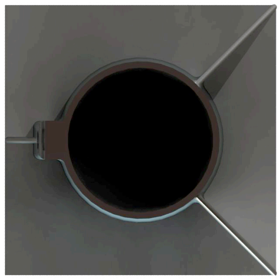
Figure 3.5

	
From below	From the top

3.1.5. Injection molding

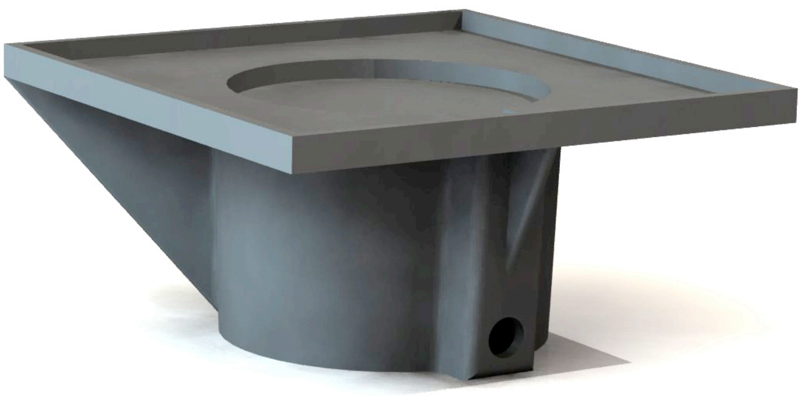
As a second option an injection molding design was developed. For this design a clamping mechanism would be used. A tube would be placed on the pole and a bolt would then fasten the pole to this tube. A sketch of this design can be seen in Figure 3.6. To give the panel support more strength ribs were added. In the first design there were 4 ribs, but later this was reduced to three, combining the two ribs in the middle. This was found to be the minimum as two ribs would not be able to support the construction entirely as four ribs were found to be to much. The ribs would be distributed like a star as visible in picture. The 3rd rib would also function as a guide for the electric wire of the solar panel and thus because of its thickness be able to give enough support.

Figure 3.6

	
Sketches of the first Injection Molding Concept	Star of ribs

An overview of the design can be seen in Figure 3.7. No model was made of this product because of the complex structure. But there have been some tests with a tube of the same thickness and diameter. These tests did show that there should be some sort of protection to prevent the user from tightening the screw to much, the force acting on the tube would deform and weaken it.

Figure 3.7



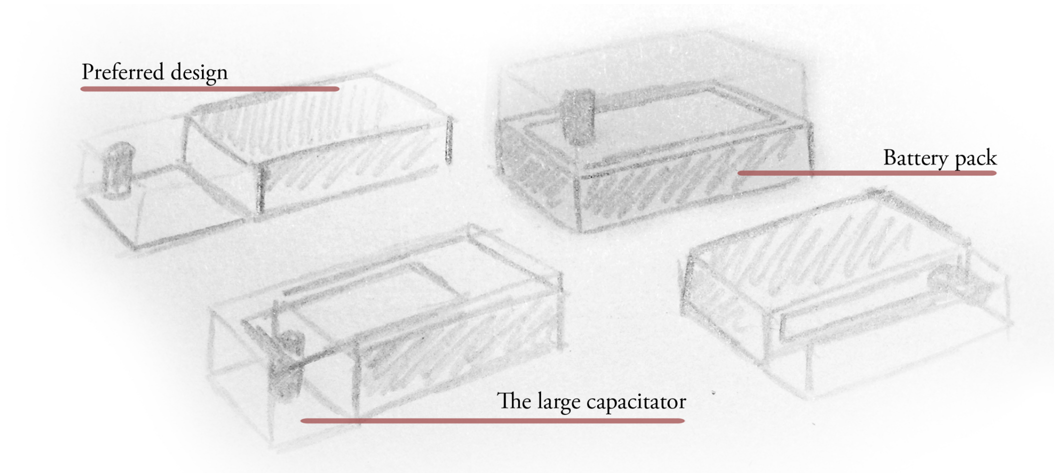
3.2 Concept Generation: *Charger*

As the Solar Phone Charger focus has to be primarily on a low price to make the product available to poor people the concept generation was primarily focussed on the development and integration of functions in the design.

3.2.1. Components

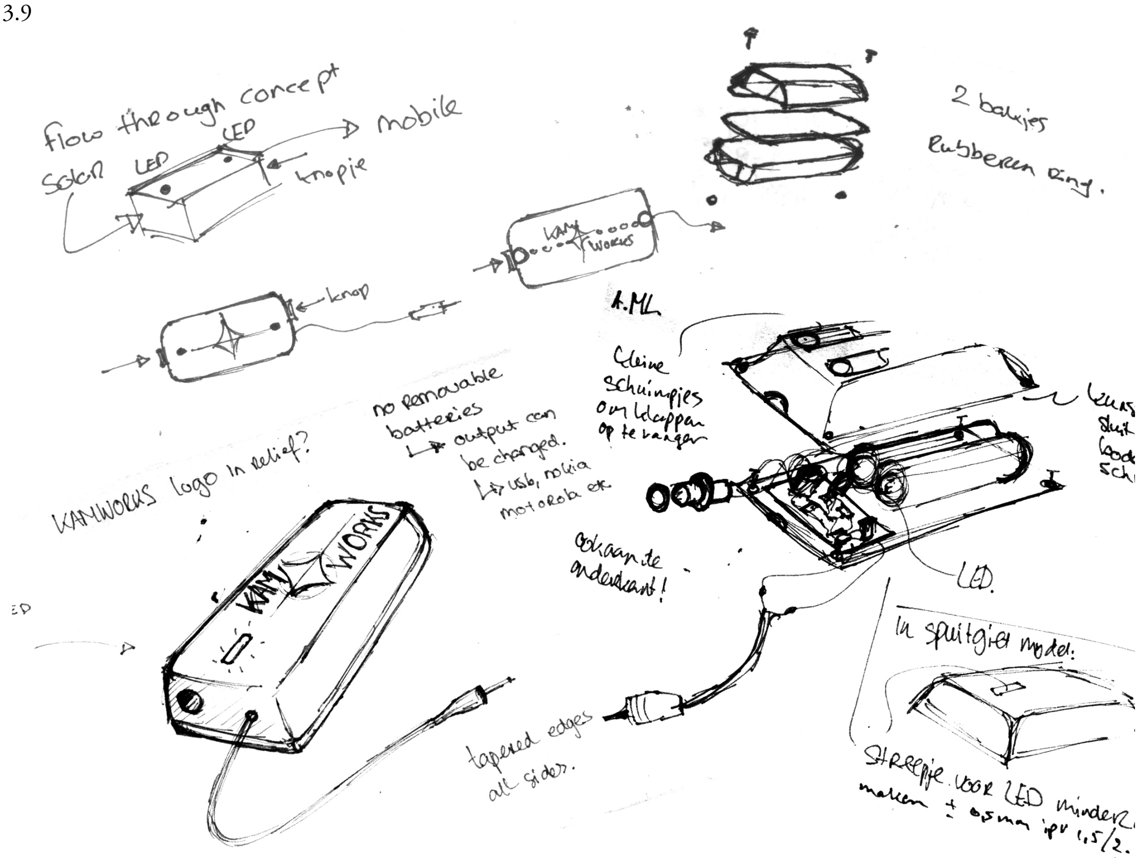
The components of the Solar Phone Charger would consist of 2 internal parts, the battery pack and a PCB. The size of the battery pack is 52mm in length, 31mm in width and 14,5mm in height. The size of the battery pack defined a large part of the dimensions. Because the PCB was not yet designed there was flexibility in it's dimensions. There was one constraint, a capacitor used had a height of 11mm, even if it was mounted horizontally. Thus the shape was primarily defined by the size of two AA batteries and the circuit board.The PCB would ideally be mounted on the bottom of the product shell to keep dimensions as small as possible. The solution was to place the PCB next to the battery pack to form a rectangle. Other configurations where also explored but seemed to be impractical. The shape would become thick or bulky. The rectangle shape also resembles the mobile phone and could easily fit into a trousers pockets. There was one variation where the PCB would partially overlap the battery pack. While this seemed to be a nice design solution, it would bring several complications. The chances that the battery pack would damage the PCB are higher and a more complicated design would have to be made to protect the PCB from such events, secondly the battery pack can no longer be used as a construction part of the device. If the shells directly connect to the battery pack the forces will be directed to the battery pack and protect the device from cracks caused by too much pressure. This directs the forces to work on the battery pack instead of the shell. If this possibility is taken away the shell needs to be reinforced to take these forces. The design variations are shown in figure 3.8.

