Designing sustainable solutions for the 'Base-of-the Pyramid'

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Abstract

Recent work is re-conceptualizing global poverty as an attractive growth opportunity for firms that can simultaneously alleviate the problem of poverty. The so-called 'Base of the economic Pyramid (BoP)', exists of 4 billion people that live on an income of less than $3 a day. Tapping into these overlooked markets will require companies and designers to reconfigure their business and product innovation models. The challenge is the creation of accessible and affordable product and service solutions to fit the local economical and socio-cultural preferences, without expanding the current of environmental resources. In this paper we will discuss the experiences of the Faculty of Industrial Design Engineering of the Delft University of Technology in developing sustainable product solutions, especially affordable sustainable energy and light solutions for BoP households. This will be done by illustrating and discussing the participatory design process of the 'MoonLight' in Cambodia. The 'MoonLight', developed in collaboration with the social enterprise Kamworks, is a locally produced solar energy powered light. This project illustrates the transdisciplinary approach, needed for a successful development and introduction of PV-powered lighting. By using input from different design knowledge domains like sustainability, user context, technology and business a locally fine-tuned solution is developed. Participatory design methods have proved to be essential in these for western designers and enterprises unfamiliar contexts.

Keywords: Design for Sustainability, Base of the Pyramid, renewable energy, participatory design methods, emerging markets

1. Introduction

1.1 Base of the Economic Pyramid

A considerable part of the world's population struggles with poverty. Their living circumstances are habitually characterized by lack of access to basic needs as education, health care and infrastructure, such as clean water supply and electricity. Often these problems are connected to each other. For example a lack of access to water results in people spending many hours per day collecting water. This spending of time alternatively could be used for working (income generation) or for going to school (education). In many cases the collected water is polluted or gets contaminated during storage in the simple houses or during the handling, which results in diseases. Diseases again reduce the time that people can work or use for other activities. Some facts related to water according to the Human Development Report 2006 (UNDP 2006) are:

- 1.700.000.000 people in the world lack access to clean water;
- 3.300.000.000 are without proper sanitation facilities;
- 2.200.000 people die from preventable water- and sanitation related diseases each year;
- Every day 600 children die.

The current challenge for firms, professional designers as well as design schools is to make a breakthrough in these vicious circles. The question is 'How can companies and designers contribute to reduce these and other numbers?'.

In recent years, the poorest people around the world are slowly being recognized as consumers in their own right (Prahalad 2004; Hammond 2007). According to the World Bank (2005), 4 billion people live on an income of US$ 3 or less per day and more than 1 billion people live on less than US$ 1 a day. This part of the world population is nowadays often referred to as the 'Base of the Pyramid' or abbreviated 'BoP' (Prahalad and Hammon 2002; Prahalad and Hammon 2002). Most companies, professional designers and design schools used to (or still) target only end-users in advanced markets. This is a group of 'only' 0.5 billion people living at the 'Top of the Economic Pyramid' with an average purchasing power of more than US$ 10,000 per year (Rocchi 2006). Many global companies start developing specific solutions targeting the Base of the Pyramid.

In this article, we will use the particular case of providing affordable sustainable energy and light solutions for BoP households and discuss the challenges for the design world. This will be done by illustrating and discussing the participatory design process of the 'MoonLight' in Cambodia.

The ‘MoonLight’, developed in collaboration with the social enterprise Kamworks, is a locally produced solar energy powered light.

1.2 Design for the Base of the Pyramid

To develop and distribute products for these sofar overlooked BoP markets will require companies and designers to reconfigure their business assumptions, models, and product innovation approaches and products designs (Boyer 2003). BoP markets are rather different from the developed markets in the diversity of the user needs, motivations and the business environment dynamics. In order to address this situation new integral design methodologies, tools and courses, which bring together user context research (based upon ethnography and anthropology), business development, sustainability and new technologies & innovations (high-tech combined with low-tech) in a focused way have to be developed.

