Master Thesis

University of St. Gallen
M.A. International Affairs & Governance

# Innovation for Developing Countries through Human-Centered Design

## The Example of a Micro Solar Pump in Bangladesh

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19 November 2012

**Abstract**

In recent years, it has become more and more evident that traditional development strategies or charity alone will not solve the complex problems of poverty, inequity and unsustainability that humankind faces today. Increasingly, the private sector is called upon to use its know-how, influence and innovations to sustainably serve those billions of poor people that have been neglected by global markets until this day. This is the central quest of the “base of the pyramid” (BoP) theory brought to prominence by C.K. Prahalad. Despite a vast amount of academic articles and lively discussions about the topic, many aspects of the BoP theory still need to be studied more thoroughly. This thesis aims to contribute to the closing of one such knowledge gap by broaching the issue of *design for the BoP*.

Three central questions guide this research: first, *why* should a company venture into the BoP market? Second, *how* can a company design goods and services that meet the special needs of poor people? And third, *what* kinds of design innovations are most needed in the developing world? It will be argued that, in order to design innovations that have a real impact on poor people’s lives, the design process has to be human-centered and context-driven and should be seen as an iterative trial-and-error process, rather than a sequence of orderly steps.

Against the background of the theoretical part, one practical example of design for the BoP will be assessed: the case of a micro solar water pump that was designed for the needs of smallholder farmers in the developing world. In accordance with what is argued in the theoretical part, this innovation will be assessed on the basis of its technical reliability, its desirability to the farmer and its affordability. It will be concluded that the solar pump probably will not enter the market as a one-to-one replacement of existing fuel powered irrigation technologies, but has great potential if it is marketed as one part of a comprehensive solar system that offers also other amenities – light, for example.

Overall, the combination of theoretical knowledge and practical findings from the field allow us to uncover the difficulties in designing for the BoP and to give practical advice how to overcome those barriers.

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## Abbreviations

| | |
|---|---|
| BADC | Bangladesh Agricultural Development Corporation |
| BDT | Bangladeshi Taka |
| BMDA | Barind Multipurpose Development Agency |
| BoP | Base of the pyramid |
| BRDB | Bangladesh Rural Development Board |
| BUAS | Bern University of Applied Sciences |
| BWDB | Bangladesh Water Development Board |
| CMES | Center for Mass Education in Science |
| DTW | Deep tube well |
| FAO | Food and Agriculture Organization of the United Nations |
| Ha | Hectare |
| HP | Horse power |
| IDCOL | Infrastructure Development Company Ltd. |
| iDE | International Development Enterprises |
| IIMS | Improving Irrigation Market Systems project |
| Kg | Kilogram |
| kWh | Kilowatt hour |
| l | Liter |
| LED | Light-emitting diode |
| LLP | Low lift pump |
| m | Meter |
| MAWTS | Institute of Technology Engineering and Technological Services |
| NGO | Non-governmental organization |
| PV | Photovoltaic |
| R&D | Research and development |
| ROI | Return on investment |
| RSF | Rural Services Foundation |
| sec | Second |
| SHS | Solar Home System |
| STW | Shallow tube well |
| UN | United Nations |
| UNDP | United Nations Development Programme |
| USAID | United States Agency for International Development |
| USD | US-Dollar |
| W | Watt |
| WRI | World Resource Institute |

# 1. Introduction

## 1.1. The bigger picture

How can we safeguard our planet's fragile ecosystem? And how can we make sure that all people – today and in the future – can live healthy and fulfilling lives? These are the defining challenges of the 21st century. The United Nations (UN), therefore, have taken the latest issue of the Human Development Report as an opportunity to survey two critical aspects of human development: *sustainability* and *equity*.

"Human development", as stated in the report, "is the expansion of people's freedoms and capabilities to lead lives that they value and have reason to value" (UNDP 2011, p. 1). At the same time, the expansion of the substantive freedoms of people today must not compromise those of future generations. Sustainability and equity have to go hand in hand. However, there is increasing evidence that causes concern: the consequences of environmental degradation are felt around the world and there is a potential of future deterioration. This, in turn, increases inequalities because climate change affects mostly those people that are already disadvantaged. "In many cases the poorest countries bear the brunt of environmental deterioration, even though they contribute only a small share to the problem" (UNDP 2011, p. 43). The poor carry a double burden of deprivation because they are most affected by the increased intensity and frequency of natural disasters, and at the same time do not have the tools to cope with these situations.

In an earlier issue of the Human Development Report it is argued that "[h]uman life is ultimately nourished and sustained by consumption" (UNDP 1998, p. 1). While world consumption has expanded at an unprecedented pace over the last century, billions of people still lack access to energy, water and sanitation, healthcare and education. Continuing failure to reduce these inequalities threatens the progress in human development and bears the risk of violent conflicts (UNDP 1998).

In recent years, it has become more and more evident that traditional development strategies or charity alone will not solve these complex problems of inequity and unsustainability. Increasingly, the private sector is called upon to use its know-how, influence and innovations to sustainably serve those billions of poor people that have been neglected by global markets until this day. One of the first to formulate this quest was C.K. Prahalad. He argues that business ventures targeting what he calls the "base of the economic pyramid" (BoP) do not only generate profits to the private sector, but can also serve the diverse needs of poor people around the world. In the literature it is argued that by engaging previously excluded voices, concerns and interests, "the corporate sector can become a catalyst for a truly sustainable form of world development and prosper in the process“ (Hart and Simanis 2008, p. 5).

This new, market-based approach to the BoP has received considerable attention from development practitioners and scholars. Despite a vast amount of academic articles and lively discussions about the topic, many facets of the BoP theory need to be more deeply assessed. One such knowledge gap is related to the question of how to find out what people at the BoP need, and how to design those goods and services. Gearing design processes towards the very different needs and circumstances of developing world consumers is seen as a vital step in addressing BoP markets (Ahern et al. 2006, p. 48). Yet, little has been said about *design for the BoP*.

This master thesis attempts to contribute to the closing of this gap by proceeding as elaborated hereafter.

### 1.2. Objectives

The objective of the theoretical part is to bring together the concepts of *design* and *base of the pyramid.* In a first step, both those terms will be defined by reviewing the literature on the topics. After having defined what we mean by design for the BoP, we shall proceed to answer three questions:

1. **Why** should a company decide to design for the BoP market in the first place?
2. **How** can a company design its products and services in order to better meet the specific needs of poor people?
3. **What** kind of design innovations are most needed in the developing world?

Against the background of the theoretical part, we shall then proceed to analyze a practical example of design for the BoP. During a four-month internship with the NGO iDE (International Development Enterprises) in Bangladesh, the author evaluated the viability of a micro solar water pump. Designed to serve the needs of small-scale farmers, this technology was tested in the field for the first time. Again, three central questions will guide the research:

1. **Reliability**: As from the experience made during the field testing, is the micro solar water pump technically sound?
2. **Desirability**: Can the pump cover the farmers’ needs in terms of irrigation water and is the system desirable to them?
3. **Affordability**: Does the price of the pump correspond to the farmers’ ability and willingness to pay – especially in view of other irrigation methods that are available in Bangladesh?

Overall, combining theoretical knowledge with practical findings from the field shall allow us to uncover the difficulties in designing for the BoP and to give practical advice how to overcome those barriers.

### 1.3. Methodology

The theoretical part mainly consists of a literature review on the topics of design and BoP. The value of this master thesis is that it tries to bring those concepts together in an attempt to better understand what is needed to produce designs that are suitable for the third world context.

The findings in the practical part are drawn from primary, as well as secondary sources of information. Important insights have been gained from the interviews with farmers and other key actors within the irrigation sector in Bangladesh (see appendices B to F). Besides the field investigation, meetings have been held with NGOs and government agencies that are active in the field of renewable energy and irrigation i.e. the Bangladesh Agricultural Development Corporation (BADC), the Barind Multipurpose Development Agency (BMDA), Grameen Shakti, Renewable World and Rahimafrooz Ltd.

### 1.4. Limitations

There are a number of limitations to this research. Due to the limited scope of this thesis, the focus is on the aspect of design for the BoP. Other interesting aspects of the theory that need further assessment are left to future research.

The most important limitation in the practical part is that it focuses on the specific case of Bangladesh. The interviews and field visits were all done in a specific and preselected area: the district of Rangpur in the North of Bangladesh. Given the limited sample size and confined geographic area covered, the findings of the study may not represent the entire country. It should also be acknowledged that the statements made in the practical part exclusively refer to the field testing in Bangladesh. The conclusions about the viability of the micro solar water pump might therefore not apply to other countries and their specific conditions. To get a broader idea about the market viability of the micro solar water pump, similar studies should be conducted in Nepal, India, Ghana and Honduras where the pump systems were tested as well.

# 2. Definitions

## 2.1. Base of the pyramid

### 2.1.1. The difficulty of defining the BoP

“Forget Tokyo’s schoolgirls and Milan’s fashionistas. Instead, try the world’s 4 billion poor people, the largest untapped consumer market on Earth”, recommend C.K. Prahalad and Allen Hammond (2004, p. 40). What they express is their conviction that not the wealthy few in the developed world, but the billions of “aspiring poor” are the key source of future growth for global companies (Hart and Prahalad 2002, p. 1). Their thesis is simple but striking: by selling to the poor, who build a massive and underserved market, companies can not only generate profits, but also help set an end to the economic isolation throughout the developing world (Hammond and Prahalad 2004, p. 30).

Prahalad, an influential business scholar and consultant, has been working on new solutions for the long-standing and seemingly intractable problem of poverty for many years. Teaming-up with Allen Hammond (2004), Stuart L. Hart (2002; 2012) and Ted London (2004; 2012), Prahalad takes a market-based approach to what he calls the “base of the economic pyramid” (BoP). At the top of this pyramid are the affluent middle- and upper-class consumers in the developed world, as well as the rich elites in developing countries. The poor customers in developed countries and the rising middle class in the third world together form tiers two and three. Tier four, the base of the economic pyramid, is composed of those people that earn less than the minimum considered necessary to sustain a decent life – which, according to Hart and Prahalad, is the case for the majority of the world’s population (Hart and Prahalad 2002, p. 4).

A 2007 report published by the World Resource Institute estimates that there are four billion people living at the BoP, all with yearly incomes below $3’000 in local purchasing power (WRI 2007, p. 3). Aneel Karnani criticizes that the size of the target market at the BoP is defined inaccurately and that there is no consistency in the literature about where to draw the poverty line: at a yearly income of $1’500, $2’000 or $3’000? Karnani also warns that Prahalad and his co-authors overestimate the number of people living at the BoP and the market potential of this segment (Karnani 2006, pp. 100-101). In response, Prahalad argues that it is more important to recognize that there are billions of people who are neglected by the organized sector and the opportunities that arise from this, rather than continuing the debate over poverty lines (Prahalad 2011, pp. xxvii-xxviii). Even though the individual households may dispose only over a small income, the BoP collectively possesses most of the buying power in many developing countries (Hammond and Prahalad 2004, p. 32). Putting aside the difficulty in defining the exact size of the BoP, it can still be concluded that it is a large market which promises vast economic returns to those who start to serve it. What makes Prahalad's approach interesting is that it not only promises benefits on the business side, but also a way out of poverty for the people living at the BoP.

### 2.1.2. The mutual value proposition

At its core, the BoP literature is based on the proposition of "mutual value creation" (Anupindi et al. 2010, p. 582). This means that business ventures serving the BoP are expected to generate economic returns for the investors, but also to provide returns for the local community in which they operate. In a sort of win-win engagement, business strategy and poverty alleviation are brought together (Hammond and Prahalad 2004, p. 33). In line with this, and contrary to more traditional approaches to poverty, poor people are not seen as aid recipients but as consumers that can participate well in an organized market system (WRI 2007, pp. 5-7). Advocates of the BoP theory start from the premise that what poor people really need are not charitable gifts or social assistance, but access to a greater choice of goods and services. They argue that this will help them to increase their productivity, raise their income and ultimately allow them to escape the viscous circle of poverty (Hammond and Prahalad 2004, p. 35). On a larger scale, "the resulting decrease in poverty produces a range of social benefits, helping to stabilize many developing regions and reduce civil and cross-border conflicts" (Hammond and Prahalad 2002, p. 48).

Karnani disagrees with this line of thought and raises the question of how engaging the poor in the formal economy will improve their situation and how consumption can alleviate poverty. He argues that "[g]etting the poor to consume more will not solve their problem" (Karnani 2006, p. 107). Prahalad responds to this by saying that "[p]overty alleviation is, simply, improving the disposable income for the families – by reducing the costs of services, improving its quality, and releasing their time to do work that is productive" (Prahalad 2011, p. xxix). He argues that there is a link between consumption and income generation and adds a number of examples that illustrate this. Buying a refrigerator, for example, or eating better food can improve a person's health and increase his or her earning potential. Buying a cell phone can help a day laborer find work more easily. Buying a solar light can allow a woman to make handicraft in the evening and to sell them for profit - and so on (Prahalad 2011, p. xxviii-xxx).

### 2.1.3. Next generation business strategies for the BoP

In recent years, the market-based approach proposed in the BoP literature has provoked discussion and controversy among scholars and development practitioners. Critical voices started questioning the appropriateness of selling to the poor and profiting from them (WRI 2007, p. 25). Others are concerned that "BoP businesses will spur consumerism among the poor, resulting in accelerating environmental destruction" (Hart and London 2011, p. 4). Furthermore, there are still doubts how exactly the market-based BoP approach will eradicate poverty on a large scale (Walsh 2005, p. 477). In response to those concerns, and as a result of the lessons learnt from the first generation of BoP ventures, Hart and London together with other experts in the field published a book entitled *Next Generation Business Strategies for the Base of the Pyramid* in 2011.