Figure 3.8



Two other small components are the connector to the solar panel and the Nokia cable. There could also be made variations in the way these would be placed: a side-by-side and a flow-through concept.

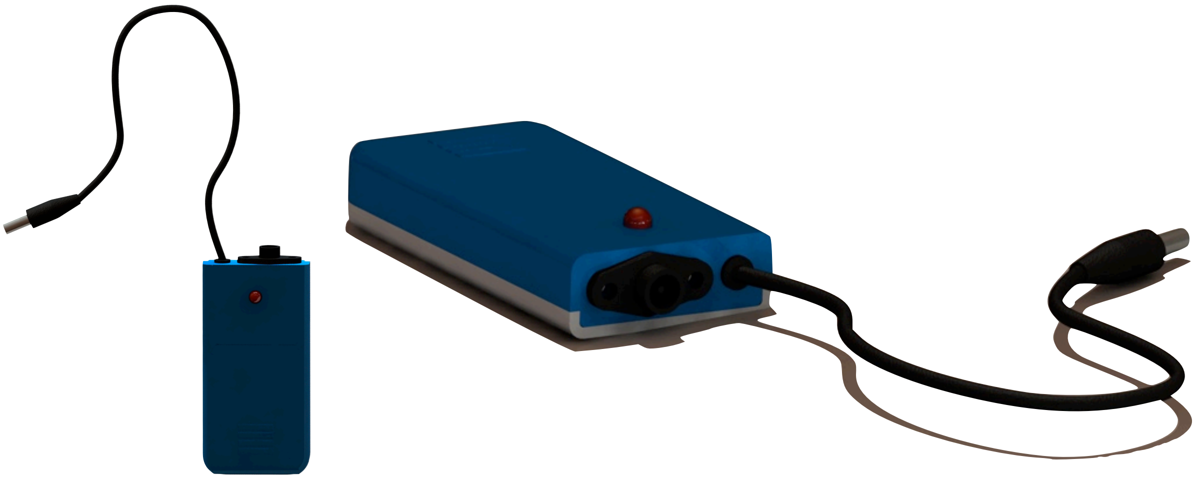
Figure 3.9



3.2.2 First model

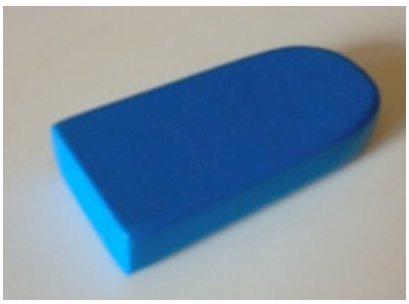
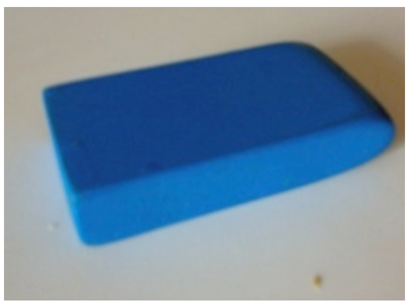
In the first design a small LED was incorporated and measures of components available at Kamworks were used. Difficulties had to be solved primarily concerned the construction of the parts of the shell. It had to be made of at least two different parts to form a shell that can house the electronics inside. After making these sketches one design was modeled in Solidworks to get an overview of the size of components and thus the size of the product. These sizes were taken fairly large to make sure everything would fit easily and room was left over for assembly of the product. The basic size of the product was at that moment determined at 42x100mm with a height of 20mm. One side would be used for the connectors of the solar panel and the Nokia charger cable. In this way one side could be nicely rounded to make the product fit into a pocket easily.

Figure 3.10



Because there were several ideas for the design and it was necessary to be able to test all of them only one model was made into a working prototype and of the other 5 designs a visual model was made. Design 4 was developed with a working electronic circuit to be used in the market survey.

Figure 3.11

		
Design 1	Design 2	Design 3
		
Design 4 (working prototype)	Design 5	Design 6

3.3 Market survey

To gain insight into the wishes and needs of the target group of the Solar Phone Charger, the rural population, it was necessary to perform a market survey. Even though another extensive market survey had already been performed in Q4 of 2008 there still were some gaps in the understanding of the target group. Some relevant conclusions can are set out below.

3.3.1. Conclusions from the AgeConsult survey

Average income is $5.29 a day, with an average of $3.29 at a poorer area and $6.66 in a richer area. The average family comprises of 5.3 members. 96% of the respondents make use of electricity and pay an average of $0.47 a day for it. Most people use car batteries for electricity, 10% uses kerosine and 6% uses a generator. Many people, 49%, also use penlight batteries.
Of all 112 households only 11 did not have a mobile phone, surprisingly many households have more than one phone as the total number of phones is 164 pcs. On average people charge their phone every 3.1 days. 24% says to charge every day. 59% of the people were willing to pay up to $10 for a product that could charge their phone with solar energy.

Some additional conclusions of the report:

1. Although most people (92%) can charge their phone at home, there is interest in a service for fast charging. 73% said they were willing to pay extra for this. Most of them want to pay $0.13 extra, some of them $0.25. Of course this raises the question if this is enough to make the fast-charging service profitable enough to explore and develop the technical possibilities. Another important question before starting this service is how far people are willing to travel for this. If one looks at the comments on the travel time towards the charging station for car batteries (where most respondents didn't have to travel more than 1 hour) it should be within half an hour reach at most.
2. A solar charger for the phone also raises enough interest to investigate further about prices and possibilities people want. They were willing to pay a little more for a charger for two phones.
3. Respondents with power grid are equally interested in the solar charger as respondents without.

3.3.2. General

For the market survey that was conducted in the framework of this assignment the following information was pursued.

1. Get information on their knowledge and use of electricity
2. Mobile phone possession and use
3. Requirements considering charging
4. Reactions to the solar concept, design and functionality
5. Indication of pricing

Seventeen households were interviewed in the survey, these households ranged from 1 to 3 in the Kamworks scale (see Figure 2.3). Both men and women were interviewed as the questions would also assess some designs and specific functionality. In the map below an overview of the area is shown to give an impression of the households that were interviewed. The questionnaire is in Appendix II.

3.3.3. Assessment of Electrical situation

The survey showed electricity has already been very integrated with the rural population of Sre Ampil. 95% of all families used a car battery to watch TV, light their house and do other things. Only one family has no electric devices at all. Two families make use of a generator and battery to supply themselves with electricity. Interestingly one family has been making use of a solar panel since 2004 already. Of all respondents 70% has heard of solar energy.

Figure 3.12

3.3.4. Mobile Phones

75 % of all respondents has a mobile phone, the other 25 % has owned and used a mobile phone but stopped using it because they found it too expensive, thought it had bad calling quality, bad battery life or simply no longer needed the connection. The people that had a telephone were using the Nokia brand (72%). Other brands were; Motorola, LG, Phillips and one unknown Chinese brand. Most phones were new, but only by a small difference; 53% vs 47%. Phones were most actively used by men, as can be seen in Figure 3.13. Most phones were charged at home, while few others turned to their neighbors and some charged the phone with their employer in Phnom Penh (Figure 3.14). With an average age of 26 months most phone batteries will probably not be on their top capacity and therefore not need more frequent charging. Of one tested phone the battery capacity was 2.03 kWh. With a cheap grid(!) price of 1100R per kWh and an average mobile phone battery of 2.0 kWh the yearly electrical expense for a mobile phone is $66.55.

Figure 3.13

Men	9	52%
Women	4	24%
Kids	1	6%
Students	2	12%
Other	1	6%

Figure

At home	11	78%
Neighbors	1	7%
Phnom Penh	2	15%

3.3.5. Design of the Charger

To get an idea of peoples design preference 5 visual models and the working model were showed for comparison. People were asked to choose two models they liked the most. The designs showed in Figure 3.11, are referenced by their number. Figure 3.15 shows the outcome. In the first place a distinction has been made between male and female, eventually all votes are counted in the last column.