Figure 1: An integral product development approach for the BoP (Diehl, Silvester et al. 2008).

Getting insight and understanding into the BoP context (i.e. the local business ecologies) as well as observing and understanding the BoP user needs (social, cultural, economic) in his or her context are key issues to identify the latent needs in order to come up with socio-economic and cultural appropriate design solutions that meet the real needs of the user (Diehl and Christiaans 2007). In this situation it is clear that researchers and designers should engage with the cultures and contexts directly in order to better understand local people. Solutions should not be developed only in western design studios and schools. Understanding people’s needs and interaction with the material, economical and socio-cultural world is a basic starting point for successful product innovation, especially in the BoP (Rodrigues, Thompson et al. 2007). From that perspective, participatory approaches (like Participatory Rural Appraisal) and co-design methods have proved to be very helpful and essential during all stages of the product development process (needs assessment, concept development, prototype testing as well as market introduction) in order to be successful in these for western companies, designers and students unfamiliar contexts.

1.3 Need for electrical light at the BoP

Light, one of the basic needs is required for education, improving the security of communities and advances productivity (Ramani and Heijndermans 2003). Therefore access to affordable domestic electric lighting could contribute considerably to the well-being of people living at the BoP (Gooijer, Reinders et al. 2008). 1.7 billion people or 350 million households, representing about 44% of the total BoP population still lack access to the electricity grid (UN 2005; World-Bank 2007). Electricity has traditionally remained in the realm of the public infrastructure. However, the conventional grid is not likely to be the answer to the electricity problems of the poor, at least not in the short run. According to the International Energy Agency, current expansion of electricity infrastructure will still leave 1.4 billion people without a connection to the electricity grid by 2030 (Nehme 2007). Extending the electricity grid is often economically unattractive, given the geographical distances and the relative low energy consumption (which means low turnovers for the electricity providers) of the poor. But even the 56% connected to the grid, often lack stable electricity supply. Rolling blackouts, ranging from 4 to 6 hours a day are common in many regions (Sambasivan 2008).

As a result one in three people in the world do not have access to electricity and rely on costly and low-grade lighting sources such as candles, kerosene lanterns, or gas lamps to provide light at night. These sources are unsafe, inefficient and expensive. BoP markets pay among the world's highest unit costs – and get some of the world's poorest quality energy (ESMAP 2003). Lighting costs can be as high as 10-15% of total household income (Mills 2005; Nehme 2007). Their lighting fuel expenditure represents about 17% of the global lighting market, but they only receive about 0.2% of the global lighting output (Mills 2002). For example the costs calculated on base of a use of 5 hours per day result into US$ 50 per candle light point and US$ 100 per kerosene light point per year. This highlights the financial burden caused by current inefficient options. Therefore, efficient and affordable energy solutions for the BoP population have to be provided in the short run. Design students, design professionals, design schools and companies can play an important role in this. To illustrate this, the next paragraphs discusses the design process of such as sustainable light solution: the 'MoonLight' in Cambodia.

2. Participatory product development of the 'MoonLight'.

2.1 Kamworks

Kamworks, a social enterprise, is a spin-off of long-term cooperation between the Dutch charity foundation Pico Sol and the Khmer Foundation for Justice, Peace and Development.The mission of Kamworks is to provide affordable sustainable energy systems for low-income consumers in Cambodia and to locally manufacture solar products in order to create jobs and income for young Cambodians. Cambodia has a large proportion of the population under the age of 20 years (60%) and employment generation for young people is an especially pressing issue. In addition, the aim of Kamworks is to connect the product design to the indigenous culture and the socio-economic context as well as to innovative advantages for the end-user like high quality and energy efficiency (Reinders, Gooijer et al. 2007).