In this new book, BoP ventures are no longer framed as *finding* a fortune *at* the BoP, but as *creating* a fortune *with* the BoP (Hart and London 2011, pp. 2-3). In the early days of Prahalad's work, the BoP was seen as a huge neglected market that was passively waiting to be discovered. Valuable lessons have been learnt since then. While there are a number of successful cases of first generation ventures, others have failed or could not reach significant scale (Hart and London 2011, p. 2). The next generation business strategies, therefore, go beyond providing solutions for poor consumers in a top-down approach and the focus has shifted towards generating income and building capacity at the BoP. Related to this is the insight that, in order to create self-sustaining and scalable BoP ventures, the local context has to be understood and existing resources have to be leveraged (London and Hart 2011). While the early BoP literature exclusively addressed large multinational corporations, more recent publications also assign an important role to indigenous companies, cooperatives, and NGOs which can, because of their understanding of the local context, be valuable partners or even establish BoP ventures on their own (Anupindi et al. 2010, p. 583).

Another aspect found in more recent publications is that, in order to reach economic self-sufficiency at a later stage, some BoP ventures need support from government or aid agencies, at least in the beginning. Such support might come in the form of incentives (such as R&D support, access to government-owned land, tax incentives etc.) or the removal of certain barriers. It may also be financial assistance in the form of "smart-subsidies" to cover the start-up costs of BoP ventures. This is justified by the fact that incumbent industries in top of the pyramid markets also receive substantial support, and by the fact that encouraging BoP business ventures creates value for the general public. Consequently, not only the formal and informal market, but also governments and the donor community will have to play their part to create a favorable market environment and to encourage investment in the developing world (London 2011, pp. 223-224).

Overall, what makes Prahalad's approach to the BoP interesting, is the way it combines business and development strategies. For business leaders, the BoP literature is relevant because it shows how to tap into a vast, underserved market. Basically, what they have to do is see poor people as customers and "do what [they] already do so well: create wealth" (Walsh 2005, p. 474). For development practitioners, the BoP literature offers an alternative view as it reframes the poverty alleviation task "from one of constant struggle with subsidies and aid to entrepreneurship and the generation of wealth" (Prahalad 2004, p. 125).

Over the past couple of years, market-based approaches to the BoP have gained considerable prominence. There is an increasing amount of literature and lively discussions about the different facets of the BoP theory. However, many aspects like the question of how to overcome the constraints in a third world context, or how to reach scale, will need to be assessed more deeply. Another knowledge gap that needs to be addressed, is the question of how to find out what people at the BoP need and how to design those products and services. Gearing design processes towards the very different needs and circumstances of developing world consumers is seen as a vital step in addressing BoP markets (Ahern et al. 2006, p. 48). Yet, little has been said about *design for the BoP*.

This master thesis attempts to contribute to the closing of this gap by bringing together the theories about the BoP and design. In the course of the theoretical part, three central questions will be addressed: *why*, *how* and *what* should be designed for the BoP? Before that, the two central concepts, the *base of the pyramid* and *design,* need to be defined. After having talked about the BoP theory and how it evolved over the years, we shall now proceed to define the term "design" by reviewing the literature on the topic.

## 2.2. Design

### 2.2.1. The omnipresence and the ambiguity of the word "design"

In Western consumerist societies, the word "design" is omnipresent. There are design fares, design awards for the trendiest products and design firms that court the favor of the costumers by reinventing the fashion-, furniture- or car-industry on a regular basis. Still, what is to be understood by the term "design" remains unclear. Aggravating this situation, the literature on the topic does not deliver a generally agreed definition of the concept of "design". Barbara Bloemik (2007, p. 5) says that "design is defined and based on how an object or concept balances three attributes: aesthetics, function, and cost". Victor Papanek, a well-known philosopher of design, gives an even more general definition by stating that "design is basic to all human activities. The planning and patterning of any act toward a desired, foreseeable end constitutes the design process" (Papanek 1971, p. 322). While there is no clearly formulated definition of what the word "design" means, a lot can be learnt from the changing role that the discipline of design played throughout recent history. The following chapters give a short summary of modern design history with the aim to make clear what we mean by design and in what sense the term is used in this thesis.

### 2.2.2. In the early days of mass production: design as late-stage add-on

It was during the late 19th century, with the rise of the Industrial Revolution, that industrial design came first into play. In these early days of mass production, design played a very limited role within the production process. Designers were only consulted at the very last step, when it came to put a nice wrapper around the product. Hence, they had no voice during the substantive research and development process. Design, for a long time, was conceived as "an art of giving form to products for mass production" (Margolin 1998, p. 83). Throughout the twentieth century "design became an increasingly valuable competitive asset in, for example, the consumer electronics, automotive, and consumer packaged goods industries" (Brown 2008, p. 2). In most other sectors, however, design remained a late-stage add-on. The value of design was seen as lying in its ability to improve the competitiveness of companies by making their products more desirable to consumers and by enhancing brand perception (Brown 2008, p. 2).

### 2.2.3. In the 1950s: recognition of the responsibility of design

In the late 1950s, critical voices began to put into question this limited role of design that, as Dean Nieusma formulates it, focused "on creating products aimed at satisfying spurious desires of a narrow group of people" (Nieusma 2004, p. 21). Papanek was one of the first to advocate for a more socially and environmentally responsible design. In his seminal work *Design for the Real World* he writes: "[t]oday, industrial design has put murder on a mass-production basis. By designing criminally unsafe automobiles […], by creating whole new species of permanent garbage to clutter up the landscape, and by choosing materials and processes that pollute the air we breathe, designers have become a dangerous breed" (Papanek 1971, p. ix). What Papanek criticizes is that designers, rather than aiming at bringing about social and environmental improvement, are eagerly serving profit-oriented companies without thinking about the consequences of their acts. They are, therefore, not living up to the "high social and moral responsibility" that comes with the powerful tool of design that they have in their hands (Papanek 1971, p. ix). Papanek also takes issue with industrial designers that, while they know well how to address the needs of the middle and upper-class, have lost sight of a substantial part of the population: the poor, the sick, the elderly and the disabled. Papanek asks designers to be concerned also with those groups of consumers that are "outside their familiar experiences" and that have, so far, been gravely neglected (Papanek 1971, pp. 184-185).

Even before Papanek's work came into prominence, there had been efforts to refocus design practice towards better meeting the needs of marginalized people. In the 1960s, a range of scholars and design practitioners advocated the transfer of technologies to third world countries. The idea was that high-end Western technologies could also benefit the poor. The reality check in the local context, however, showed that a one-to-one transfer failed in most of the cases and expensive technology systems could not be put into use. The differences between the technology's development context and its use context were simply too significant. Because of the specific economic, social and cultural circumstances, as well as the limited availability of resources (capital, know-how, spare-parts etc.) that prevailed in the third world context, the technology scholars had to realize that the transferability of technologies was only very limited (Nieusma 2004, p. 13).

In reply to the failures of those technology transfer attempts, the so-called Appropriate Technology movement emerged. Inspired by E.F. Schumacher's book *Small is Beautiful: Economics as if People Mattered*, the movement caught momentum in the 1970s. The main argument of its adherents was that technologies, above all, have to suit the local context and need to account for the specific needs of marginalized consumer groups - the poor, for example. As Nieusma formulates it: "[a]ttention to contextual particularities became one of the guiding approaches to appropriate technology and, hence, unlike technology transfer scholars, appropriate design thinking took design as the point of intervention" (Nieusma 2004, p. 13).

Since the 1970's, the critiques and ideas formulated by authors like Papanek or Schumacher "have continued to ripple through design schools and conferences" (Margolin 1998, p. 85). In recent years, however, the Appropriate Technology movement's prominence continued to decline. Nevertheless, its central ideas are still to be found in other design communities that have arisen under such names as universal design, participatory design, ecological design, feminist design or socially responsible design (Nieusma 2004, p. 14). These approaches share the belief that design can play a game-changing role and can have a real impact on people's lives. Along with this came the insight that designers hold great responsibility and the recognition that "unless designers grasp the significant content of the products they create, their work will come to little consequences or may even lead to harm" (Buchanan 2001, p. 35).

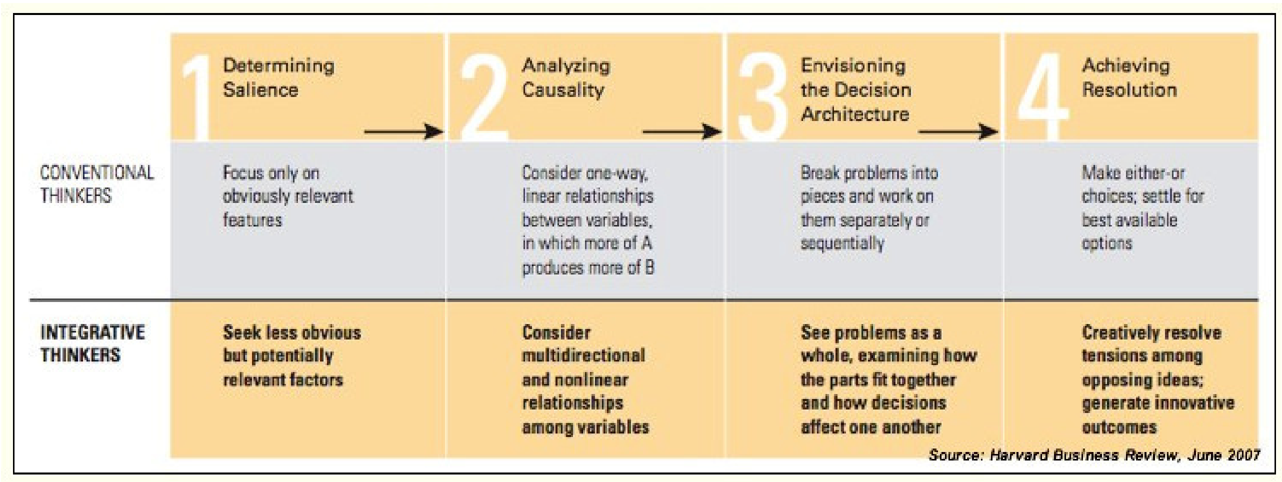
#### 2.2.4. Today: design thinking for real impact

While authors like Papanek and Schumacher have brought new perspectives into the discussion about what role design can and should play, their work does not seem to have reached current design practitioners. The vast majority of designers today are preoccupied with making things more attractive, more marketable. "[They] focus all of their efforts on developing products and services for the richest ten percent of the world's customers" as Paul Polak formulates it (2007, p. 19).

There is, on the other hand, growing resistance among design scholars and practitioners to see design exclusively as a tool of consumerism. What they promote is a more expansive view of design that aspires to have real impact and not only to produce incremental change. This more holistic approach is called *design thinking* – which is a new way of thinking about problems and creating solutions.

Design thinking starts with what Roger Martin calls *integrative thinking*. Martin interviewed more than fifty top managers over the course of six years with the goal to find out how successful leaders think. What he found out is that they all share a common trait: "[t]hey have the predisposition and the capacity to hold in their heads two opposing ideas at once. And then, without panicking or simply settling for one alternative or the other, they're able to creatively resolve the tension between those two ideas by generating a new one that contains elements of the others but is superior to both" (Martin 2007, p. 64). Integrative thinkers embrace the mess, while the most of us prefer the comfort of simplicity and clarity over complexity and ambiguity (Martin 2007, p. 64). They resist the temptation of choosing among pre-defined alternatives and "see nonlinear and multidirectional relations as a source of inspiration, not contradiction" (Brown 2009, p. 85). When integrative thinkers address a problem, they work trough the same steps as conventional thinkers but approach them in a different way (see figure 1).

**Figure 1: Conventional vs. integrative thinking**

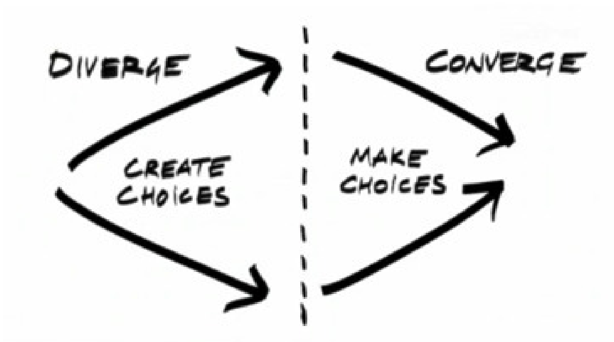



Source: Martin 2007, p. 65

While conventional thinkers "seek simplicity along the way and are often forced to make unattractive trade-offs", integrative thinkers "welcome complexity – even if it means repeating one or more of the steps" (Martin 2007, p. 65). This gives them a far greater space of opportunities how to address a problem and allows them to come up with ideas that are truly innovative.

These are exactly the traits that Tim Brown ascribes to design thinkers as well. For him, what distinguishes them is their approach to problems as they prefer divergence over convergence. Convergence means to make the best of existing alternatives. Divergence, in contrast, aims at multiplying options and unleashing creativity (see figure 2). Design thinkers are capable of this way of divergent thinking, meaning that they have an ability to bring together opposing ideas and constraints in order to create new solutions (Brown 2009).