Figure 3.15

design	sex	1st	2nd	male total	female total	**total**
1	m	7	1	8	3	**11**
	f	1	2			
2	m	2	1	3	3	**6**
	f	1	2			
3	m	3	1	4	4	**8**
	f	2	2			
4	m	2	2	4	3	**7**
	f	3	-			
5	m	-	2	2	4	**6**
	f	3	1			
6	m	-	1	1	-	**1**
	f	-	-			

Most frequent notes given during the survey were;

- small form factor is important
- design 3 and 4 should fit easy in the pocket because of their shape
- 4 people explicitly say they like the blue color, black (primarily) and yellow.

It is apparent that most votes go to design number 1. Men tend to like design 1 the most (8), second are designs 3 & 4 (4, 4). Women tend to like designs 3 & 5 the most (4, 4) but have a much more leveled overall opinion. In general people like designs with a small footprint or a small look. Design 3 was longer and thinner, while design 1 and 4 looked smaller because of the rounded or chamfered sides. While no structured questions were asked with regard to color, people said to like a black finish the most, the blue of the working model was also highly appreciated as well as yellow.

3.3.6. Pricing

As people tend to have little money they were asked what they would consider a fair price for the product. Half of the people were told the price would be $10 for the basic model and the other half was told $15 for the same model. Surprisingly people from both groups thought the price to be fair. People were also asked about an extensive model that would also be able to charge AA batteries. The price for this item was suggested to be $15 in the first half and $20 in the second. Again people did not find the product to be too expensive. But some people mentioned that the price would be too much for people in remote villages as they tend to be poorer.

3.3.7. Penlight batteries

70% of the people that participated in the survey say to be using batteries, 60% of these are AA batteries, 20% AAA and the other 20% D size batteries. These batteries are primarily used for head lamps, torches and radios. On average these batteries have to be changed every 11 days, with a price of 635R per battery this comes to an average of $21.25 for 4 batteries. A solar charger that can charge 2 AA batteries on the days it is not used for charging of a mobile phone would be a useful addition and save many people extra money.

3.3.8. Panel support
Nine people did not know how to mount the solar panel intuitively, 5 people instantly mounted it correctly. Of these 9 people 2 were not aware that a solar panel should be placed outside. A short manual was made with abstract pictures of product installation. (Appendix III). People were unable to read abstract pictures. To make the pictures clearer one woman asked for additional text next to the images. In the following figure 3.16, a table has been placed with a number of people that indicated some unwanted situations.

Figure 3.16

situation	people
considered safe	4
afraid of rain	3
take inside with rain	2
put it high from damage	3
take inside at night	3
take inside when away	2
afraid of theft	4

People were also asked to give comments regarding the design, only one person had a complaint, he thought the hole where the electrical wire goes through is prone to leakage. He asked if it was possible to us a plug or grommet-like solution instead.

3.3.9. Conclusions
On general the reactions to the product were very positive, many people asked when the product would be available to buy. They did have some questions regarding repairability and warranty, but nearly everyone said to buy the product when available. A price between $10 and $15 seems to be affordable for many people, but a lower price might be more desirable as it should allow a larger user base in poor areas. A major point in the design directions was the definition of the target group. Is it more beneficial to make the cheapest possible product that benefits the poorest part of Cambodia's society or is a premium model with a trickle down effect more effective? In a meeting with Arjen and Jeroen of Kamworks it was decided to choose for the cheapest possible product. This was decided considering the following arguments:

1. A cheaper product lowers initial cost of investment
2. A basic product is easy to improve with new features
3. Aimed at the largest group, thus conform the mission statement of Kamworks and this project

This meeting also stated the price of the product at a maximum of $12.-. Therefor the project would focus more on efficient production and pricing than usability and design. Time to market was considered more important than a aesthetically pleasing design.

The Solar Phone Charger can be a very good addition to the people considering the potential financial savings. When a households has and has average usage of both a phone and penlight batteries the savings per year can be as much as \$21.25 + \$66.55 = \$87.80. Even without subtracting the price of the Solar Phone Charger this gives significant financial benefit.

For the manuals it is advisable to use pictures of the actual product instead of abstract drawings. These pictures could be accompanied by small amounts of text.

3.4. List of Requirements
As a result of all findings the following List was assembled containing the specifications of the product.

1. *General*
   - 1.1. The design should fit the needs and wishes of the local population
   - 1.2. The product should be considered to be of high quality by the local population
   - 1.3. The product should have a minimal life expectancy of 2 years. (wish: 5 years)
   - 1.4. The exterior of both items should last at least 5 years
   - 1.5. The electronic components (ex. battery) should last at least 5 years
   - 1.6. The battery should last at least 2 years
   - 1.7. The connectors and external wires should last at least 2 years
   - 1.8. Plastic components of the product have be made with Injection Molding or Thermoforming
   - 1.9. It should be possible to replace parts or components in case of failure at the Kamworks workshop or by Kamworks trained people in Kamunasal shops
   - 1.10. Price should not exceed \$12 (wish: \$9) with a Kamworks profit margin of 30% and a 35% import tax on electronic components included
   - 1.11. The product will have two separate components, the device with an internal battery and charge controller and a solar panel

2. *The Device*
   - 2.1. The device should fit in users trouser pockets
   - 2.2. The device should be able to be hung in the house easily
   - 2.3. The device should be portable and weigh less then 85 grams light
   - 2.4. The users should be able to use the device intuitively
   - 2.5. The device should be able to charge all kinds of Nokia telephones
   - 2.6. The device should contain batteries to charge the mobile phones
   - 2.7. The device should not damage the battery and other electric components related to the charging of the mobile phones in any way
   - 2.8. The device should be able to charge at least 1 mobile phone on a full battery charge
   - 2.9. The device should disable charging or prevent electricity loss when no phone is connected
   - 2.10. The device should have feedback functionality to display battery charging and phone charging to the user
   - 2.11. Charging of the device should not require any third parties components other then the supplied solar panel
   - 2.12. The device should survive drops of 50cm (wish: 75cm)
   - 2.13. The device should be weather resistant (water and UV resistant)

3. *The Solar Panel*

   3.1. The solar panel should be compatible with the Moonlight system

   3.2. The solar panel should be able to charge the internal batteries completely within 7 hours on 90% of the days in a year

   3.3. People should be able to install the panel themselves within 15 minutes

   3.4. The panel should fit bamboo poles ranging from 2 cm to 4 cm diameter.

   3.5. The panel support should be able to be attached to the bamboo pole firmly to protect it from external damage (bumping of the pole, heavy rains, winds)

   3.6. The casing should be weather resistant (waterproof and UV resistant)

   3.7. The casing should be impermeable to water to prevent getting between the glass and PV-cells of the solar panel

4. *Safety*

   4.1. Installing and using the product should in no way endanger the users safety

   4.2. The product has to meet international safety norms for chargers (IEC 60335-2-29)

4. Prototyping and Testing

As the List of Requirements was defined, the following step was to further develop the product. To gather some additional data on the Solar Phone Charger a prototype was made. Making the prototype was likely to reveal some additional flaws or design problems. These prototypes would then be used in a field test.

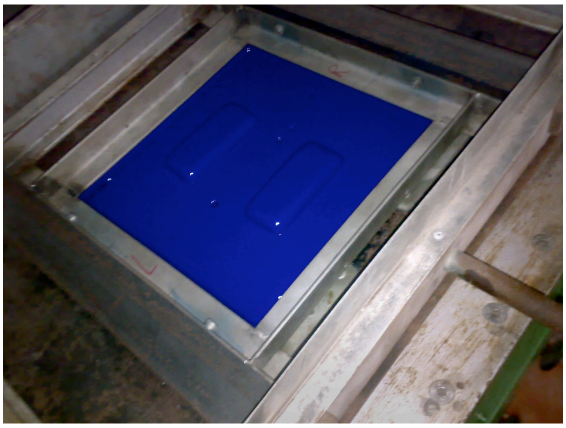
4.1. Prototyping

To prepare the field test several prototypes had to be made. These prototypes were improvements of the products tested in the market survey.