In Cambodia 94% of 2.1 million Cambodian households do not have access to electricity from the public grid. Typically, 55% of the households use rechargeable car batteries and 35% use dry cells or have no access to form of electricity at all. In the last case they depend on candles and kerosene lamps for light (Rottman 2006). Though solar energy is abundant in Cambodia (over 1900 kWh/m2 per year) (Reinders, Gooijer et al. 2007). Solar powered lighting has demonstrated to be a good alternative to provide these in people in rural areas in low income with reliable high quality light and which has meanwhile a lower environmental impact than traditional lighting (Ramani and Heijndermans 2003). See figure 2 for the typical rural Cambodian houses and current light solutions.

Figure 2: Typical kind of rural cambodian housing and kerosine lamp a car batteries as basic resource for light.

To challenge an integral solution for the need for affordable appropriate locally produced light appliances it was decided in 2008, in consultation with Kamworks and on basis of former projects (Boom 2005; Diesen 2008), to involve a Delft University of Technology (DUT) Integral Design Project (IDP) master student team. In order to create a multidisciplinary design team, the four master students as well as the two supervising academic staff members did have different industrial design backgrounds varying from strategic product design, user-centered design, design for sustainability and integrated product design.

From experiences with earlier BoP projects at DUT (Kandachar, Jongh et al. 2009), we concluded that creating products for BoP markets requires a deep understanding of the real daily needs and context of the people within it. In such a situation it is clear that designers, in this case the team of four IDP students, should engage with the cultures directly in order to better understand local people (Rodriguez, Diehl et al. 2006). Because of this reason a special emphasis of the IDP project was put on the local context research in the field. Knowing the context and observing and interacting with the user in his or her context helps to understand the latent need which come up with new appropriate product solutions that meet the real lighting needs of the user. As a result the most essential part of the IDP project took place in rural areas of Cambodia during a period of 3 months to explore and understand the local context and need as well as to come to local suitable design solutions for the lighting needs of the rural Cambodian.

2.2 Participatory market and context research
As a first step of the new product development trajectory, a thorough participatory market and context research was executed in the field. The market and context research existed of two parts: 1) observatory research and 2) participatory research.

As a first start for the designers to get familiarized to the local socio economic context as well some first detailed insights of the problems and needs for electrical light, observatory research was carried out (Alvarez, Papantoniou et al. 2008). The circumstances and use of the current lighting products were investigated in households in the Kandal area in Cambodia to gain insight in the current use of lighting and electronic products. The design team executed observations by visiting local households as well as by doing interviews (see figure 3). Questions were asked by the students with support of local translators in relation to the way and purpose of the use of light.

Figure 3: Observatory research in rural Cambodia.

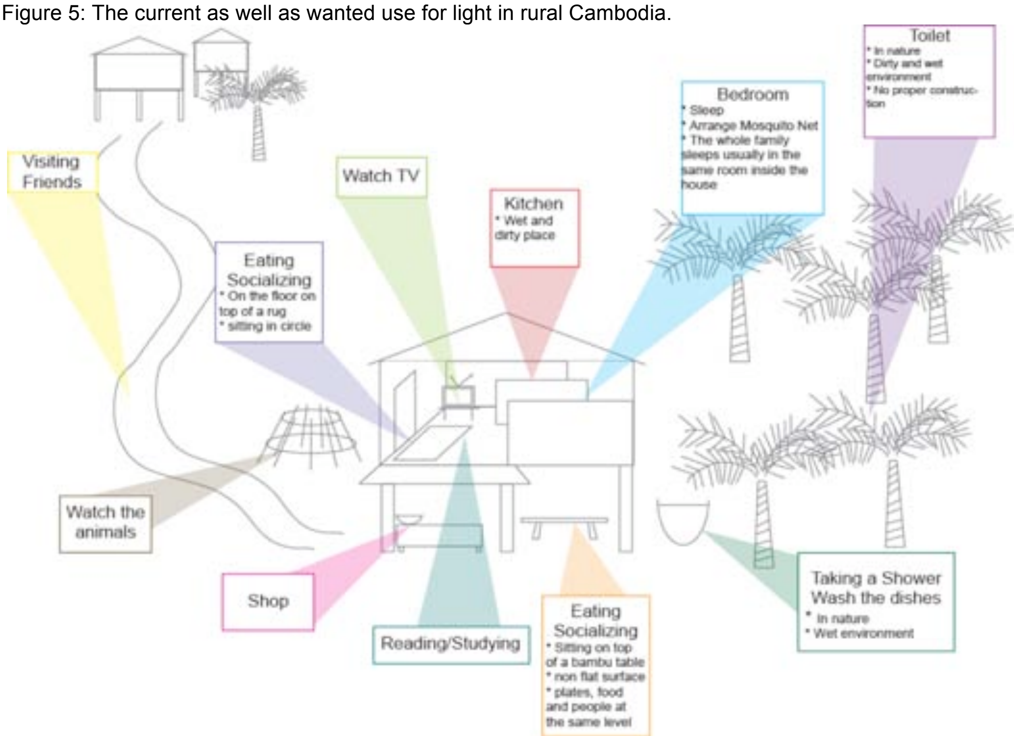
In the second phase, within the scope of the BoP, participatory methods have been used to get a deeper insight in daily life in order to identify suitable product-market combinations as well as insight in the needs. Focus groups sessions, and day mapping (see figure 4) were used in order to identify and map needs and wishes of the rural Cambodian consumers for (electrical) light in their daily life.