**Figure 2: Divergence vs. convergence**




Source: Brown 2009, p.66

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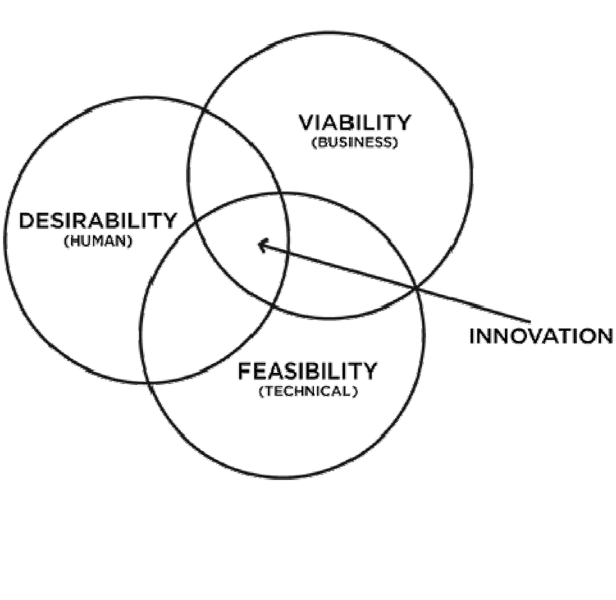
As will be further elaborated later on, designing products and services that have a real impact will require design thinkers to balance three spheres: desirability, feasibility and viability (IDEO 2012, n.p.).

**Figure 3: The three spheres of design thinking**




Source: IDEO 2012, n.p.

This means that “design thinking is a heuristic that balances customer, business and technology needs to ensure the results benefit both customers and company” (Sato 2009, p. 48).

Interestingly, not only design professionals and graduates from design schools can become design thinkers. Brown observes that a lot of people outside the world of professional design have what he calls a “natural aptitude” for design thinking. Martin even argues that integrative thinking is not something a person is born with, but a capability that can be honed (Martin 2007, p. 62). As such, everyone who is willing to leave the comfort zone of predictability and who is able to create new solutions out of complex situations can become part of a design thinking process and produce innovations that have a real impact (Brown 2008, p. 3).

At the center of the design thinking process is the focus on fundamental human needs – in opposition to artificially created or manipulated desires. In this *human-centered* design approach, the starting point is not a technology, product or service that needs to be refined, but the discovery of a local context and culture with the goal to uncover the hidden needs of people. Design, therefore, comes in at the outset of the development process and is no longer a late-stage add-on (Sato 2009).

### 2.3. Concluding remarks

The aim of this chapter was to clarify what we mean by “design” and “BoP”. Both these concepts are widely discussed in the current literature but still not clearly defined. Especially the word “design” incorporates different meanings. The way it is used in common speech – as the practice of making things more attractive and marketable – does not correspond to the way it will be used in the following chapters. While aesthetics and attractiveness also play a role when developing products and services for poor customers, what we mean by design is a much broader concept. A concept that is called *design thinking*.

In the following chapters, both these theories about the market potential at the base of the pyramid and the methodology of design thinking shall be brought together. In a first step, we will address the central question of *why* a company should decide to serve the BoP market and to apply a design thinking approach in the first place? We shall then proceed to investigate *how*, in practice, a human-centered design process looks like. Third, the question will be raised of *what* kind of innovative products and services are most suitable for the BoP marketplace.

## 3. *Why* to design for the BoP

### 3.1. Challenges at the BoP

In the previous chapter, it has been elaborated that Prahalad and his co-authors, in their pioneering work, suggest that there is a fortune to be made for entrepreneurs in the BoP market. At the same time, there is also widespread recognition that this marketplace holds great challenges.

Among the various barriers to doing business in the developing world, the distribution access is among the most critical ones. Unlike in the developed world, the necessary infrastructure (roads, transport system etc.) and distribution channels are often unreliable or nonexistent. Getting products and services to poor people, who often live in very remote rural areas, is one of the most difficult hurdles to overcome. Besides the lack of transportation and communications infrastructure, the business environment in the third world can be challenging because of the lack of robust and enforceable legal frameworks and the problem of corruption (Anderson and Billou 2007, pp. 14-15). As Shane Ahern et al. note: "contracts are seldom sufficient in developing contexts. Courts are slow to act, sometimes viewed as corrupt, and judgments can be hard to enforce" (Ahern et al. 2006, p. 57). Furthermore, "religious or racial conflict, and sometimes even war or violent insurgencies [might] stifle the enthusiasm of companies in serving people living in poverty" (Anderson and Billou 2007, p. 14).

Not only on the supply, but also on the demand side, the BoP is not the most easily accessible market. Finding the products and services that suit local needs is a difficult and time-consuming task. In addition, poor customers have a very limited income and therefore tend to be risk-adverse when it comes to trying new products (Ahern et al. 2006, p. 57).

For Prahalad, those barriers are not insurmountable. The proof for this is that many multinational companies are already serving the wealthier middle- and upper-class markets in the developing world and therefore have shown how to overcome those hurdles (Hammond and Prahalad 2004, p. 32). Furthermore, there are very positive trends to be observed in the developing world: political reforms, a growing openness to investment or the development of low-cost wireless communication networks are reducing the barriers to doing business in these countries (Prahalad and Hart 2002, pp. 49-50).

While one cannot deny that marketing to the BoP holds great challenges, there are also vast opportunities waiting in this market – as will be elaborated in a next step.

## 3.2. Opportunities at the BoP

### 3.2.1. Three good reasons why to design for the BoP

Why, in view of the challenges described above, should an entrepreneur decide to venture into the BoP market and, in doing so, adopt a design thinking approach? The reason is simple: it is in his self-interest.

- First, because it allows tapping into a market with a vast collective purchasing power and promises, at the same time, to improve poor people's lives.
- Second, because the developing world is an ideal laboratory for innovations that are also in demand at the top of the economic pyramid.
- Third, because adopting a design thinking approach can be a potential source of competitive advantage.

### 3.2.2. First reason: the promise of financial benefits and the potential to improve poor people's lives

The central idea of Prahalad's approach to the BoP, as it has been elaborated, is that market-based initiatives are the best way to fight poverty. By selling to the poor, he argues, their life can be improved. This idea has been criticized by various authors and has raised the question of how consumption can alleviate poverty. As Hart and London (2011, pp. 2-3) put it, the idea is not to tap into wealth, but to create value at the BoP. Companies that invest in developing countries, above all, do not want to do this at a loss. But, as a sort of positive side-effect, they also improve local conditions. Through the establishment of businesses, jobs are created and the local infrastructure is improved – which, in turn, benefits the whole community. Serving the BoP is further a question of respect and equity, as poor people get access to a greater choice of goods and services and are no longer excluded from the benefits of global markets. In the 1998 Human Development Report it is stated that "[h]uman life is ultimately nourished and sustained by consumption. Abundance of consumption is no crime. It has, in fact, been the life blood of much human advance" and "clearly contributes to human development" (UNDP 1998, p. 1).

Overall, the literature presents the BoP as a growth market with huge potential – especially in view of the fact that many large private sector companies seem to have "nearly saturated existing markets" (Hammond and Prahalad 2002, p. 51). At the same time, those BoP ventures can contribute to the alleviation of poverty in a sustainable and effective way that goes far beyond charitable giving.

### 3.2.3. Second reason: the BoP context is an ideal laboratory for innovation

Another reason for a private company to enter the BoP market is that it is "an ideal testing ground for developing environmentally sustainable technologies for the entire world", as Hart and Prahalad (2002, p. 2) argue. In view of the rampant environmental degradation, such green innovations are desperately needed. The fact that millions of people in emerging economies like India and China will raise towards the middle class in the coming years, makes the prospect even look darker. If we add the four billion people at the BoP, who aspire to join global markets, we reach a level of stress that our planet will not be able to sustain (Prahalad 2010a, p. 32). The current path of growth and traditional business models are therefore more and more put into question. Companies are now asked to develop innovative products, services and processes that address the social and environmental challenges of our time.

Many companies, however, struggle with this change of innovation patterns away from "the assumptions of affluence and abundance" towards sustainability (Mashelkar and Prahalad 2010, p. 133). But there are a couple of entrepreneurs in developing countries going this new path. "Faced with shortages of capital, technology, and talent", Mashelkar and Prahalad explain, they "have had no choice but to overturn accepted wisdom" and "have ignited a new genre of innovation" (2010, p. 134). A genre best termed *disruptive innovation*. While most organizations rely on well-established processes and knowledge, disruptive innovators go beyond and overturn the existing products and processes in the market. China and India, for example, have become a breeding ground for innovative cost-optimized and streamlined management processes (Halme and Kandachar 2007, p. 6). Similarly, developing countries are predestined to produce game-changing innovations in the field of communications, health care or green energy (Hart and Christensen 2002).

Ram Nidumolu et al. (2009, p. 62) argue that "it's easier for global enterprises to foster innovation in emerging markets where there are fewer entrenched systems or mind-sets to overcome". In line with this, they observe that the governments of developing countries, whose poor populations suffer most from the effects of climate change, are very supportive of companies that want to introduce sustainable products and processes. Another reason why developing countries often are a better market for innovations is that companies are competing against non-consumption. If a clean technology is introduced in a developed market first, there is a high risk that it cannot stand up to the direct comparison with wasteful but inexpensive existing technologies, or that it is refused by critical consumers. In a BoP market, in comparison, technologies do not have to compete with well-established systems and this provides innovators with the necessary time and space to refine the innovations and make them suitable for the local context (Hart and Christensen 2002, p. 55).

The knowledge gained from the testing in the BoP market is valuable for a company because it can potentially be transferred to other contexts. Thus, tier four of the economic pyramid can be seen as “testing ground for sustainable living” (Hart and Prahalad 2002, p. 12). The technologies developed there can then be transferred up-market all the way to resource- and energy-intensive markets at the top of the pyramid. An example where this strategy has been successfully adapted is General Electric (GE) which invested billions of dollars into the search for health care innovations. Among others, they designed low-cost ultrasound machines suitable for hospitals in the developing world. For GE, this strategy was successful in two ways: first, it allowed them to develop disruptive low-cost technologies before competitors came up with a similar product that could have endangered GE’s market position in both the developing and developed world. Second, GE later on introduced those machines also in the United States, where it has become a pioneer in the production of affordable health care technologies (Govindarajan et al. 2009).

In sum, the BoP market can be interesting for a private sector company for it is an ideal testing ground for disruptive innovations. In view of the most pressing problems of our time, environmentally and socially sustainable innovations are in great demand. Hence, companies that are early-movers in developing competencies in the field of sustainable development will be one length ahead of their competitors and will have a considerable advantage (Nidumolu et al. 2009, p. 58).

### 3.2.4. Third reason: design thinking leads to a competitive advantage

After having discussed the gains companies can expect when they address the BoP, the question now is why they should adopt a design thinking approach in doing so. Again, the answer is because it is beneficial for them and gives them an advantage over their competitors. Design thinking is not only a tool for creative problem solving, but also a strategic business tool (Amir 2004; Baek and Kim 2011).

There is a growing recognition that design thinking “may now have something very significant to offer when applied more broadly to business management and strategy development” (Leavy 2010, p. 6). This idea is extensively discussed in Martin’s book *The Design of Business: Why Design Thinking is the Next Competitive Advantage* (2009). According to Martin, the strength of the design thinking approach lies in its ability to reconcile two ways of thinking: exploration and exploitation. Leavy argues that most organizations are biased towards exploiting existing knowledge and analytical thinking. This is because they want to produce reliable, predictable outcomes. Other practitioners, designers for example, feel more at home in the world of originality and invention (Martin 2010, p. 38). Their aim is to explore solutions beyond what exists and to create new value through the use of their intuition. Both ways of thinking present a risk, as Leavy argues: „exploitation will lead to eventual stagnation, while an obsession with exploration is a recipe for instability and inability to scale“ (Leavy 2010, p. 8).

This is where design thinking comes in as a sort of middle way. Design thinking does not value intuitive thinking over analytical thinking, but brings them together. It helps the company to exploit conventional knowledge, but also to leap beyond what exists already. Companies that master design thinking will engage in producing innovative products and will also continuously redesign their business – and this will confer a long-term business advantage on them (Martin 2010, p. 38). The tool that design thinkers use is the „logic of what might be“, which lies somewhere between data-driven analytical thinking and intuitive thinking (Leavy 2010, p. 9). Thus, a design thinker is not confined to systematically working through existing knowledge, nor to the knowing-without-reasoning of intuitive thinking. Instead, he ventures out into the unknown, while at the same time using logic processes in order to produce results that are consistent and replicable (Dunne and Martin 2010, p. 513). Applying a design thinking approach will be beneficial for the company because it will not only produce advances in the production of innovation but also in the efficiency of the processes. And this, Martin argues, „produces the most powerful competitive edge“ (Martin 2010, p. 38). Consequently, “today’s business people don’t need to understand designers better, they need to *become* designers“ (Dunne and Martin 2006, p. 513).

### 3.3. Concluding remarks

There is a range of challenges, but also huge opportunities in marketing to the BoP. We have shown that by serving the poorest customers, companies cannot only make financial profit, but also contribute to the alleviation of poverty. We have further shown that it is in their self-interest to start ventures in the developing world and to apply a design thinking approach, because this will confer a considerable competitive advantage on them.

Prahalad underlines that, in order to succeed in their BoP ventures, business leaders need to change their approach. “Doing business with the world’s 4 billion poorest people […]”, he says, “will require radical innovation in technology and business models” (Hart and Prahalad 2002, p. 2). They will have to design products and services that are culturally sensitive, environmentally sustainable, and economically profitable. This demands a certain level of courage, as the companies will have to leave their well known path and venture out to discover radically new solutions. Design thinking is therefore well suited to guide companies through the innovation process. *How* such a design process looks like will be elaborated in the following chapter.