4.1.1 The charger

The charger was made significantly smaller, to be safe in for the market survey the casing was chosen with large margins. As the survey revealed people like small products the prototype would resemble the final product and have a smaller size. The height was reduced by 2mm to a total of 18, this would also make the batteries fit tighter. Width was reduced from 42mm to 36mm and the length was brought back from 100mm to 94mm. This could have been reduced further by using thinner wall thickness, but to sustain a solid product a minimum thickness of 1.5mm was necessary. In an experiments with thicker and thinner sheets of plastic it became obvious that this would be the best balance. A picture of the thermoforming is shown in Figure 4.1.

Figure 4.1



Thermoforming shells

Figure 4.2

Hole for knot in wire

When assembling the electronics a problem appeared, some components that had to be available were missing and prevented production of multiple prototypes. As a result only one prototype could be made . To make the field test worthwhile it would be tested on multiple households, with a testing time of two weeks.

4.1.2. The panel support

As one of the people in the survey mentioned the hole of the electronics wire a small improvement was made, in the mold for the panel support a tiny top piece was added. This extruded the plastic at that given point and provided a small hole for the knot to sit in. This shape gave more space for the knot in the wire and would prevent water to enter the support. This is shown in Figure 4.2. There were no other refinements on this design.

4.2. Field test

The field test was performed to get additional data on the usage of the Solar Phone Charger. At the beginning of the field test it was the intention to test at least 3 different families for a duration of 2 weeks. Unfortunately the first week of the field test revealed a major flaw in the design of the electronics. The circuit that boosts the voltage from the two AA batteries of 2.4V to the required 5.5V continues to work when battery voltage drops below 1.4V. As a result the batteries are entirely drained with a voltage of only 0.35V per cell. At that point the cells are completely drained and will need to be replaced. Even though the field test did not take more then a week it did reveal some information.

Figure 4.3

The field test was held at the house of Dina. His family has an income of $1000.- / year and he works as a duck farmer. He uses a Nokia phone that he charges every 3 days. He has no experience with solar energy.

Findings and Recommendations

1. very easy to use (intuitively)
2. make sure it is waterproof
3. missing indication of charging - useful to know if connected properly and placed the solar panel correct
4. size is very good
5. the nokia cable could be shorter (5 instead of 12 cm)

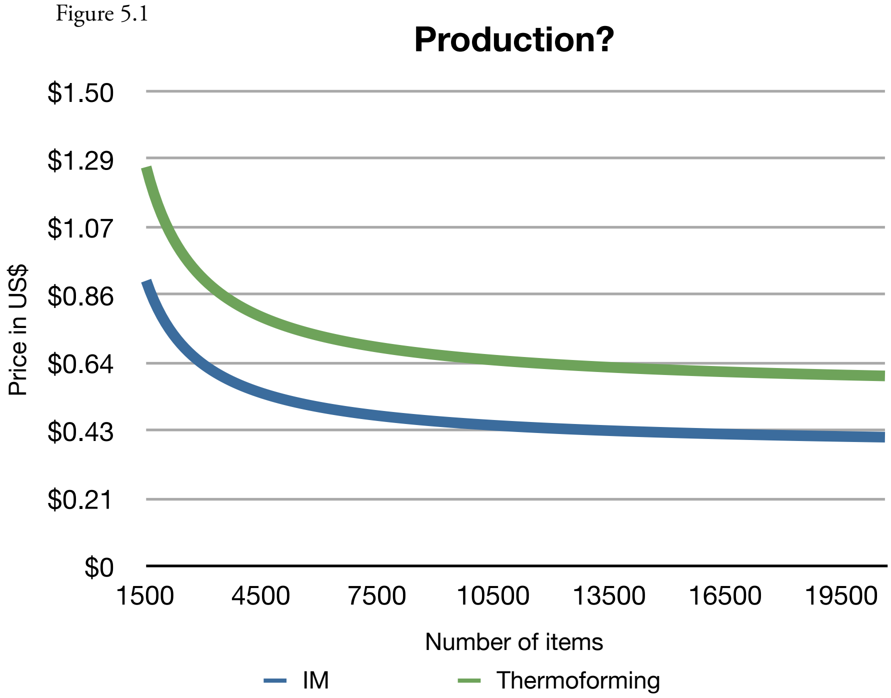
5. Production development

During the the field test and afterwards the design was refined and prepared for production. This encompassed calculations on the best production method, refining designs and finding suppliers for components.

5.1 Panel support

To save costs the choice was made to choose for a thermoforming based panel support. Molds were designed in Solidworks and calculations were made to get as many molds out of a sheet of plastic. One part was experimenting with distances between and placement of the molds in the mold area. This resulted in a calculation of the price for 2000pcs. The most expensive part seemed to be the molds themselves. Twelve molds would cost about $1068. This was much more than anticipated, $15 per mold, and made the price of the final product extremely high; $1.08.
To compare the price to injection molding a preliminary model of that design was sent to an injection molder. The price offered for a complete injection mold was only $800.- and a material price of $0.23 per product. With 2000pcs the price would then be $0.76. This was a significant difference and also provides the benefits of injection molding: a product is delivered completely ready and no additional actions have to be taken to finish it. The rate of failure is expected to be lower as less work is done by people and the products are likely to have a better surface finish. To further substantiate this decision a graph was made to show the difference, as shown in Figure 5.1.

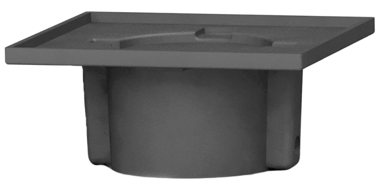
Figure 5.1



The choice for injection molding did mean a refined design of the model was necessary. In Figure 5.2 the evolution from the original to the final design is shown. The design with ribs was abandoned in favor of a second ring in the design. This second ring would support the outer side of the panel support and distribute power in a balanced way to the inner ring that is formed by the supporting tube.