Figure 4: Participatory research in rural Cambodia.

2.3 Participatory field research: User needs
One of the first outcomes of the participatory field research was a map of the current needed as well as wanted (electrical) light functions in and around the household like for example studying, managing the shop, eating, cooking, watching the animals, washing the dishes, visiting friends etc. Figure 5 provides a more detailed overview of needed and wanted light functions. It is clear that light is needed for a multiple of functions.

The participatory filed research led to the following main conclusion: the new light device should be a completely substitute of the kerosene lamp. The poor quality of the light, the flammability and health hazards as well as the highly volatile fuel prices are the main drivers. In addition the lamp should be portable. Different rooms are to be lit, and most households cannot afford more than one lamp. Furthermore, a dimmed light during the night was needed, to orientate in the dark and to feel safe while saving energy at the same time. The dimmed light only has to last for a few hours per night. About three hours of full light are needed during the evening. In addition, the inventive character of the Cambodians and the completely improvised style of their houses called for a flexible product that people could use as they wished, without too many restrictions. The product should provide enough luminosity to be able to read. Last but not least, the lamp should be shock, water and dirt resistant. Incorporating all these requirements would create a specific added value for the rural BoP Cambodian households.

Figure 5: The current as well as wanted use for light in rural Cambodia.



2.4 Technological challenges

Parallel to the participatory field context and user needs research the IDP team executed technical 'lab' research focussing on: efficiency, reasonable purchase costs and low total costs of ownership.

At present most solar powered lighting systems and solar lanterns use compact fluorescent lamps (CFLs) or fluorescent tubes. They are appropriate for the circumstances of use, but photo voltaic (PV) powered CFLs are still rather expensive. Moreover once disposed of, CFLs generate waste with toxic elements such as mercury. White light emitting diodes (LEDs) have become a serious alternative for CFLs in PV applications. The white LED is highly energy-efficient, it can meet the minimum requirement for lighting levels of visual tasks, it cuts down costs of lighting considerably and is durable compared to other electric light sources. In addition, LEDs are operated at low voltage levels in the order of several volts, for which reason their energy requirement can be easily met by small battery-based PV system (Kan 2006). The use of LEDs light emitting diodes (LEDs) in stand-alone battery-based PV systems might both reduce costs and environmental impact of lighting (Gooijer, Reinders et al. 2008).

For the energy supply of the system, two options were possible:

1. A battery charging system powered by photo voltaic (PV) cells with low initial costs (for the user) but higher running costs. The batteries are taken out the of the products and charged by a local entrepreneur by PV.

2. A totally independent system with higher initial costs but no running costs for the end-user. The product is directly charged by the PV-cells (integrated in the product or connected thru a cable with an external PV panel).