# 4. *How* to design for the BoP

## 4.1. Difficulties that cause design projects for the BoP to fail

As has been discussed in the preceding chapters, market-based approaches to the BoP promise to generate income for the private sector and to improve poor people's quality of life by letting them participate in the economic exchange. Due to the complex and interwoven constraints present in the developing world, however, designing products and services for those societies is not a straight forward process. Proof of this is that many design projects in the developing world have failed to produce sustainable outcomes. Alike, "[m]any well-intended technologies devised for the developing world have not become commercially viable and have remained in the realm of the design studio or as charitable distribution programs" (Ahern et al. 2006, p. 48). The literature offers two explanations for these failures: first, there is a gap between the context where the innovations are designed and the conext where they are used. Second, the needs of BoP customers are poorly defined and the context they live in is not sufficiently understood.

The fundamental task of every designer is to imagine the needs of the target group. Designing for poor customers is particularly challenging, because in many cases the designers are expected to address needs and problems that they do not experience themeselves (Nieusma 2004, p. 14). Often, an important part of the desing process takes place in the developed world and is performed by designers who are used to deal with the wants and needs of customers in advanced economies. Further, most of the design literature has been written in an industrialized context and therefore does not address the specific challenges that designers face in their BoP projects. While there has been an increase in the amount of reserach done on the BoP, the aspect of product desing for this market has been largely ignored (Sridharan and Viswanathan 2012). This results in a disconnect between the designers and the users in the third world.

Related to the lack of understanding of the local conext is another difficulty that causes many development projects to fail: the inadequate definition of needs. Defining needs is central to every design process. If this is not properly done, the outcome might be a product that is innovative but probably not very sustainable, nor appropriate for the needs of the customers. The difficulty is that the needs of the people at the BoP are very different from those of the middle- and upper-class customers in the developed world. Sridharan and Viswanathan observe that "[p]roduct needs in BoP markets are shaped by life experiences of chronic resource, literacy, psychological, and social barriers" (2012, p. 52). In their consumer decisions, poor people constantly face trade-offs. BoP consumers, for example, "are more likely than middle-class consumers to take on severe shortfalls in meeting extremely critical and basic needs (e.g. skipping one meal a day) while at the same time saving or investing toward their transformational aspirations (e.g. child education fees)“ (Sridharan and Viswanathan 2012, p. 66). Martin Fisher (2007, p. 34) argues that what poor people need most, is a way to make money. Even in most rural areas a subsistence lifestyle is no longer viable. People need cash to buy food, clothes, to pay for healthcare or education.

Generally speaking, the severe situation of deprivation produces wants and needs that are very different from those of middle- or upper-class consumers. The BoP should, however, not be seen as a monolithic bloc because such factors as language, tradition, food, religion but also the geographical and economic environment vary from country to country, even from region to region. Hence, a thorough analysis of the context is necessary to design products and services that meet the local needs. Designers tend to simplify this realtiy and often „take process shortcuts“, as Krista M. Donaldson formulates it. This means that they modify existing products to make them match the local context. What Donaldson critizes about this approach is that „[d]evelopment projects that should be market-pull quickly become technology-push“. She continues by saying that „design for development must move from being technology-centric to being user-centric“ (Donaldson 2006, p. 151). In line with this, other authors request to „put people first“ (Brown 2009, p. 39) and remind us that „design is for people“ (Amir 2004, p. 73). Overall, there seems to be large agreement that design for the BoP market has to be user-centric and context-driven (Sridharan and Viswanathan 2012, p. 54). This is where the design thinking approach plays an important role again. IDEO, the design and consultancy firm founded by Tim Brown, was asked by the Bill & Melinda Gates foundation to codifiy the process of design thinking. What they came up with is a human-centered design toolkit that shall help organizations to successfully go through the design process. Before talking about *how* a human-centered design process allows designers to better adress the needs of their customers, it shall be briefly discussed in what sens it is difficult to identify those needs.

### 4.2. The challenge of uncovering needs

Robert Becker and Dev Patnaik have intensively studied the “why and how of uncovering people’s needs” (1999, p. 37). What they found out is that designers often concentrate on problems that they can immediately solve – and this unnecessarily limits the information that they can gather. If they would look for needs, rather than for solutions, they would keep all possible solutions open for consideration and would avoid prematurely limiting possibilities (Becker and Patnaik 1999). Uncovering those needs, however, is not an easy task.

One possibility is to use traditional market research methods - such as surveys or focus group discussions. These methods generally “work very well in quantifying customers’ preferences among existing solution options”. They, however, “do little to identify the needs people can't readily articulate (Becker and Patnaik 1999, p. 38). Consequently, these methods are useful if a company wants to improve existing products, but fail to deliver the information needed to create innovative solutions. Brown and Wyatt (2010, p. 33) agree on this when they argue that conventional market research tools rarely yield important insights because they simply ask people what they want. Very often, however, people have a hard time reflecting on activities of everyday life and expressing their needs (Hey and Van Pelt 2010, p. 690). Henry Ford, one of the biggest innovators of all times, understood this when he said: "If I'd asked my customers what they wanted, they'd have said 'a faster horse'" (Ford cit. in Brown and Wyatt 2010, p. 33).

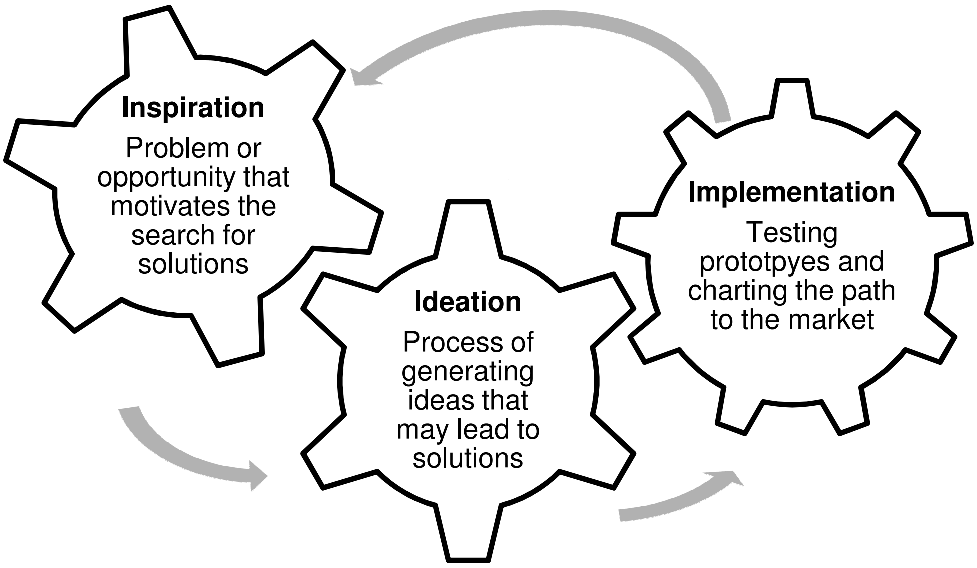
Especially in a context of ongoing deprivation, people tend to get used to their situation and to certain difficulties. Beyond that, poor people often show a high level of inventiveness and use the limited capital, material and knowledge they have at their disposal to work around problems and unmet needs. Again, traditional market research methods that rely on the customers' description of their own situation probably fail to uncover the latent needs of the people at the BoP (Becker and Patnaik 1999, p. 39). A better starting point for designers, Brown and Wyatt argue, is to go out into the world and to explore the living space of the people they design for (2010, pp. 33-34). The human-centered design kit developed by IDEO offers a range of tools and techniques that guide the design team through this process, as will be elaborated in a next step.

### 4.3. The human-centered design process

As the name suggests, human-centered design puts the people in the center of attention. What helps innovators find the solutions that are really useful for the target group is a thorough understanding of their everyday life, of their aspirations and their needs. The designer then will have to bring this aspect of desirability into balance with "feasibility" and "viability". As has been said earlier, design thinkers are looking for solutions that emerge at the overlap of those three spaces (see Figure 3, p. 11) and try to find a balance between what is desirable to the customer, what is technically and organizationally feasible and what is financially viable (Brown 2008).

The human-centered design process that will lead to such solutions is not a sequence of orderly steps but more a system of three overlapping spaces: inspiration, ideation and implementation (Brown 2009, p. 16).

**Figure 4: The three spaces of the human-centered design process**




Source: Brown 2009, pp. 16-18, own illustration

The reason for applying the concept of spaces, rather than steps, is the nonlinear, iterative nature of the process. As illustrated in figure 4, design projects may well loop back several times, especially through the inspiration and ideation space. As such, human-centered design is an ongoing learning process during which the solution is gradually refined (Hey and Van Pelt 2011, p. 690). For practitioners used to linear, milestone-based processes, this way of approaching a design problem might seem chaotic and time-consuming. Brown, however, argues that this kind of discovery process will "motivate the team to revisit some of its most basic assumptions" and they will produce solutions that are "more interesting, more promising and potentially more profitable" (Brown 2009, pp. 16-17).

### 4.3.1. Inspiration

The human-centered design process generally begins with the inspiration space. This is the moment when the problem or opportunity that motivates the search for solutions is identified. Brown and Wyatt propose that the design team should start its journey with a brief where they formulate a set of objectives to be realized, define the benchmarks by which progress can be measured or constraints that may come up. This brief should neither be too narrow, as this might be an attempt to answer the question before it has not even been asked, nor should it be too abstract, leaving the team wondering (Brown and Wyatt 2010, p. 33).

After the brief has been constructed, the designers proceed to uncover the needs of the target group. As has been discussed just before, this is not an easy task, especially in a third world context where traditional market research methods will only be of limited use. What the human-centered design toolkit recommends instead, is that designers become embedded in the lives of the people they are designing for (Brown and Wyatt 2010, p. 33). This means that they leave their laboratory and go out into the field to observe smallholder farmers, nurses or schoolchildren in their natural environment. Becker and Patnaik (1999, p. 41) are convinced that by immersing themselves in the target group's context, designers can gain a better understanding of the people's needs and can make more-informed decisions. The designers will not only have to learn what kinds of needs are unmet, but will also have to understand the broader economic environment. As has been said before, what poor people need most are innovations that help them to generate money and allow them to escape poverty by their own efforts.

Ideally, the local population is not only observed but actively involved in the design process. In this co-creation approach, the people are given a voice and encouraged to innovate themselves. This, ideally, equips them with the skills to address problems in many other contexts as well, and leads to greater empowerment of the community (Smith 2007, p. 31). Viswanathan (2011, p. 152) adds that important insights can also come from interactions with BoP "experts" such as shop owners, vendors, local opinion leaders, community-based organizations, collectives or NGOs. All this will further help to make best use of local resources – which is something that Anupindi et al. (2010) as well as Hart and London (2004) consider essential for BoP ventures. "Results suggest that the success of initiatives targeting low-income markets is enhanced by recognizing that Western-style patterns of economic development may not occur in these business environments. Business strategies that rely on leveraging the strengths of the existing market environment outperform those that focus on over-coming weaknesses" (Hart and London 2004, p. 350).

Studying people's behavior in their natural environment and observing them when they perform everyday tasks, can deliver valuable information about latent needs. As already discussed, people often have difficulties in telling designers what they want and need. On top, the oral communication between developers and users may be difficult due to language barriers. Therefore, techniques such as role plays or drawings are tools that make it easier for some people to express their views and feelings. These types of need finding techniques "[avoid] reliance on customer's memory, descriptive ability, or awareness of a need. In addition, the customer's environment facilitates communication between the researcher and the customer by allowing them both to refer to and use objects in the environment during the discussion" (Becker and Patnaik 1999, p. 40).

Hey and Van Pelt warn, however, that having a research team in their home inherently changes the behavior of the people that are being observed. They may, for example, alter their usual work routine because they want to make a good impression, or give the interviewers the answers they want to hear (Hey and Van Pelt 2011, p. 690). In order to minimize these effects, it is recommended to limit the intrusion into the environment by for example wearing appropriate clothing and to behave and speak in a way that is appropriate to the local context (Becker and Patnaik 1999, p. 41). Overall, the goal of this contextual research is to help designers see the world through the eyes of the people they are designing for. It is also an expression of a fundamental rule of human-centered design: solutions ought to be found in cooperation with the customers and not imposed in a top-down mentality that ignores the particularities of the local context (Viswanathan 2011).

### 4.3.2. Ideation

The second space of the process is ideation. At this point, the design team tries to synthesize the insights gained during the field research. The goal is to generate as many ideas as possible and to identify a great variety of potential opportunities. A useful tool to do this are brain storming sessions during which all team members are encouraged to speak their mind. This works best if the research team comprises people from many different backgrounds. Because the problems that have to be addressed tend to be very complex, it can be fruitful to collaborate across disciplines. As Brown formulates it, interdisciplinarity "has replaced the myth of the lone creative genius" (Brown 2008, p. 3). The idea is to bring together people from various fields such as design, psychology, architecture, engineering, marketing or ethnography to reflect on a problem (Buchanan 2004, p. 35). While those disciplines, and many others, have been contributing to the development of new products and services before, they have rarely worked together in the same team, in the same room, following the same process (Brown 2009, p. 26). True design thinkers form an interdisciplinary team in which – contrary to a merely multidisciplinary team – people are no longer trying to impose their view on the problem, but show "empathy for people and for disciplines beyond one's own" (Brown and Wyatt 2010, p. 34).

### 4.3.3. Implementation

The third space of the human-centered design process is implementation. This is when the best ideas are turned into an action plan and prototypes.