Figure 5.2

1. Original design with 3 ribs

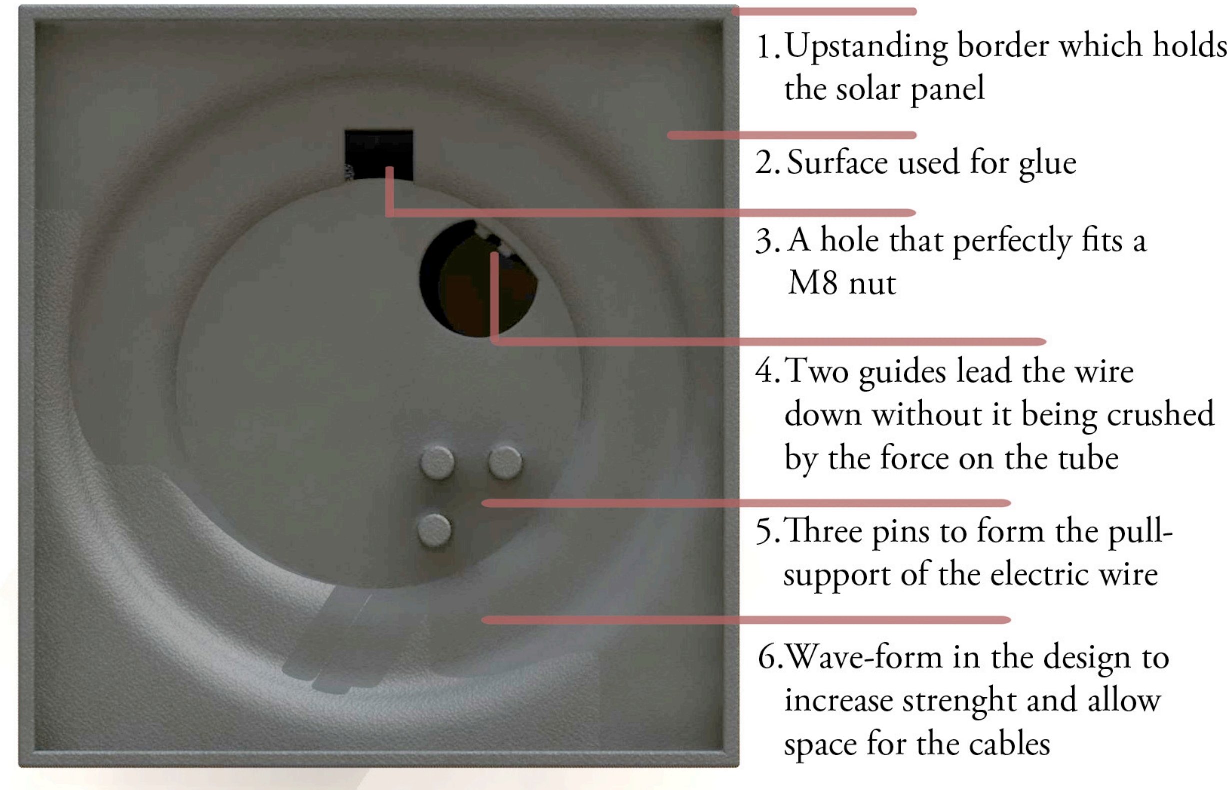


2. Redesigned with 2 large ribs

3. Redesigned with an inner circle

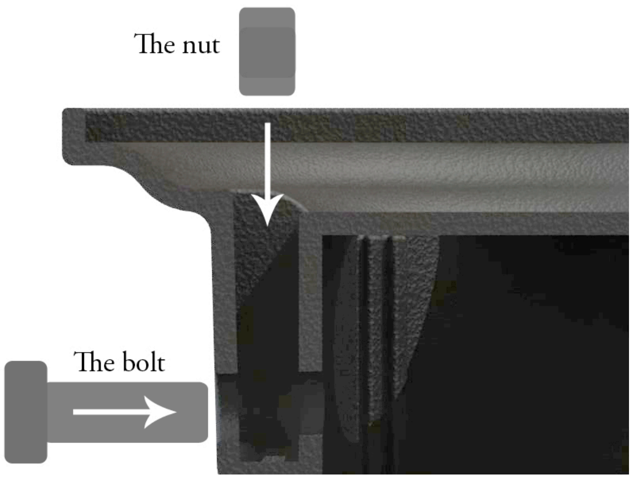
In the refinement of the design some significant changes were made. The electric wire was guided through the hole in the middle of the holder, next to the pole. As the solar panels were delivered with the plugs already soldered to them the hole had to be large enough to fit the plug. The best way to hide that hole was in the middle. Explanation is found in Figure 5.3. A drawing with indication of dimensions can be found in Appendix IV.

Figure 5.3



In the following Figure 5.4, a section view is shown of the panel support. This shows the hole where the nut is put in and where the bolt goes through. The bolt is chosen with a sharp point to make sure it will drive itself in the bamboo pole and prevent to large forces on the support when installed. The nut is fastened with a small amount of silicone.

Figure 5.4



5.2. The charger

The production preparations on the side of the charger were a little more complicated. This part has a lot more functions and features to fulfill while being relatively small and leaving only a little space for it's internal components.

5.2.1. Design features

There are several different functions that had to be put into the device. The in- and output of electricity is done with connectors, these have to be fastened in the shell of the device to make sure they don't get pushed into the device or get pulled out. On the inside the shell has to fasten both the batteries and the PCB, it also needs to allow room for expansion in the future and cables running through the device. Additionally the shell has to be reinforced to give ruggedness that makes the device feel durable. Finally the shell has to be designed with the possibility to use it flipped, the single-mold design feature. This means there is one shell and this shell can be flipped to make the other side of the product. Using inserts it is possible to give the surfaces of both shells a different look. To accomplish this the following design decisions were made:

- In- and output on opposite sides of the shell
- Internal pins that can be fastened into each-other with a M1.2 12mm screw

In the following figure a glass rendering is shown of one of these shells. It shows several different parts of which all of these perform a specific function.

The solar plug input (*1*) was placed on one side and the Nokia charger cable (*11*) on the other side. This was done to make the product a perfect mirror and make it possible to flip it over the long axes. A name was quickly found: Flow Charge, because the energy flows through the product to your mobile phone. The Nokia plug is a standard 1.2mm plug with 13.5mm wire. At 40mm from the plug a grommet is placed that fits into the Nokia plug hole (*11*). This is sketched in Figure 5.5. For the solar plug the same connector is used as with the Moonlight (Figure 5.6). For the Solar Phone Charger it would have been better to use a PCB mounted adapter, unfortunately that was not available for this plug. The circular plug is fastened by a nut that jams it tight to the shell and fits in the Solar Plug Hole (*1*). To stand forces working on the shell the reinforcement lines (*4*) are extended to the shells border.

Figure 5.5

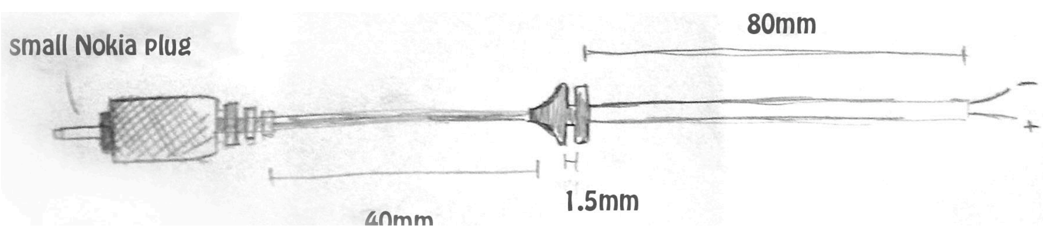
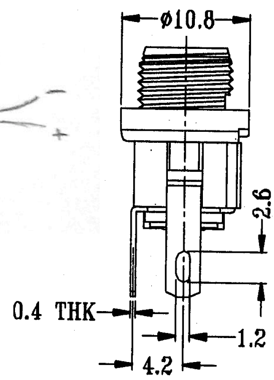


Figure 5.6

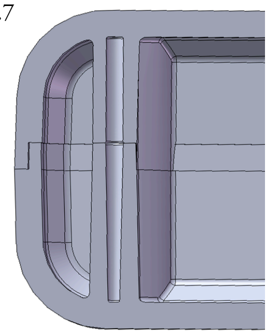


The PCB is placed on 4 different points, (*2* and *8*). Of these points two are active and allow the PCB to be fastened with a M1 3mm screw. A small pin (see *8*) is present to fit the PCB during assembly. There are two reinforcement lines (*4*) in the length of the shell, these will prevent the shell for bending. At the place where these lines connect to the vertical side of the shell the height is increased a little to support the PCB at it's end. More information on the PCB in the next chapter.

The batteries are supported by ribs with a circular form (*5*). These fit the batteries with a margin of 0.5mm on both sides and prevent the batteries from moving inside the device. To secure the batteries in

the PCB side of the device a small standing rib has been placed. This rib is 1.5mm high and with a margin of 0.5mm on the PCB side and 0.5mm on the opposite side this tightly secures the batteries.
The shells border is layered (*3*), this means that it is divided in two heights. These height differences make the two shell parts fit together without sliding. It thus decreases the movement between the two shells. A more detailed view of the way these borders connect can be seen in figure 5.7.