The decision was taken to continue with the last option and to design an independent PV white LED-light system. To keep the product simple and the cost as low as possible it was decided not to integrate the PV-cell into the lamp, but develop a separate lamp and PV panel.

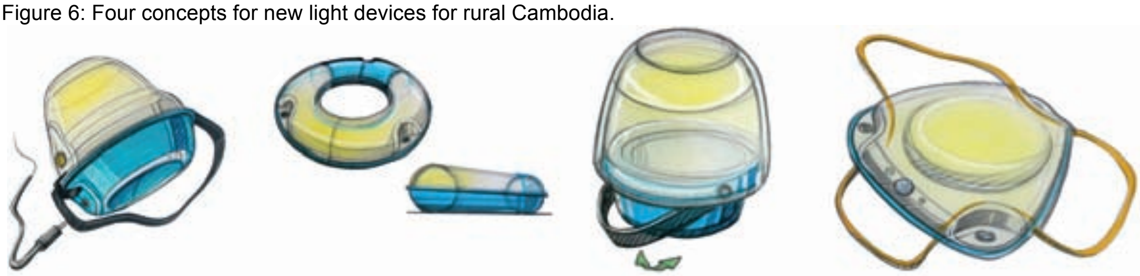
Simply said, a PV-LED light product consists in that case of one or more LEDs, a rechargeable battery and a small PV module. However from former studies it was concluded that electronics play a crucial role to provide a series of necessary functions. The electronics have: (1) to match the solar power to the battery characteristics; (2) to control the charging and discharging of the battery and (3) to control the power to the LED ('driver'). The first and second function will result in a longer and more effective lifetime of the rechargeable batteries. The last function will result in a longer lifetime of the LEDs. Continuous high currents can reduce the lifetime of the LEDs considerably. This can be avoided and arranged by operating the white LEDs with an electronic driver which applies either a constant current or pulses of higher currents (Gooijer, Reinders et al. 2008). In addition smart functions have been build in like an automatic switch off after a certain time in order to save energy. Finally the LEDs will start to blink when the battery is almost empty.

As a result of the electronics, the light device will be more energy efficient, perform better, will have a longer life time and will be more convenient to handle. This way the Kamworks light products can provide more constant quality, reliability, higher performance and added value to the end-user compared to the cheaper (often made in China) PV lamps. Quality and performance are the most important selling points in the rural Cambodian BoP (Rijke 2008)

2.5 Co-development

Based upon the inputs of the extended participatory local context research, the competences of Kamworks, as well as the technological development, four concepts were developed (see figure 6). This is in line with the 'normal' product development as in any other market.

Figure 6: Four concepts for new light devices for rural Cambodia.



In order to come to appropriate design solutions, which really fit into the BoP context of Cambodia, local stakeholders were intensively involved in the concept development, so–called co-design. Co-design can be defined as cooperative, contentious process bringing everyday people together with design professionals to find new and better ideas for daily life (Simanis and Hart 2008).

Potential end-users as well as potential sales channels like micro-entrepreneurs were confronted with product ideas in an early stage (see figure 7). The direct feedback from the field led into practical as well as socio-economic and cultural driven suggestions for improvements of the concepts.

Figure 7: Co-development with local stakeholders.

2.6 The final product: the Moonlight

The final design is called MoonLight ("Ampoul Preahchan" in Khmer). It has a triangular shape and includes a cord that is attached at the three corner points (see figure 8). It can be hung from wall or ceiling, carried by hand or hung around the neck. It has 6 wide-angle LEDs, which is equivalent to the light output of about three kerosene lamps. It comes with a 0.7 Wp solar panel, which can be fixed to a bamboo pole with a standard clamp. This option was chosen as several people had stated during the interviews that they were so afraid of the solar panel getting stolen they would prefer to keep the panel inside all day, leaving a window open for charging. Currently, this 'anti-theft' technique is used for TV antennas, in other words this technique is not new to the people.