Prototyping plays an important role within the human-centered design process and should be done as often and as early as possible. The purpose of early prototypes is to test whether the idea has functional value and to generate useful feedback (Brown 2009, p. 90). This "fail-early-to-succeed-sooner mentality" as Hey and Van Pelt call it (2011, p. 689), allows to uncover unforeseen problems and possible side-effects of the innovation and to gather feedback from the users. If the prototype is "too finished" and has cost too much money when it is put through the practical test, it will most likely not be dropped, even if the team realizes that it has not developed the best solution. Overall, the field testing aims at uncovering the strengths and weaknesses of the idea and to directing the design team towards further refined prototypes. Human-centered design should therefore be seen as a flexible trial and error process, during which the design team loops back several times through the three spaces of inspiration, ideation and implementation in order to gradually refine the solution. In line with this, prototyping is not the last step of the design process, but one part of iterative cycles of prototyping, testing and refinement (Brown 2008, p. 4).

### 4.4. Concluding remarks

If an innovation is to have a real impact on poor people's lives, it has to meet their needs and suit the local economic and social context.

The human-centered design approach offers a set of tools and techniques that help designers to discover the environment of their customers. Those tools allow them to see the world through different lenses and to produce products and services that are desirable, technologically and organizationally feasible and viable on the business side. The process that leads to such ground-breaking innovations is not linear and makes the design team go through the same spaces of inspiration, ideation and implementation over and over again. Of special value are the different views and approaches to the problem that the members of interdisciplinary teams can bring in. No matter if they are designers, engineers, psychologists or business people; they all become design thinkers trying to find solutions at the intersection of different problem areas.

After having discussed *why* a company should design for the BoP and *how* it can apply a human-centered design process, we proceed now to discuss *what* kinds of innovative designs are needed in the developing world.

## 5. *What* to design for the BoP

### 5.1. The success story of telecommunication ventures

Besides the many small-scale ventures that are successful on a village or regional level, there are only a limited number of BoP businesses that have reached considerable scale. Amongst them are mainly ventures related to telecommunication and information technologies. Worth mentioning is the example of Grameen Phone – an experiment which started in rural Bangladesh on a very small scale and that has morphed into a multitude of telecommunication businesses worldwide focusing on BoP customers. Today, Grameen Phone employs over 250'000 women all over the country who can now contribute to the family income. Similarly, in Africa there are over 100'000 telephone booth operators. And it is estimated that about half a million entrepreneurs are needed to sell prepaid cards and equipment to cell phone users in India (Prahalad 2011, pp. xxix-xxx).

Being able to communicate with relatives, customers, retailers or employers makes it easier for poor people to organize themselves in their private and professional lives. Even the people with very restricted financial means have access to those technological innovations because cheap cell phones are largely available and prepaid cards allow them to buy telecommunication services in small units (Hammond and Prahalad 2002, p. 56).

Communication technologies, which are in high demand and hold great potential in developing countries, will certainly be the focus of many BoP ventures in the future. It should, however, not be ignored that there are unmet needs in almost every aspect of poor people's lives. Agriculture, education, health care, housing, energy, transport, water purification – to name only a few aspects that could be interesting for both business people and designers. As different as those innovations will look like, they will all have to be affordable, environmentally sustainable and suitable for the local context – as shall be elaborated hereafter.

### 5.2. Affordable design

An innovation, as sophisticated as it may be, remains without impact if it is not affordable to the people it is meant for. Paul Polak, the founder of iDE (International Development Enterprises) goes as far as saying that affordability is the most important consideration in designing for BoP customers. This is why designers not only need to find out what people need, but also what they are able and willing to pay for such products or services (Polak 2007, p. 24). Fisher (2007, p. 34) agrees on this and says that "the poor live hand-to-mouth, and spend almost every penny as soon as they earn it". Therefore, he concludes, cash flow is the biggest constraint for poor customers who have little money to save.

As a consequence of the very limited disposable income, poor people tend to buy consumer goods in very small units – a spoon of tea or sugar, one candle or a bit of kerosene just to cover the needs of one day. There are various examples in the BoP literature how companies have reacted to this constraint. They have, among others, started to sell smaller unit packages. Because poor people cannot afford to buy large packages of things such as detergents or shampoo, companies like Hindustan Lever or Procter & Gamble now offer single-servings of their products. This, according to Hammond and Prahalad (2004, p. 35), benefits both sides as "companies selling small unit sizes at affordable prices make money, expand markets, and generate broader access to goods and services that improve people's quality of life". The proliferation of single-servings, however, has one serious side-effect: it results in piles of solid waste. In reaction to this, scientists are currently working on organic plastic that is biodegradable – an innovation which would revolutionize packaging in the developing as well as in the developed world (Hart and Prahalad 2002, p. 26). The example of single-servings makes clear that innovative business strategies are needed at the BoP, but at the same time attention must be paid to the environmental and social implications such strategies might have.

Another financial barrier for many poor customers is the considerable upfront investment that they have to make if they want to buy certain devices. If they can, on the other hand, repay the technology (for example a solar light) through monthly installments that are not higher than what they have previously spent (in this case on candles or kerosene), such technologies come within reach for poor people. In the same way, making phone calls has become an affordable option for many people in the developing world because prepaid cards are largely available and allow them to pay-as-they-go.

Consequently, what is needed at the BoP are not only innovative products and services, but also new business models to overcome the financial constraints poor people face. For business leaders, this means that they have to reframe their "Western" strategies and mindsets because BoP markets, among other aspects, do not allow "for the traditional pursuit of high margins" (Hart and Prahalad 2002, p. 26). Giving things out for free distorts local markets and is a near-sighted strategy. Both the BoP theory as well as the design thinking approach are looking for self-sustaining BoP ventures which supply goods and services that are affordable to poor people and allow them to escape poverty through their own efforts.

### 5.3. Green design

As has been briefly mentioned before, innovations sometimes solve one problem and at the same time create a new one – notably environmental degradation. Therefore, a second consideration that needs to be integrated in the design process is that innovations for the third world need to be environmentally sustainable.

Climate change has become tangible for everyone. The poor, however, suffer the most from its effects, as the World Bank warns. If the temperature, the sea-levels and the frequency of weather-related disasters change in the way it is forecasted today, this will have serious consequences for the agricultural sector, food security and water supply (WB 2012). That the future path to growth, in both developing and developed countries, needs to be sustainable seems to be out of question. The massively unsustainable consumption patterns of the "West" cannot be recreated in the developing world because this would put an unbearable level of stress on our planet (Hart and Prahalad 2002; Prahalad 2010a).

Serving the BoP sustainably requires what Kennedy (2009) and Hart (2011) call "leapfrog" green innovations in such fields as renewable energy, biomaterials, water purification or agriculture. These innovations, it is argued, "could hold the keys to addressing environmental challenges from the top to the base of the economic pyramid" (Hart 2011, p. 80). As already discussed in chapter 3.2.3., developing countries are an ideal testing ground for innovation. The BoP is an "attractive early incubation space" for green technologies because "[r]ural villages and shantytowns typically do not have preexisting physical infrastructures, and there are few large incumbents with significant positions to lose" (Hart 2011, p. 80). Most of the green technologies enumerated just before are disruptive in character. This means that they will threaten those technologies that serve existing markets and therefore will encounter significant resistance at the top of the pyramid. In contrast, the BoP is the ideal testing ground for green technologies from where they will "trickle up to the established markets at the top of the pyramid – but only after they have proven themselves to be reliable, affordable and competitive in comparison with the existing infrastructure" (Hart 2011, p. 85).

In sum, if the billions of people at the BoP are to be lifted out of poverty, if they are to get a reliable energy supply and if they are to participate in the global exchange of goods and services, this must not happen at the price of environmental degradation. Designing environmentally sustainable goods and services, therefore, must be a priority for every designer. Using the BoP as laboratory for such technologies benefits both the poor that suffer the most from the effects of climate change, and the top of the pyramid which urgently needs to shift towards more sustainable consumption patterns.

### 5.4. Customized design

As extensively discussed in previous chapters, exploring and understanding the local context is an essential part of design for the BoP. It is important to understand that the BoP is not a monolithic bloc and that one design or business strategy does not necessarily serve all the people that live in poverty. Instead, what is needed are solutions that are tailored to the local situation.

Such customized designs can come in many forms. Ideally, innovations are designed in such a way that they are multifunctional and contextually malleable. Sridharan and Viswanathan (2012, p. 64) found out that concepts like health, food or cooking carry unique local, cultural meanings. Hence, consumers may have very different ideas about what "healthy" means or about how certain products have to be processed. It was notably discovered that many consumers prefer nutrient additives that come in separate packets over enriched products (e.g. flour or milk), because this gives them the flexibility to use the additive in combination with whatever product and as often as they want to. In line with this, Sridharan and Viswanathan (2012, p. 62) conclude that flexible products (e.g. soap for personal hygiene and laundry in cold and warm water) are more likely to be successful in BoP markets than products marketed for specific usage situations (e.g. hand-washing soap).

In this customization approach, local stakeholders play an important role. Using the example of nutrient additives, it is conceivable that shopkeepers are trained to mix different nutritive ingredients according to the customers needs (e.g. children, elderly people, pregnant women etc.). This sort of "fine-tuning" at the point of sale allows to better meet the needs of the customers. Another example presented by Viswanathan (2011, pp. 153-155) are communication solutions, which in many countries and regions come with different language or dialect interfaces. Here again, the last adjustment of the technology has to be done at a local level in order to best accommodate social and cultural needs. An additional consideration that should be incorporated in the design process are the needs of the many illiterate or low-literate people in the developing world. Icons or simple explanations in the local language can help those people navigate through the marketplace and use the products properly.

### 5.5. Concluding remarks

Takeaways from chapter five are that innovations are needed in almost every aspect of poor people's lives. As different as those designs will look like, they all have to be affordable, environmentally sustainable and suitable for the local context.

The conclusion of the theoretical part of this master thesis is that if the needs of the people living at the BoP are to be better served, design will have to play an important role and new business strategies will have to be developed. It has been argued that business ventures serving the BoP are expected to generate economic returns to the investors, but also to be beneficial to the local community in which they operate. Those benefits come in the form of jobs that are created, infrastructure that is improved and, above all, in the form of increased choices. After all, serving the BoP is also a question of respect and equity because poor people get access to a greater choice of goods and services and are no longer excluded from the benefits of global markets.

How these goods and services can be designed to better meet the specific needs of BoP customers, has been discussed extensively in the previous chapters. Furthermore, it has been explained how a human-centered design process looks like and in what sense it helps designers to produce innovations that are desirable for the customer, technically and organizationally feasible and viable on the business side.

Against the background of what has been learnt in the theoretical part, we shall now proceed to analyze a practical example of *design for the BoP* - namely the example of a micro solar water pump designed for the needs of small-scale farmers.

## 6. Context of the case study

### 6.1. Introducing the case

In the practical part of this master thesis, we shall analyze an example of *design for the BoP.* Against the background of what was concluded in previous chapters, the viability of a micro solar water pump system will be assessed. This innovative irrigation technology was developed by students and professors at the Bern University of Applied Sciences (BUAS) in Switzerland. Business experts and experienced development practitioners, who provided valuable inputs, completed the interdisciplinary research and development team. In summer 2012, the solar pumps were tested in the field for the first time. During a four-month internship with iDE, the author witnessed the testing of the pump prototypes in Bangladesh. The practical part draws on the field observations and interviews made during this time (see appendices A to F).

As stated in the introductory notes of this thesis, the goal of the practical part is to assess the market viability of the micro solar water pump on the basis of three criteria: its technical reliability, desirability and affordability. This is consistent with the findings presented in earlier chapters, where it was argued that innovations ideally emerge at the intersection of three spheres: desirability, feasibility and viability. The desirability of the pump will be assessed by analyzing if it meets the irrigation water needs of small-scale farmers and by listening to what the test farmers say about this new technology. The aspect of feasibility is integrated in the assessment by looking at the technical performance of the pump. Finally, the question of the economic viability is treated by questioning whether the price of the pump system corresponds to the farmers' ability and willingness to pay.

The questions that will guide this research are the following:

1. Reliability: As from the experience made during the field testing, is the micro solar water pump technically sound?

2. Desirability: Can the pump cover the farmers' needs in terms of irrigation water, and is the system desirable to them?

3. Affordability: Does the price of the pump correspond to the farmers' ability and willingness to pay – especially in view of other irrigation methods that are available in Bangladesh?

In the sense of a human-centered design approach, it is important to give voice to those people the pumps are designed for. During various field visits, members of the research team got the chance to observe the test farmers in their natural environment and to ask them about the utility and usability of the pumps. This helped to uncover the strengths and weaknesses of the solar pump system and provided valuable insights about how to proceed in the design process (see interviews in appendices B to F).

For a better understanding of the case, we shall begin with a short presentation of the solar pump and an overview of the minor irrigation[1] sector in Bangladesh.

### 6.2. Introducing the technology

A solar pump consists of a solar panel (in the field tested with 80W panels), electronics, a DC motor and a water pump[2]. The particularity of the water pump assessed in this study is, that it is among the smallest solar irrigation systems currently available on the market (see pictures appendix A). One goal of the engineers was to downsize the pump system and to reduce the required panel surface in order to minimize costs. Due to its small size, the solar pump is easily transportable from borehole to borehole and can be protected from stealing – two important features from the perspective of a farmer in rural Bangladesh. Another particularity of the system is that the electronics, the so-called "solar drive", can easily be adapted to the millions of mechanical hand pumps (e.g. treadle or Tara pumps) that exist in countries like India or Bangladesh. The output of the system is estimated to be in the range of the power output of a human being operating a manual pump (e.g. treadle pump) over a longer period of time. As such, the micro solar water pump was designed to cover the needs of a smallholder family that, up to this date, has used mechanical means of pumping. According to these technical features, the engineers at BUAS have identified three potential application areas for the pump: First, small-scale irrigation systems in rural areas without connection to the electricity grid. Second, micro entrepreneurs who provide irrigation services to other farmers and third, household water supply systems (BUAS 2010, p. 5).