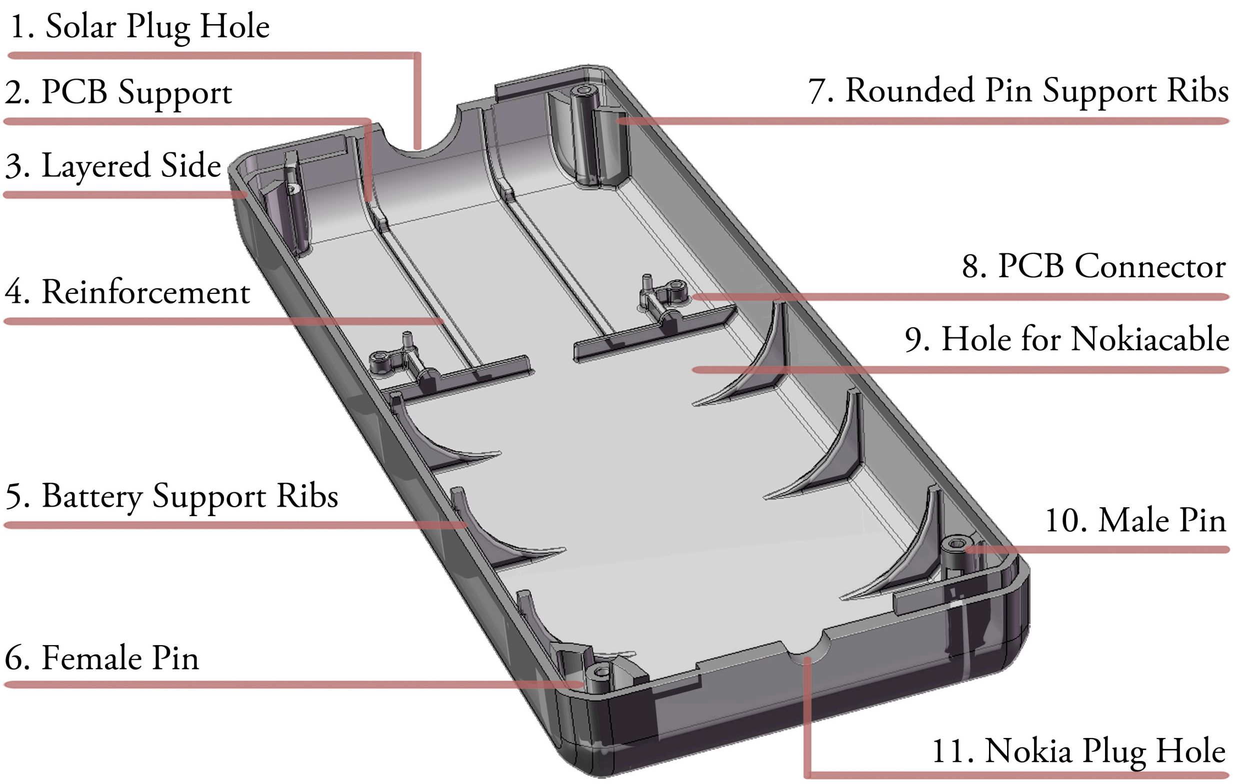
Figure 5.7



Connecting the two shells together is done by pins, there are two pins used, male and female. The male pin (*10*) is 9mm large and fits in the room created between the rounded pin supports on the female side (*6*) which is 6mm. To connect a M1.2 10mm screw is used, this is the one of the largest screws at this diameter, as a result the pin has to pierce 1.5mm shell and 6mm pin. Then 2.5mm is left for the actual connection in the male pin. A detail of this connection is showed in figure 5.8. The rounded Pin Support Ribs (*7*) provide support to the pins and strengthen the corners of the shell for impact of drops.

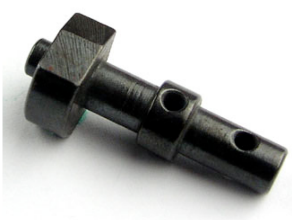
Here the total model with referring numbers of design features.

Figure 5.8



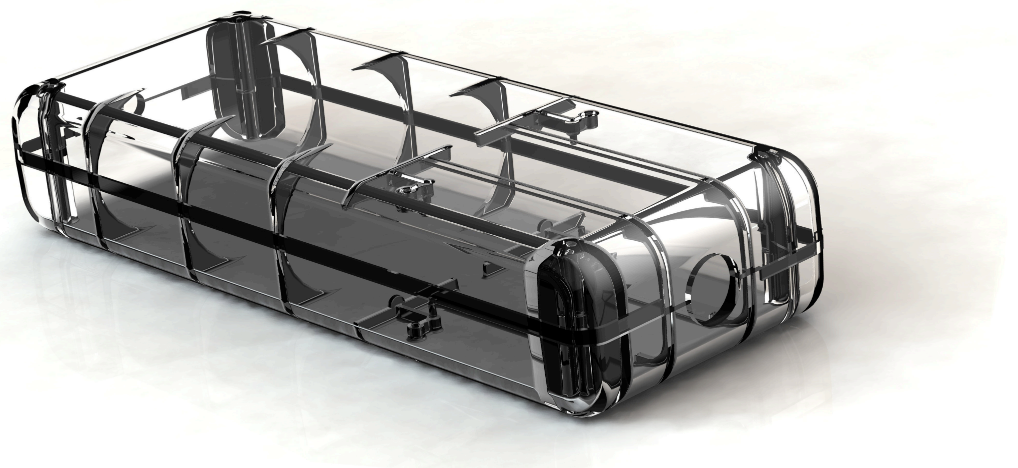
Some other details concerning the charger have to do with small details. As the color of the product will most likely be matte black, as this is the most universal color and during the market survey people seemed to prefer it, the two screws that will be used to hold the shells together, a finish similar to the shells was looked for. A Chinese supplier was found that could provide this finishing, a sample is shown in figure 5.9.

Figure 5.9



In the following (glass) render the two sides are shown as they will be mounted on each other. A drawing with indication of the dimensions can be found in Appendix V. All vertical faces were chamfered 1° to make the mold come loose from the final product.

Figure 5.10



5.3. PCB

The PCB is a very flexible component of the product. The only constraints are the Solar Plug connector, and the large capacitor. To fit the PCB in the device a blueprint has been made of the PCB's dimensions. TO first define these, an estimation was made together with Tim van Steen. The minimal dimensions needed for the components would be 30mm x 25mm. To have the possibility to add additional components later in the process the dimensions were determined at 32mm x 30.5mm. To make the PCB fit neatly into the shell the corners will have to be cut though. In the following render the PCB is shown. Figure 5.11

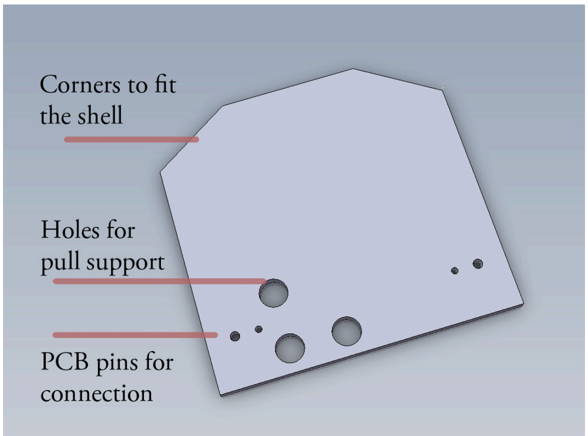
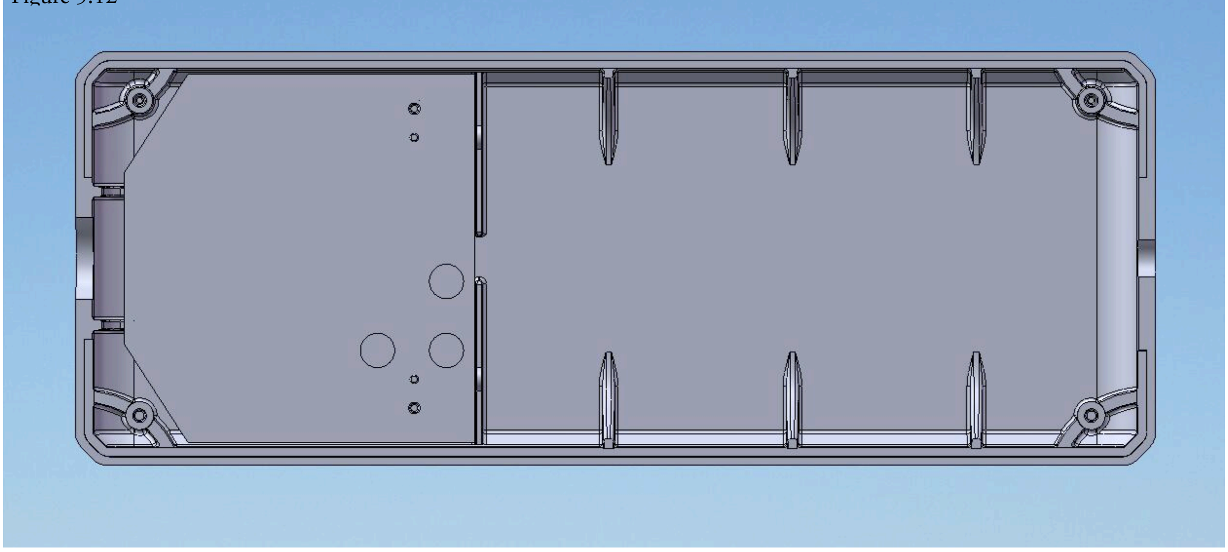


Figure 5.11

In Figure 5.12 the PCB is shown mounted in the shell. Maximum height of components on the PCB is 11.5mm, at some points there are ribs in the shell, at those points maximum height is 10.5mm. A drawing with an indication of dimensions is in Appendix VI.