Figure 8: The 'moonlight', exploded view, 3D rendering and in practice.

The product mainly consists of two injection-moulded outer shells and two also vacuum-formed blisters that hold the electronics together and buffer them at the same time for possible shocks. As a result it can be produced easily locally and create income for local entrepreneurs.

The strap represents the most crucial handling feature allowing to wear it comfortably around the neck and need to easily connect the product to building constructions. The upper shell is semi-transparent to diffuse the bright LED light, hiding at the same time inner components such as the batteries and electronics. The light has three settings: bright (reading/work), medium (eating/socializing), low (orientation/safety). Using it at full power the product delivers about 42 lm by 6 low efficacy LEDs (7 lm per LED) during 3.5 hours. In dimmed mode it produces diffuse – amenity - light for 6 hours. The expected lifetime is 5 years.

2.7 Feedback from the field

Several prototypes of the MoonLight have been made at the local workshop of Kamworks and were tested by the IPD team with families in rural Cambodia in night- and daytime. The final user tests pointed out that the product is indeed an appropriate solution for the local context. The product was appealing to them and the usage intuitive: People could easily understand and use the product: hanging it around their neck and placing it at the walls and ceiling of their houses (see figure 9). Most of the families of the final user test were enthusiastic and even willing to buy the prototypes on the spot.

Figure 9: Field tests in rural Cambodia with working prototypes.



2.8 Extended field tests
Based upon the positive feedback from the potential end-users, it was decided to do a more longitudinal test. Ten ‘MoonLights’ were produced which included a ‘data-logger’ to record the charging as well as the using behaviour. These MoonLights were used and observed during one month in ten rural households at two different locations. These participants were off-grid households in the lower income segment of the BoP and were not confronted with the product before. In addition tests were done with the batteries, PV panels, LEDs and printing circuit boards in the local context to test their efficiency and duration. The outcomes of this field tests led to several inputs for improvement of the MoonLight.

For example it was concluded that the solar panel orientation was problematic, as such the pole mount was redesigned. It was also observed that using different kind of solar cells could optimize the performance of the PV panel. Lastly, the villagers preferred to have the ‘bright’ mode more bright, and the ‘dimmed’ mode more dimmed.

In the perception of the local people the MoonLight is better solution than a kerosene lamp since it provides more light, will not go off in the wind, no risk for fire and no running costs. Nine out of ten of the test households would like to buy the product. Based upon the positive consumer and technical feedback form the field it was decided to go for production. Currently the production is being prepared and the product is expected to come into the market fall 2009.

2.9 Costs
The market price of the MoonLight including the accompanying PV panel is less than US$ 20. However compared to a kerosene lamp of US$ 1 it’s still a relatively high initial investment for a low-income family. On the other hand compared to CFL based PV lanterns which cost about US$ 60 to 80 such as LED lamp is reasonably affordable.

What is counting in the end, is the life cycle cost or also called total cost of ownership: After purchase, operating costs determine the costs of ownership of a certain option for lighting. Costs of operation comprise replacements of spare parts and costs of energy to power light, such as electricity for grid-connected (GC) lighting and fuel for kerosene lamps. Kerosene lamps have very high costs of ownership of US$ 12.00/1000 lux-hours, mainly due to fuel consumption. Halogen flashlights with costs of US$ 3.40/1000 lux-hours require frequent replacement of primary batteries. A 1 Watt PV-LED lamp is the cheapest option of two PV-powered lamps. With costs of ownership of US$ 0.22/1000 lux-hours, it’s the cheapest option for autonomous lighting available (Gooijer, Reinders et al. 2008).

In other words, A LED PV powered MoonLight has higher initial costs. But on the short term these costs can be overcome and light will be cost-saving for the household. The expected pay-back time is one year compared to kerosene lamp. One of the reasons of the still rather high price is the local tax system. Kamworks has to pay 35% import tax on the batteries, LEDs, electronics and PV panel. In addition 10% VAT.