The micro solar water pump was designed to "address poverty at a grass root level and to boost the agronomical business of small-scale farmers" (BUAS 2010, p. 5). iDE has significant experience in the commercialization of technologies, which can be a driver of productivity increases and income generation at scale. iDE's many successful projects, notably the diffusion of treadle pumps in rural Bangladesh, have shown that access to low-cost technologies can help smallholder farmers to transform agriculture from a basic level of subsistence into profitable micro-businesses (iDE 2012). It was the lack of affordable irrigation technologies tailored to the needs of small-scale farmers in many developing

[1] As minor irrigation are defined those schemes that cover less than 1000 ha of cultivable land (Source: iDE 2009, p. 10).
[2] For more detailed technical information please see:
http://hitech.bfh.ch/de/archiv/hitech_22009/micro_solar_water_pump.html or
http://rwsnforum.files.wordpress.com/2011/11/8_andrea_vezzini-ennos_solar_water_pump_drive.pdf, accessed on 2 November 2012.

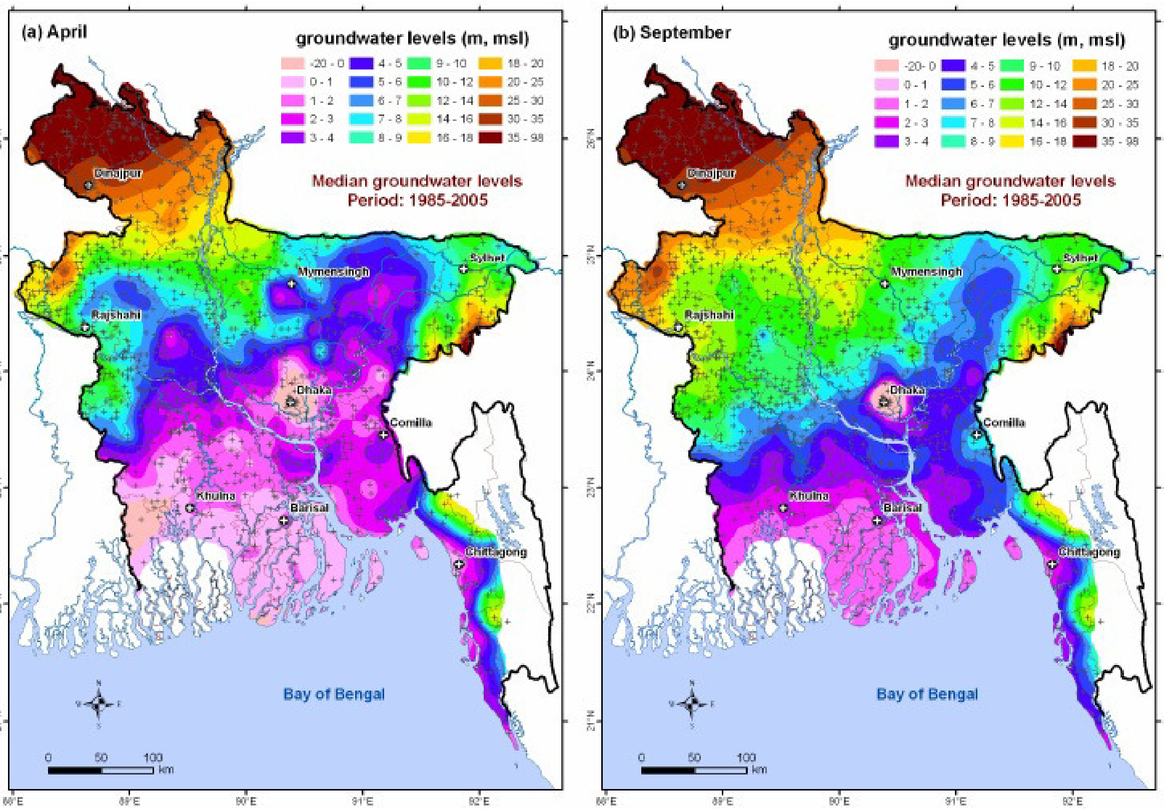
countries that motivated the search for innovative and environmentally sustainable solutions in this field.

### 6.3. The need for irrigation in Bangladesh

Bangladesh has both too much water and not enough of it. It has fertile agricultural land and an abundance of water during the wet season - but only limited water resources during the dry season from January to April. Water is the “lifeblood” of the agricultural sector, which is contributing substantially to the economic growth of the country and the welfare of its people. Both these factors make irrigation a key ingredient for crop production and a prerequisite for future agricultural growth in Bangladesh (Mujeri and Hussain 2001, p. 3).

Wide seasonal variations in rainfall are characteristic of the sub-tropical monsoon climate in Bangladesh. The average annual rainfall varies between 1429 and 4339 millimeters, with maximum rainfall recorded in the coastal areas of Chittagong and the northern part of Sylhet district, and minimum rainfall in the western and northern parts of the country. The monsoon season, which accounts for eighty percent of the total annual rainfall, starts in July and ends in October (BBS 2010, p. XIX). Irrigation is required mainly during the dry season from November to April. Supplemental irrigation during pre- and post-monsoon further increases crop yield. Figure 5 maps the groundwater situation in different regions in April (end of the dry season) and in September (after the monsoon season).

**Figure 5: Median ground water levels 1985-2005 in April and September**




Source: Shamsudduha et al. 2009, p. 2378

Until the 1950s, traditional agricultural practices were followed by the farmers in Bangladesh. Dry season Aman rice was the main crop and supplementary irrigation was only necessary when rainfall was irregular (BADC 2010, p. 1). The rapid expansion of irrigated Boro rice farming in the 1960s not only accelerated growth in rice productivity, but also reduced the unit cost of production and was a major factor behind attainment of food security. Interestingly, the surface covered by rice fields only marginally increased (from 10.1 to 10.5 million ha) over the last four decades while, over the same period of time, rice production more than doubled from 17.1 to 41.4 million tons (Hossain 2009, p. 10). This remarkable production growth of the dominant staple in Bangladesh has been brought about by the adoption of high-yielding varieties, the introduction of fertilizers and pesticides, and major changes in minor irrigation practices.

From the 1960's onwards, there were a range of policy reforms that contributed significantly to these changes in irrigation practices. Among them were (Mandal 2001, p. 29):

1. The liberalization of imports and of the distribution of irrigation engines and spare parts;
2. the rationalization of duties and taxes on irrigation equipment imports;
3. the removal of engine standardization restrictions;
4. the withdrawal of tube well spacing and siting regulations, and
5. the withdrawal of subsidies on irrigation equipement prices.

The privatization of the procurement and marketing of minor irrigation equipment had far reaching consequences. It triggered a marked reduction in the prices of engines and irrigation equipments, which became more widely available and affordable to the farmers. Suddenly, even owners of small farms could afford to buy a minor irrigation equipment (Hossain 2009, p. 4). Related to this development was the emergence of a large number of local businesses that started manufacturing spare parts and providing repair services to irrigation equipment owners (Mandal 2001, p 29). Overall, the liberalization policy of the Bangladshi government led to a rapid expansion of irrigation technologies and of the irrigated area, as shall be illustrated hereafter.

### 6.4. Availability and use of minor irrigation technologies in Bangladesh

The growth of minor irrigation in Bangladesh was mostly propelled by privately owned shallow tube wells (STWs)[3]. As can be seen in table 1, the number of STWs increased from

[3] The term *shallow* generally indicates that the well is connected to a steel/PVC pipe with a diameter between four and six inches (100-150mm). Usually, shallow tube wells (STWs) are used in combination with a centrifugal pump that can pump water from up to 40 to 60 meters. *Deep* tube wells (DTWs) are cased wells where the pump is submersed below the water surface. DTWs are more costly and in most cases owned by the government and not by farmers (Source: BADC 2010, p. 6).

93’000 to 1.4 million between 1982/83 and 2009/10. In comparison, the expansion of low lift pumps (LLPs)[4], and especially of higher-cost deep tube wells (DTWs), has been rather moderate (BADC 2010, p. 11).

**Table 1: Use of minor irrigation equipment, 1982/83-2009/10**

| Year | Deep tube wells (‘000) | Shallow tube wells (‘000) | Low lift pumps (‘000) |
|---|---|---|---|
| 1982/83 | 13.8 | 93.1 | 35.5 |
| 1986/87 | 18.7 | 160.3 | 40.6 |
| 1990/91 | 21.5 | 270.3 | 51.6 |
| 1994/95 | 26.7 | 488.9 | 57.1 |
| 1998/99 | 26.7 | 736.1 | 72.9 |
| 2002/03 | 23.4 | 924.0 | 79.9 |
| 2006/07 | 29.2 | 1202.7 | 107.3 |
| 2009/10 | 32.9 | 1425.1 | 150.6 |

Source: BADC 2010, p. 11

By 2009/10, a total of 1.6 million irrigation equipments were used in Bangladesh. In the same year, out of the 8.2 million hectares net cultivable land, an area of 5.2 million hectares was under irrigation. There are two major sources of irrigation in Bangladesh: surface water irrigation (20.9 percent of the irrigated area) and ground water irrigation (79.1 percent of the irrigated area) (BADC 2010, p. 3). Table 2 gives the area covered per equipment and the source of power for the different types of irrigation technologies.

**Table 2: Area covered per equipment and source of power, 2009/10**

| Mode | Area covered per equipment (ha) | Source of power (electric or diesel) | |
|---|---|---|---|
| **DTW** | 23.5 | Diesel | 8.97% |
| | | Electric | 91.03% |
| **STW** | 2.34 | Diesel | 84.23% |
| | | Electric | 15.77% |
| **LLP** | 6.41 | Diesel | 8.97% |
| | | Electric | 91.03% |

Source: BADC 2010, pp. 13-15

[4] Low lift pumps (LLPs) pump surface water for irrigation purposes (Source: BADC 2010, p. 9).

It is important to note that there are considerable variations between the different regions of Bangladesh in terms of irrigation development. The districts of Bogra, Jaipurhat, Naogaon, Dinajpur, Gaibandha, Chuadanga, Tangail and Rangpurhave experienced relatively rapid growth of minor irrigation. In other areas, this development is a lot slower. M.A. Sattar Mandal identifies three factors that explain these variations: first, they can be attributed to the varying socioeconomic conditions, such as farm size and land tenure systems, that prevail in the different regions. Second, there are differences in the local physical conditions, e.g. the agro-ecological characteristics, the existence and recharge rate of groundwater aquifers, the expansion of the equipment market at the local level or the growth of physical infrastructure and provision of electricity. Third, the variations can be explained by the fact that in some areas bank loans are insufficient or difficult to obtain, which generally slows down the growth of the irrigation market. Finally, the profitability of irrigated agriculture is an important factor affecting the expansion of minor irrigation. Hence, a low paddy price discourages farmers to grow irrigated Boro rice and to purchase an irrigation equipment (Mandal 2001, pp. 29-30).

Overall, it can be argued that the expansion of minor irrigation has accelerated rice productivity through the expansion of irrigated Boro rice farming – which has considerably contributed to attaining food security and reducing poverty in Bangladesh (Hossain 2009, p. 1). Simultaneously with the expansion of minor irrigation technologies occurred another development: the establishment of an irrigation service market, which will be analyzed in a next step.

### 6.5. Irrigation as a service

As elaborated before, the agricultural development of Bangladesh in recent decades has been largely driven by the expansion of groundwater based minor irrigation. This, in turn, was only possible because of the market liberalization that made irrigation equipments more widely available and affordable to farmers. Still, the question remains whether this development benefitted the small and marginal farmers[5], as well.

In the early 1980s, the perception was that the privatization of the irrigation market would create inequitable access to irrigation water at the disadvantage of smallholders. Table 3 below summarizes the information obtained from a series of national-level surveys conducted in 63 villages all over Bangladesh in 1987/88, 2000/01 and 2007/08. The aim of these surveys was to “assess the impact of the diffusion of modern technologies on income distribution and poverty” (Hossain 2009, p. 7). Valuable information can be drawn from table 3 in terms of the distribution of ownership and the development of the average cost of STWs

[5]Marginal farms are holdings of less than 0.05 acres (202 $m^2$). Small farms are holdings between 0.05 and 2.49 acres (202-10‘076 $m^2$) (Source: BBS 2010, p. 105).

over time. While in 1988 only 4.6 percent of the farmers owned a STW, this number grew to 16 percent in 2000, and 22 percent in 2007. Over the same period of time, the average cost of tube wells declined from USD 671 to USD 223. According to Hossain (2009, p. 7), “this decrease [in costs] is due to the availability of relatively low-cost machines imported from China and the increasing use of second-hand machines”.