Figure 5.12



5.4. BOM

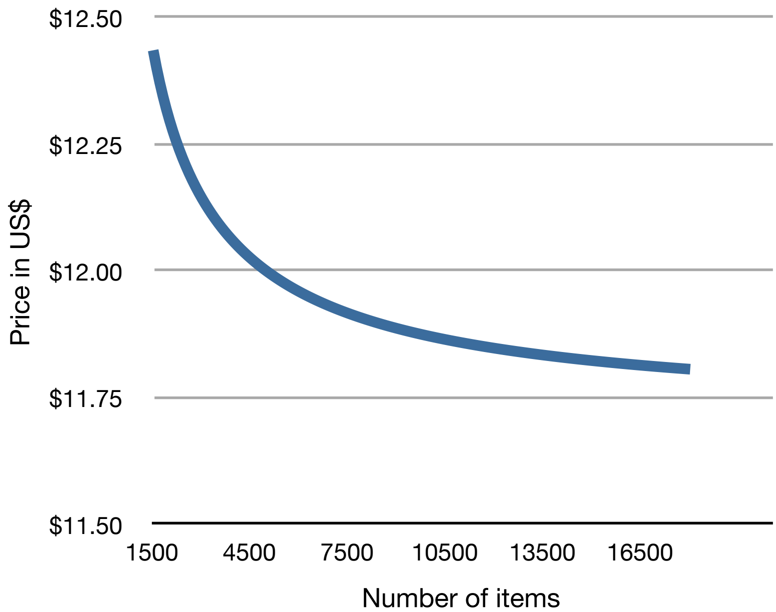
Figure 5.13

Component	*Price*	*Amount*
solar panel (35% import taxes)	*$5.07*	*1*
panel support	*$0.57*	*1*
shell	*$0.18*	*2*
pair of AA batteries	*$0.78*	*1*
PCB with components (35% import taxes)	*$1.00*	*1*
connector	*$0.20*	*1*
Nokia connector & grommet	*$0.12*	*1*
screws	*$0.01*	*4*
packaging & manual	*$0.30*	*1*
labour cost	*$0.22*	*1*
Total	*$8.45*	

5.5. Pricing

On the right a graph is shown with the line describing the total price of the Solar Phone Charger. This includes import taxes, transportation cost, labour cost and Kamworks margin. When 5000pcs are sold the $12.- barrier is broken. See Figure 5.14.

Figure 5.14



With future price drops of solar cells, at this point the costliest component of the charger, prices will drop even further. With these drops a retail price of $11.- could very likely be possible. WIth increasing quantities with which Kamworks buys solar panels from its supplier prices are also likely to drop. Larger quantities result in lower prices.

5.6. Investment cost

The total production cost for a product launch of 2000pcs would be US$17,305. This excludes advertising and other costs. Some components have to be bought in very large quantities and are therefor available at quantities of 5000 or even 20,000pcs. A table with calculations of investment cost to manufacture the first 2000pcs can be found in Appendix VII.

5.7. Suppliers

As Kamworks has already built up a good network of manufacturers with the production of the Moonlight many items could be produced at these locations. The solar cells and PCB will be manufactured in China, all electrical components and screws will be bought there as well. Production of the injection molds is done at Tan Y, Vietnam. This is an injection molder visited by Arjen in July 2009 when doing a trip through Vietnam in search for a production partner for the Moonlight. At this moment there are no companies making injection molds in Cambodia, it is however possible to produce the molds elsewhere and do the injection molding in Phnom Penh. Assembly of all components is done at Kamworks. Packaging is made from a mold with the thermoforming machine, as is the case with the Moonlight, and also produced at Kamworks. A list of all suppliers can be found in Appendix VIII.

6. Recommendations and Conclusions

While a lot of the product design is finished, some aspects still have to be finished.

6.1. PCB

The electronic circuit has to be looked through to add at least the ability to stop boosting when 1.4V is reached. Additionally it is desirable to add a feedback LED that gives an pulsating signal when the charger is connected to the solar panel and charging. In the future it is recommended to add additional functionality to stay ahead of competitors and keep customers bound to Kamworks for electricity needs.

6.2. Manual

For the manuals it is advisable to use pictures of the actual product instead of abstract drawings. These pictures could be accompanied by small amounts of text.

6.3. Color & Finishing

Considering the looks of the product the following colors are recommended: Black, Blue and Yellow. Black appears to be an appreciated color among many Cambodians, the blue and yellow would reflect the Kamworks colors and appear to be popular with the population as well. Further information can also be found in a study by Mariska on colors for the Moonlight.

6.4. Future revisions

For future chargers is might be good to look at opportunities to add more functionality, for example the possibility to change connector plugs, allowing different devices to be used with the charger, expanding the range of the product from only Nokia to all mobile phones, MP3 players and electrical gadgets. With the future universal phone connector, that will be launched in 2010, this should very easy be accomplished.Backwards compatibility with older devices would still be necessary.

Adding the possibility to use rechargeable batteries in the device, this expands it's functionality a lot, it could be used to charge batteries to power all kinds of electric devices that use AA-batteries. It could also be of help when the the solar panel is broken or not available, normal AA-batteries could then be purchased and used to charge the peoples personal devices.

At this moment the batteries used in the Solar Phone Charger and the Moonlight are NiCd batteries, NiCd contains the very toxic metal Cadmium, at disposal of the batteries this heavy metal will come into the landfill and could seriously harm people and the environment. As an alternative NiMH batteries could be used. For now it could be considered to collect waste batteries for proper disposal to prevent further harm to the environment.

7. Personal experiences

Looking back at the design process, things went well, many did not go as expected and some went wrong. In the first few weeks it was hard to get started and get used to the rhythm of Cambodian rural life, the broadness of the assignment also was a struggle for me, as I was often confused where to start. Weekly meetings with Arjen and Jeroen did contribute to structure in the process. The biggest struggle though was dividing time between the Bachelor Thesis and the minor assignment. In general I am content with the results of the both.

Making the prototypes also posed some problems, I am not used to making many things myself and it took some time for me to get used to finding solutions, but also equipment as they were often spread through the building. I also find is difficult to be in an environment I was not used to, as I was not aware of the equipment and material available I often had to ask Arjen and other students. This did became very tedious, but during the stay I did pick up more and could get around. For me it would have been of help to see a list of equipment available and a short description of their usage (for example the thermoforming machine).

Many people have been of great help and I found Cambodian hospitality very charming. The friendliness of these people has contributed for a large part to the design process.

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Appendix I Country Study: Cambodia

In this chapter the country Cambodia will be described in short to give an idea of the countries history and present situation.

Geography and Climate
The country of Cambodia, the former Democratic Republic of Kampuchea, is situated in the South-East Asia, with it's most southern points only 10 degrees above the equator, and is bordered on the west and north-west by Thailand, on the north-east by Laos, on the East and South-East by Vietnam. The southwest is bordered by the Gulf of Thailand (Britannica, 1990). The country covers an area of 181.035 square km and it has a varied geography. It is dominated by large central plains that cover three-fourths of the total land surface mostly grown by forests, the Tole Sap lake in central Cambodia and the Mekong river that traverses from the north to the south-eastern border with Vietnam.

With a tropical monsoonal climate the country experiences average annual temperatures between 21^{0}C and 35^{0}C. Annual rainfall varies from 5,000m in the south-west to 1,400m in the central plains. The country not only has an abundance of rain, but also lots of sunshine, an average of 5 kWh/m2 per day.