2.10 Sales and distribution
For the dissemination of the MoonLight and the other Kamworks PV products, a network of vendors - micro-entrepreneurs – is being established by Kamworks. The vendors are trained and equipped by the company. For this purpose a training centre, called the Solar Campus, has been founded. It provides micro entrepreneurs with a commercial training to improve their business skills and with a technical training to enhance their knowledge about PV technology. An agreement has been signed with a local Micro Finance Institution. They will enable the

possibility to buy the MoonLight on micro finance credit. The current strategy to sell the products is two fold (see figure 10):

1) Peri-urban with container kiosk
The Kamunasal solar shop is an adapted shipping container. Inside the shop a displaying cabinet contains a show and try-out model for each item. As rural customers and micro-entrepreneurs in Cambodia prefer to have stock placed visibly, and to keep a clear overview for the micro-entrepreneur, each product type is placed in a separate compartment, together with additional stock (Rijke 2008).

2) Rural mobile solar kiosk
For this purpose a mobile kiosk has been developed which enables micro-entrepreneurs to make a daily move around the villages (Reitenbach 2007). The mobile kiosk has been designed as a carrier bicycle with a softly shaped polyester box. Because of promotional objectives the mobile kiosk is equipped with lighting and sound equipment powered by a small solar panel.

Figure 10: The two sales channels, mobile solar kiosk and solar kiosk.

3. Conclusions

Because of the upcoming importance as well as interest in the needs of people living at the so called Base of the economic Pyramid, design professionals and educators should invest more in research and education for ‘Designing for the BoP’. The challenge is the creation of accessible and affordable solutions to fit the local economical and socio-cultural preferences, without expanding the current of environmental resources.

As this project illustrates, providing lighting to the people of Cambodia – that they love to use and is affordable - is not simply ‘designing’ a product. This project is a challenging example of a transdisciplinary approach, needed for a successful development and introduction of PV-powered lighting. By using input from different design knowledge domains like sustainability, user context, technology and business a locally fine-tuned solution is developed.

Participatory design methods have proved to be essential in these for western designers and enterprises unfamiliar contexts.
The sequence of steps – observation, focus group selection/day mapping during the analysis phase, co-design with potential end-users and sales people during the concept development phase, small-scale field tests with prototypes, improvements, extended field tests with zero-series (N=20) and final adaptation for first series (N=2000) is quit common in product- and service-development all over the world. But the steps have to be carefully elaborated because of the unfamiliarity of the designer/developers with the specific socio-cultural context. Involving and educating local people like Kamworks is doing, is an important requirement for establishing this context research.

In former projects Kamwork – as a social enterprise – tried to design and develop the PV-powered products in such a way that it was producible within their own workshops by their own employees and students. This is causing a dilemma. On the one hand the products should be suited for simple production techniques to be able to produce in the local workshop. The simplicity is attractive because it generates a lot of local employment. On the other hand it is more difficult to establish the needed quality, it is easy to copy and it is relatively expensive,

The strength of the Kamworks approach lies in the offering of sustainable solutions of high quality fitted to the local needs. It is not just a product, but also the services like education, communication about PV-technology, financing & after sales of the lighting solutions. These services make them competitive with the low-prized imported products offered in local shops. The services make it possible to build up a long-lasting relationship with their customers.

Kamworks is a very interesting experiment of devoted people into sustainability. All the dimensions of sustainability are addressed by the work of Kamworks;

- The social aspects by providing education, employment.
- The economic aspects by generating new business development locally and regionally, by providing the low-income people of Cambodia a possibility to cut their budget for lighting
- The environmental aspects to reduce the use of non-renewable energy sources and to improve the in-door climate.

This commitment towards sustainability is motivating already a considerable amount of students from all over the world to contribute to the fulfillment of Kamwork's ambitions.

For more information:
http://moonlight.kamworks.com/
www.io.tudelft.nl/bop
www.intocontext.org

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