**Table 3: Ownership and average replacement cost of STWs 1988, 2000, 2007**

| Farm size (ha) | Percent of households with own STWs | | | Average replacement cost of STWs (USD per unit) | | |
|---|---|---|---|---|---|---|
| | 1988 | 2000 | 2007 | 1988 | 2000 | 2007 |
| Up to 0.4 | 2.4 | 2.8 | 6.8 | 598 | 278 | 194 |
| 0.4 to 1.00 | 2.1 | 15.6 | 22.7 | 692 | 263 | 191 |
| 1.00 to 2.00 | 3.9 | 36.5 | 60.9 | 560 | 280 | 218 |
| Over 2.00 | 17.2 | 81.4 | 89.7 | 770 | 343 | 273 |
| All farms | 4.6 | 16.1 | 22.1 | 671 | 302 | 223 |

Source: Hossain 2009, p. 7

This illustrates the considerable expansion in the use of minor irrigation equipment after the market liberalization – especially among those farmers that own more than two hectares of land. Smallholders got increased access to irrigation technologies because neighbors started to rent out their equipments, or to offer a water pumping service.

Hence, as an effect of the increased availability and use of electric and diesel pumps, an irrigation service market emerged in Bangladesh. Richard Palmer-Jones (2001, p. 2) notes that the terms “water market” and “irrigation service market” are often used interchangeably and that “while water is transferred, it is not the economic good produced and sold, rather it is the service of raising and delivering the water to the famers’ fields”. Practically speaking, the water is pumped from a well that usually “consist of the well itself – generally a cast iron pipe of some 200 feet in length, joined to a perforated filter pipe at its end which lets in groundwater. This pipe is connected to a centrifugal pump mounted at the surface (or in some places below the surface), and a prime mover – generally a 5 to 12 horse power diesel engine or an electric motor” (Palmer-Jones 2001, p. 10). In most cases, the pumped water is guided to the designated plot through open, earthen canals.

Concerning the mode of payment for the irrigation service, different kinds of arrangements have emerged: giving a defined share of the crop to the service provider at the time of harvest, a flat charge per acre and season paid in cash, or an hourly charge. The farmers interviewed in Rangpur currently pay one fourth of the harvest or the following charges in cash:

**Table 4: Charges for the irrigation service by method**

| | Charges for the irrigation of rice fields *per acre and season* | | Charges for the irrigation of vegetables *per hour* | |
|---|---|---|---|---|
| | With electric engine | With diesel engine | With electric engine | With diesel engine |
| From DTW | BDT 2'500 (USD 29) | – | – | – |
| From STW | BDT 4'000 (USD 47) | BDT 6'000-7'000 (USD 71-83) | BDT 75-100 (USD 0.90-1.20) | |

Source: Interviews with farmers, Rangpur, 19-20 April 2012

As discussed earlier, it is mostly the richer farmers with large holdings that own STWs. Social scientists therefore argued that they would be "in a local monopoly situation in relation to owners of neighboring plots, many of whom would also be poorer and less socially and politically powerful than the tube well owner" (Palmer-Jones 2001, p. 7). It was anticipated that the water sellers, labeled as "water lords", would strategically withhold water at crucial stages of crop growth and keep the charges for their service artificially high. The dominant hypothesis was that the agrarian structure in Bangladesh - characterized by highly unequal land ownership - would prevent the emergence of a competitive irrigation service market.

Mandal (1993, p. 99) disagrees with this argument and states that "owners of irrigation equipments are not necessarily landlordscum–waterlords and may not operate their tube wells as monopolists, but they are entrepreneurs who appear to have earned normal profits considering the high costs and risk of operating tube wells". Because most of the service providers are paid one quarter of the total harvest, they have a vital interest in delivering water timely and in sufficient quantities, in order not to reduce the yield of the crop. Palmer-Jones (2001, p. 15) further found out that irrigation equipment owners, who often own scattered holdings, "prefer to irrigate the plots of others that are contiguous to their own WEM [Water Extraction Mechanism] and let others supply water to their plots not readily accessible to their own WEM". The result is a network of mutual dependencies and various economic and social interrelations which let emerge a dynamic and competitive irrigation service market (Palmer-Jones 2001, p. 19). It is estimated that more than 1.52 million irrigation service providers are active in Bangladesh today, serving 89 percent of the farmers in the country and covering more than 86 percent of the land irrigated by minor irrigation methods (iDE 2011a, p. 16).

Hence, the irrigation service market allows small and marginal farmers to get access to water at a comparatively cheap rate. It should, however, not be ignored that the farmers that buy irrigation services often suffer from this relationship of dependency. The farmers interviewed in Rangpur complained about the fact that, because of the high demand for water during the dry season, the service providers are very busy and cannot serve all the farmers in time. If the irrigation is delayed, the yield and the quality of the crop are deteriorated and the market price reduced. Even though the water delivery is organized according to a fixed order, family members or friends of the service providers sometimes are afforded preferential treatment. Furthermore, the service providers are not interested in irrigating very small plots for a couple of Taka. The interviewees further noted that the rising diesel and electricity prices make the irrigation charges go up regularly, placing an increasing financial burden on them. This explains why many farmers desire to buy their own water pump system that would make them independent from the water sellers (Interviews with farmers, Rangpur, 20-24 May 2012).

### 6.6. Concluding remarks

The aim of this chapter was to illustrate the importance of irrigation in Bangladesh and the change that came about with the introduction of modern minor irrigation technologies. It has been shown how the liberalization of the irrigation equipment market made minor irrigation equipments widely available and let to the emergence of an irrigation service market in Bangladesh. The background information gathered in this chapter will be put into context in the following section, where the market viability of the solar pump will be assessed on the basis of three criteria: its technical reliability, the desirability to the farmer and its affordability.

# 7. The market viability of the micro solar water pump

## 7.1. Reliability: is the micro solar water pump technically sound?

### 7.1.1. Overview field testing

A total of 150 micro solar water pumps were tested in Bangladesh, Honduras, India, Nepal, Ghana and the United States in the summer of 2012. The findings presented hereafter relate exclusively to the piloting project in Bangladesh, which was divided into three phases:

- *Phase 1*: training of the field staff, installation of the micro solar water pumps and testing in the field.
- *Phase 2:* development of a new comprehensive prototype (making the system multitasking) and training of field staff.
- *Phase 3*: dissemination of the new prototype.

Phase 1 started in August 2011 with the recruitment of seven technicians that received training at the Institute of Technology Engineering and Technological Services (MAWTS) from Cédric Martin Simonin, a student from BUAS. The field testing started after the pumps and electronic drives had arrived from India, and the motors and solar panels from China.

In January 2012, iDE signed a Cooperation Agreement with the local NGO CMES (Center for Mass Education in Science) organizing the further implementation of the field test. The 40 pump systems under the responsibility of CMES were installed and tested as foreseen. iDE received 31 sets: one deep-set, 15 vane pump and 15 treadle pump sets. Out of these, 15 vane pump systems and one treadle pump system were installed and tested in the field in Rangpur. In addition to that, one solar drive was installed on a treadle pump at the technology center of iDE in Savar.

### 7.1.2. Performance of the micro solar water pump in the field

Because of the upcoming monsoon season, the solar pumps were uninstalled at the beginning of June 2012. In the course of the field testing, several technical problems were identified.

When CMES started testing its 40 pump systems in December 2011, the weather was very cloudy and foggy – as usual at this time of the year. Consequently, the water output was very low (about five to six liters per minute) and the farmers had to use diesel pumps in parallel to save their crops. This raised the question whether the farmers will need a backup, in the form of electric or diesel pumps for example, to guarantee the irrigation of their crops at any time of the season. Interestingly, the farmers continued using their diesel pumps even when the solar pumps started to work at full capacity. As it is to be expected when a new technology is introduced, the farmers do not seem to have enough confidence in the micro solar water pumps yet to rely exclusively on them. Furthermore, the fact that the farmers used diesel and solar pumps simultaneously makes it difficult to estimate what surface can be covered by one solar pump under real conditions in Bangladesh.

iDE started to test its 15 vane pump sets in January 2012. Contrary to what happened in the CMES testing field, the farmers chosen by iDE only used the micro solar water pump and combined it with a shower irrigation technology. Furthermore, iDE was very interested in testing the solar drive in combination with the treadle pump. The treadle pump is a human-powered irrigation device mounted on top of a well. “Pumping is activated by stepping up and down on treadles which drive pistons, creating cylinder suction that draws groundwater to the surface” (iDE 2012, n.p.). In Bangladesh, iDE played a vital role in popularizing this low-cost technology. To this day, 1.4 million treadle pumps have been sold to Bangladeshi farmers, giving them the opportunity to grow crops during the dry season and to generate additional income for their families. The advantage of “upgrading” this widely-used and well-known technology by installing a solar drive is, that it would liberate the farmers from the drudgery of treadling for several hours every day. Furthermore, it allows them to perform other (income generating) tasks during the time that previously was spent pumping. Another advantage is that, in case of the above mentioned foggy or cloudy days when the solar pump does not run, the treadle pump is ready to be manually operated by simply disconnecting the solar drive. Furthermore, as there are technicians who are familiar with the treadle pump all over the country, and because spare parts are readily available on the local market, technical problems with this pump system can be solved easily.

Due to the limited time frame and a lack of trained technicians, only two treadle pump sets were tested. The system installed in Rangpur pumped about three to four liters of water per minute. It was assumed that the low water level was the reason for this small water output. However, and contrary to expectations, when it was tested at a location with a higher ground water table, the output did not increase. The solar powered treadle pump at iDE’s technology center reached a higher water output but, due to unidentified technical problems, stopped after about half a minute of pumping and only restarted if the cables were de- and reconnected. Table 5 lists the types of pump sets that were tested and their status at the end of the field testing in June 2012.

**Table 5: Overview status of tested pumps at the end of field testing**

| Test field | No of pumps delivered | Type of pump | In working condition | Faulty | Stolen | Remarks |
|---|---|---|---|---|---|---|
| CMES | 40 | Vane pump | 26 | 14 | - | |
| iDE | 15 | Vane pump | 10 | 4 | 1 | |
| iDE | 15 | Treadle pump | 2 | - | 10 | 3 others not tested |
| iDE | 1 | Deep-set pump | - | - | - | Has not been tested |

Source: Meeting with CMES, Dhaka, 14 June 2012

The CMES technicians closely monitored the water output during the whole field testing phase and reported that a 80W vane pump system, connected to a 100W panel, on average delivers 16 liters of water per minute. When the pump started in the morning, it delivered about eight liters per minute and reached up to 22 liters per minute during peak hours from 12am to 1.30pm. Provided that there are no technical problems, the pump ran for six and a half hours and reached a discharge capacity of about 5'700 liters per day from a depth of twenty feet. This amount of water allowed the iDE test farmers, which used hose pipes and shower heads, to irrigate between 10 and 34 decimals (400-1360m$^2$)[6] depending on the crop and the soil conditions. Badrul Alam, irrigation engineer at iDE Bangladesh, estimates that one 80W micro solar water pump can cover between 25 and 30 decimals (1000-1200m$^2$) of vegetable fields during winter. During summer, when the weather is hot and the dry soil drains applied water quickly, about 10 to 12 decimals (400-500m$^2$) of vegetables will be covered by one 80W micro solar water pump. Table 6 summarizes the most important data gathered during the field testing.

**Table 6: Overview results field testing**

| | |
|---|---|
| Panel size | 100 Watt |
| Motor | 80 Watt |
| Pump | Vane pump |
| Diameter outlet | ½ inch (1.27 cm) |
| Water output | Minimum 8 liters per minute<br>Maximum 22 liters per minute<br>Average 16 liters per minute |
| Operating hours | 9am until 3.30-4pm |
| Peak hours | 12am until 1.30pm |
| Static water table | 17-20 feet |

Source: Interviews with farmers, Rangpur, 19-20 April 2012

[6] 100 decimals = 1 acre = 4046m2

As of the technical problems faced during the field testing, most of them have already been solved. At an early stage, it was the water loss due to leakage that caused concern. Another problem was that small sand and algae particles passed through the filters and caused the pumps to stop. Those and other problems were solved during the field visit of Alois Müller, an experienced engineer and consultant to the research team, in February 2012. The installation of a modified microcontroller furthermore increased the overall water output by extending the operation time of the pump by half an hour in the morning and evening respectively.

At the end of the field testing in June 2012, there were challenges related to the performance and the handling of the pumps that remained unsolved. One major concern still is the unpredictability of the pump. While it runs smoothly and without interruption on one day, it suddenly stops on the next day for no apparent reason. Second, the technicians in the field are not able to diagnose, nor to solve, problems related to the mechanical solar drive. Third, the handling of the pump is time intensive as several joints have to be dis- and reconnected every morning and evening. A lot of maintenance is needed because the pumps need to be flushed on a regular basis (Meeting with CMES, Dhaka, 14 June 2012). These challenges will have to be addressed if the system is to be made more reliable and easier to handle for the farmer.

#### 7.1.3. Feedback from users

In April 2012, ten test farmers were interviewed in the villages of Ranipukur and Buzrok Santosphur, Rangpur district. They were asked about their irrigation practices, as well as their experience with the micro solar water pump. The farmers identified a range of advantages of the micro solar water pump, but also criticized certain features of this new technology.

**Advantages identified by the farmers:**

- The farmers particularly liked the fact that, other than the often used diesel pumps, the solar water pump runs without fuel. In view of rapidly increasing diesel prices in Bangladesh, this is considered being a major advantage of the system.
- Contrary to electric pump users, they do not rely on the increasingly expensive electricity supply and are not affected by the frequent power cuts.
- Those farmers who used treadle pumps previously are glad they are liberated from the drudgery of treadling for several hours a day.