History
After a long period, from the 9th till 13th century, in which the prosperous Khmer Empire was the most powerful civilization in East Asia, the power of the country was starting to decline. It was able to hold it's power until the 15th century, but then surrounding kingdoms attacked and ushered the start of raging wars until 1594. In this year the final incarnation of the once glorious empire was ended. During the following three centuries Cambodia would suffer from wars and be the battleground of disputes between Thai and Vietnamese kings.

France was eventually asked for protection in 1863, Cambodia would remain a France colony until 1953. The French were primarily interested in the country as a buffer state between Thailand and Vietnam and had no plans what so ever on developing Cambodia into a western-orientated modern society. They made benefit of workmen form the local population and was responsible for a large part of it's agricultural development, in particular the rubber plantations. While exploiting the local people their presence did not only have a negative effect on the countries economic development. In Phnom Penh businesses took of and provided employment.

After the establishment of the independent Kingdom of Cambodia in 1954 things began to look somewhat brighter. The prime minister Sihanouk started out with development in education and the construction of roads, unfortunately his success was only moderate and in the late Sixties an uprising ended the buy up of large rice harvests and lease of land by corrupt officials. Shortly after the American invasion aimed at disrupting the Vietcong and Khmer Rouge made over 2 million Cambodians refugee and killed many.

While farmers' cattle had died and the country faced famine, struggles within the countries political establishment eventually ended with the coup of the Khmer Rouge in 1975. The leader of this regime, Pol Pot, attempted to rebuild the country through centralized economic autarky. A strong social re-engineering of the Cambodian society took place and by imposing a radical agrarian communism, the population was forced to work in large collective farms. Anyone involved in free market activities was to be eliminated. As result of this approach nearly two million people were murdered, a fifth of the total population. Vietnamese involvement ended the regimes reign in 1978, but fights between the Khmer Rouge and Vietnamese forces continued throughout the Eighties. In October 1991, after two years of efforts to resolve the conflict, a peace treaty was signed and the United Nations appointed as peacekeeper and responsible for the cease fire, disarmament, the refugees and opportunities for free elections. After two more years free elections were held and a parliament was appointed, this parliament chose Norodom Sihanouk, son of the former prime-minister, as new head of the state. In 1994 the country again became a constitutional monarchy. The country still wasn't entirely free from internal upheaval, but had set out a new direction.

Economy & Infrastructure

As a result of it's history Cambodia's economy is primarily dependent on agriculture. As a result of the raging wars in the preceding years its development was stuck at infancy and numerous attempts to make the country self-sufficient failed. This was not only caused by political in-stabilization, but also by uncontrollable factors like weather. The countries only seaport, Kampong Saom, resumed it's trading activities in 1975. In 1987 a little signs of a revitalizing economy could be spotted as small industry was stated and transportation and telecommunication resources were re-established.

In an attempt to revitalize the economy Cambodians working abroad where encouraged to remit money to families. But it helped only a little because the country did not have any industry most goods where imported. These goods, tractors, vehicles, machinery and fuels, were used to produce primary products like rubber, maize, rice, tobacco and timber, Cambodia's principal export. When the wealth in western countries increased tourism started and at this moment provides together with the textile industry the biggest source of income for the country.

Appendix II - Questionnaire

Questionnaire Market Survey Kamworks (May, 2009)

Dear sir/madam, this questionnaire is a part for a market survey of Kamworks, a company located in Kandal provence. The company is specialized in electronic devices and is currently developing a new product for mobile phone charging. It would be very appreciated if you could give your opinion on it. Before we would also like to ask some other questions regarding your household situation.

1. How many persons live in your household? (write down number of persons)

2. What are your income generating activities?

Farmer Shop Fisherman

Other: ....

3. Have you ever heard you could get electricity from the sun?

No

Yes

4. What kind of electric / electronic do you have in and around the house?

Radio:	Amplifier with speakers:
Lamp:	Refrigerator:
Fan:	TV (black and white / colour)

5. How are those electronic appliances powered?

Car battery	Power grid
Kerosine	Generator

Other: ………………………………

Mobile Phone

6. Do you have a mobile phone,

a. No, why not?

b. Yes, what brand and type, and how many in your household ?

Nokia: Other (ask brand):……

7. Who are the primary users of the mobile phone? (age, sex)

8. Where do you charge your mobile phone(s) (rate according to frequency)?

at home friends neighbours

shop other:……

a. (if not at home) Do you pay for charging your phone?

no

yes (how much): $.........

9. How is the phone charged?

by the grid generator

carbattery other:……

10. How old is your phone?

Months: .....

11. Did you buy a new or used one?

New Used

12. How often do you charge your phone

every day every other day

every three days other:….

13. When do you charge your phone:

When it is empty

When it is nearly empty

Every night

Always when I'm not using it

Other …………….

14. How long much time may it take to charge the phone?

1 - 2 hours

3 - 4 hours

5 - 6 hours

7 - 8 hours

15. How important is it for you to have your phone battery charged?

extremely important

important

of little importance

not important

Now the interviewer shows the prototype of the solar charger for mobile phones and explains what solar energy is and explains you can take the battery with you when you need to go away and can charge anywhere until the battery is empty That you have to buy the equipment first, but that you don't need any fuel once you have it. Once every 1 year you need to replace the batteries (2 times 3000 riel). The solar panel has a life expectancy of 10-20 years) The charger will be able to

16. Would you pay $10 for this?

No

Yes

17. Do you use batteries (show a penlite battery)?

No

Yes, where do you use them for?

……..

a. **Which size battery do you use? (show the batteries)**

AA AAA Other: .....

b. **How often do you exchange them for new ones?**

....

c. **What do they cost?**

$ ....

d. **Have you heard of rechargable batteries?**

No

Yes

You will be able to take the charger with you as you leave, when the batteries inside are empty you can exchange them for regular AA batteries and charge your phone. You can also charge your own rechargeable batteries, take these out of the charger and put them in other devices to power them.

18. **If the solar charger can charge rechargable AA batteries would you use that feature?**

19. **Would you pay $15 for this?**

No Yes

Show the different models and ask which one people like the most

20. **If all of these models have the same functionality which one would you like the most?**

Show the Solar Panel

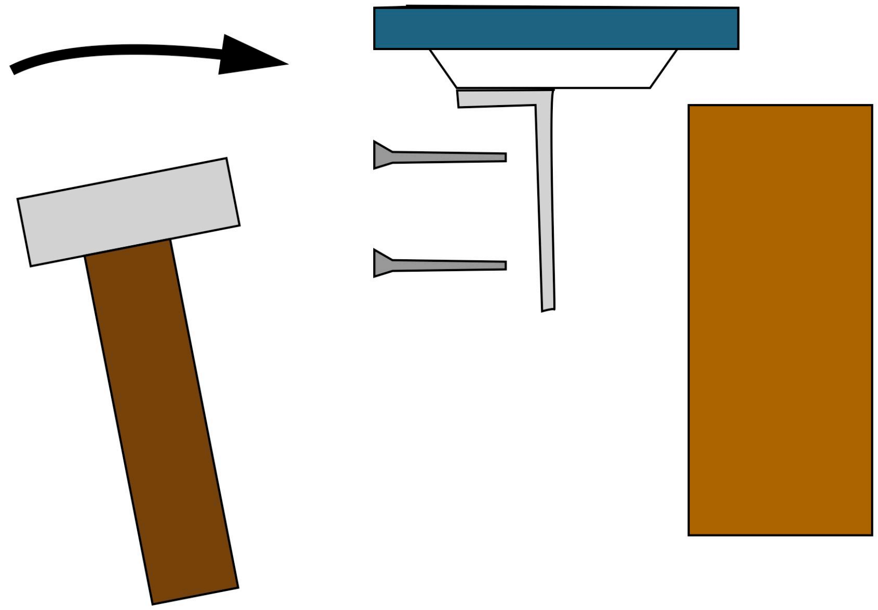
21. How do you think you should attach this?

Show a picture of connecting the Solar Panel

22. What do you think of it (considering safety outside, durability)

Many thanks for you cooperation!

1



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