- The interviewees liked the fact that, compared to e.g. diesel pumps, the operating costs of the solar pump are very low.
- For those farmers who do not own a diesel or electric pump and/or buy water from water sellers, owning a solar pump means freedom and independence because they do not need to wait until the service provider has time to irrigate their plot.
- The farmers find the solar pump a very safe, eco-friendly and noiseless alternative to diesel pumps.
- The small size and the light weight, furthermore, make the system ideal for those farmers with scattered plots of land. The pump can easily be protected from stealing, too.
- When Amrita Rozario from Caritas Switzerland visited the test site, one farmer showed here two fields: one where he practiced flood irrigation with a diesel pump and one field where he tested the solar pump. The crops in the second field looked greener and healthier, indicating that the field irrigated by the solar pump probably produces higher yield.
- Overall, the farmers liked the idea to use the power of the sun to drive a water pump. Solar powered technologies have become very popular in Bangladesh in recent years and the farmers feel privileged if they can use a solar powered irrigation device.

**Disadvantages identified by the farmers:**

- Eight out of ten farmers who were interviewed expressed the concern that the output capacity of the pump is not sufficient to cover their irrigation water needs. They unanimously said that they want a delivery of at least 1.5 inch diameter, compared to 0.5 inch as it is now.
- Some of the farmers mentioned that using a solar pump makes irrigation more time consuming. They said that normally they pay an irrigation service provider to flood their fields about every two weeks. Now that they use a shower irrigation technology, they have to walk from plant to plant to apply water which makes irrigation much more time intensive. This means that they have to invest more of their own time or pay a day laborer.
- Another major concern was that the pump does not run on foggy or cloudy days.
- Furthermore, the farmers worried about the fact that the pumps sometimes stop pumping for no obvious reason, even though the sun is shining.

In sum, all of the farmers liked the idea to use a pump that is powered by the sun, making them independent from increasingly costly fossil fuels and the unreliable electricity grid. For those who do not own a diesel or electric pump, owning a solar pump would mean independence from the irrigation service providers and liberation from the physically demanding task of operating a treadle pump. The farmers, however, expressed the concern that the pump is not reliable enough, that it will not run on foggy or cloudy days and, most importantly, that the amount of water it pumps is not sufficient to irrigate their fields. To what extent this last concern is true shall be addressed in the following chapter which discusses how desirable the micro solar water pump is to a farmer in Bangladesh.

## 7.2. Desirability: Can the pump cover the farmers' needs in terms of irrigation water and is the system desirable to them?

### 7.2.1. Demand for small size pump systems

After a short analysis of the technical performance of the micro solar water pump in the previous chapter, we shall now address the question whether the latter is an attractive product in view of the farmer's water needs and the alternatives he can chose from (i.e. buying water from a service provider, buying a diesel or electric engine etc.).

In a scoping study published in 2009, iDE Bangladesh and Katalyst analyzed the market dynamics, constraints and opportunities of existing irrigation technologies. In this study, farmers that currently buy water from irrigation service providers were asked about their interest to purchase a diesel or electric water pump. In line with the market studies written by Prantarova and Gala (2008) as well as by Ahmed and Samad (2010), the scoping study found out that there is a high demand for small-scale irrigation equipments in the range of two to four horse power. This can be explained by the fact that the small size of such pump systems makes them lightweight and easily transportable, by the fact that their costs are low and that they are suitable to irrigate the small and scattered plots of a typical farm holder in Bangladesh (iDE 2009, p. 54).

Tables 7 and 8 give an overview of the pump systems that were available on the local market in Rangpur during the visit in April 2012.

**Table 7: Electric water pumps available on the market in Rangpur**

| Horse Power (HP) | Water discharge (l/sec) | Weight (kg) | Fuel consumption (l/hour) | Average Price engine+pump (BDT)[7] | Longevity engine (years) |
|---|---|---|---|---|---|
| **0.5** | 0.5 | 5 | - | 2500 | 5-7 years |
| **0.75** | 0.75 | 7 | - | 4500 | „ |
| **1.5** | 1.5 | 8 | - | 5500 | „ |
| **2** | 8 | 10 | - | 12500 | „ |
| **3** | 10 | 10 | - | 15000 | „ |
| **4** | 14 | 14 | - | 18500 | „ |
| **5** | 19 | 16 | - | 25500 | „ |

Source: Interviews with engine retailers, Rangpur, 18 April 2012

**Table 8: Diesel water pumps available on the market in Rangpur**

| Horse Power (HP) | Water discharge (l/sec) | Weight (kg) | Fuel consumption (l/hour) | Average Price engine only (Taka) | Longevity engine (years) |
|---|---|---|---|---|---|
| **4** | 8 | 45 | 0.5 | 12800 | 8-10 years |
| **6** | 10 | 70 | 0.75 | 13500 | „ |
| **8** | 14 | 80 | 1 | 15200 | „ |
| **12** | 20 | 110 | 1.5 | 26000 | „ |
| **16** | Not for irrigation | 120 | 1.65 | 27500 | „ |
| **20** | Not for irrigation | 130 | 2 | 30500 | „ |

Source: Interviews with engine retailers, Rangpur, 18 April 2012

Despite an existing demand for lower horse power diesel engines, the majority of systems sold are in the range of four horse power and bigger. This can be explained by the fact that the government of Bangladesh has imposed 35 percent customs duty on diesel engines below three horse power and above 30 horse power (iDE 2009, p. 9). Consequently, importers are not interested in bringing small engines into the country, but instead import devices above three horse power for which they pay only three percent import tax (Ahmed and Samad 2010, p. 26). As a consequence of this, many of the pump systems are oversized in relation to the water needs of the farmers. iDE's scoping study revealed that especially diesel engines are not used at their full capacity. The frequently used four horse

[7] On 12 November 2012: 1 CHF = 84,1688 BDT.

power diesel engine, for example, covers 5.8 acres[8] on average which corresponds to only 65 percent of its capacity (see table 9).

**Table 9: Theoretical and practical irrigation coverage per engine**

| Engine | Capacity (HP) | Average coverage (acres) | Maximum coverage (acres) | Coverage capacity utilized (%) |
|---|---|---|---|---|
| **Diesel** | 4 | 5.8 | 8.9 | 65 |
| | 8 | 10 | 15 | 67 |
| | 12 | 12 | 20 | 60 |
| **Electric** | 3 | 12 | 13 | 92 |
| | 4 | 18 | 18 | 100 |
| | 5 | 18 | 24 | 75 |
| | 7.5 | 10 | 30 | 33 |
| | 8 | 33 | 60 | 55 |

Source: iDE 2009, p. 51

Overall, it can be concluded that there is a strong market demand for small size irrigation devices (two horse power or smaller) that are affordable and suitable for the needs of smallholder farmers. It is this group of customers that the designers of the micro solar water pump had in mind originally, and that could be served with a solar powered technology. How attractive this solution is in terms of the surface that can be irrigated will be discussed hereafter.

#### 7.2.2. Water requirements of different crops in relation to the water output of the solar pump

One of the main concerns expressed by the test farmers was that the amount of water the solar pump supplies could be insufficient to irrigate their crops. This is mainly a perceptual problem: the farmers are used to see water gushing out of large motorized pumps, flooding their 30 decimal plots in about half an hour. The solar pump, with an outlet diameter of half an inch, delivers a comparatively small amount of water over the same period of time. Over a longer period of time, however, the solar pump can deliver a considerable amount of water. Due to the continuous flow from the early morning until late afternoon, a daily output of about 5’700 liters was reached at the test site in Rangpur.

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[8] 100 decimals = 1 acre = 4046m2

What does this mean in terms of the surface that can be irrigated by using a micro solar water pump? Based on the water requirements per season for different types of crops, the following estimations can be made:

**Table 10: Surface covered by one solar pump calculated for different crops**

| **Crop** | **Water requirement per season** *l/m²* | | **Crops per year** | **Water requirement per year** *l/m²* | | **Surface covered with 4000 l/day and 250 days** *in m²* | | **Surface covered with 4000 l/day and 250 days** *in decimals* | |
|---|---|---|---|---|---|---|---|---|---|
| | Min | max | | min | max | min | max | min | max |
| Rice | 900 | 2500 | 3 | 2700 | 7500 | 370 | 133 | 9 | 3 |
| Maize | 500 | 800 | 3 | 1500 | 2400 | 667 | 416 | 16 | 10 |
| Potato | 500 | 700 | 2 | 1000 | 1400 | 1000 | 714 | 25 | 18 |
| Onion | 350 | 550 | 3 | 1050 | 1650 | 952 | 606 | 24 | 15 |
| Tomato | 400 | 800 | 2 | 800 | 1600 | 1250 | 625 | 31 | 15 |
| Cabbage | 380 | 500 | 2 | 760 | 1000 | 1316 | 1000 | 33 | 25 |

Source: FAO 2012, n.p.

For these calculations, the daily water output of the solar pump was estimated conservatively at 4’000 liters per day. The water requirements of different crops are listed per liter and square meter over the whole cropping season. Due to the varying climatic and soil conditions, the actual water requirements at a certain location in Bangladesh probably lie somewhere between the minimum and maximum amount given in the table. If we take the minimal water requirements to estimate the surface covered, then one solar pump can irrigate 9 decimals (370 $m^2$) of rice fields, 16 decimals (667 $m^2$) of maize, 25 decimals (1000 $m^2$) of potatoes, 31 decimals (1250 $m^2$) of tomatoes or 33 decimals (1316 $m^2$) of cabbage.

Because of the considerable amount of water needed to keep paddy fields flooded throughout the whole crop cycle, the micro solar water pump is not suitable for the irrigation of rice crops. Knowing that almost every peasant cultivates at least one small rice field to cover the needs of its family, this means that the farmer will have to buy a diesel or electric pump, or continue to buy water from an irrigation service provider, to irrigate this plot. As of the different kinds of vegetables chosen for this estimation, they not only require a smaller amount of water, but also generate a considerably higher return on investment than rice (see also table 11 hereafter). One micro solar water pump can cover about 24 to 33 decimals (952-1316 $m^2$) of these crops. This means that the amount of water supplied is sufficient to cover the needs of millions of farmers in Bangladesh, knowing that 52 percent of them hold less than 2000 $m^2$ of land (USAID 2010, p. 3).

The numbers given above are estimations and the actual surface that can be irrigated with one solar pump will vary considerably according to the crops grown, as well as the local weather and soil conditions. They nevertheless give a rough idea of the capacity of the pump and clearly show that a farmer that buys a relatively expensive solar pump, with a rather limited output capacity, cannot afford to waste one single drop of water. This, however, stands in sharp contrast to the current irrigation practices in Bangladesh. In the scope of the so-called Improving Irrigation Market Systems project (IIMS), iDE Bangladesh strived to promote water efficient irrigation technologies with the goal to minimize water loss and to reduce irrigation costs for the farmers. This program was launched because an assessment undertaken in 2009 had revealed a lack of knowledge about proper irrigation and water management techniques on the part of the farmers. Irrigation costs constitute an important share of the total production costs: 30 percent in the case of rice, 23 percent for maize, 21 percent for brinjal or 10 percent in the case of cabbage (iDE 2009, p. 23). The study further revealed that, even though the farmers spend considerable amounts of money on water, they often do not get the expected yield - due to improper irrigation. Continuous excess irrigation can cause different kind of diseases, reduce the growth of the plant or even destroy it. iDE came to the conclusion that "proper irrigation scheduling is a key element in irrigation water management. Irrigation scheduling should be based on knowing the daily water use of the crops, the water-holding capacity of the soil, the lower limit of soil moisture for each crop and soil, and measuring the amount of water applied to the field" (iDE 2011b, p. 12). The program showed that, by teaching farmers how to apply water efficiently (e.g. by using drip technologies), water can be saved and the yield be increased. Furthermore, if the solar pump is used in combination with such a water saving technology, the irrigated surface can be enlarged considerably.

After having discussed the technical reliability and the desirability of the micro solar pump, we will now proceed to assessing the affordability of the system.

## 7.3. Affordability: Does the price of the solar pump correspond to the farmers' ability and willingness to pay – especially in view of other irrigation methods that are available in Bangladesh?

### 7.3.1. Cost and risk aversion as barriers to the expansion of solar technologies

Besides the technical reliability and the appropriateness in terms of the amount of water pumped, the price is another factor that determines whether or not the micro solar water pump is desirable to smallholders in Bangladesh.

In this context, a report on the diffusion of solar technologies published by J.R. Siegel and Atiq Rahman in 2011 is very insightful. The main goal of this paper was to analyze "the process through which more than 650'000 off-grid households decided to purchase a solar home system (SHS) from 1996 to 2010" (Siegel and Rahman 2011, p. 1). In the course of their analysis, Siegel and Rahman address the question why the non owners decided not to purchase such a solar powered technology. They identify two main barriers to the diffusion of SHSs: cost and risk aversion. For many people, the costs of such a SHS are simply too high. The costs might be a factor that prevents the dissemination of the micro solar water pump, as well. Knowing that the average monthly nominal income in the rural areas of Bangladesh is at BDT 2'130 per person (BBS 2011, p. 493), the costs of a solar pump, which are estimated to be at around BDT 32'000, are a huge burden.

Furthermore, risk aversion plays a role because "purchasing an appliance that requires a large monthly installment for three years requires a high level of confidence in the economic future of the family" (Siegel and Rahman 2011, p. 13). In the case of the solar water pump, the buyer faces low maintenance costs but a high upfront investment. Even if these initial costs are spread out over several years through the use of microfinance, as it is the case for the SHS, the customer has to pay a considerable amount of money every month. It therefore must be expected that a farmer will decide to buy a solar pump only if he is convinced that the technology is of use to him and technically reliable.

Besides the cost of the system itself, the cost of alternative options might deter a potential customer from buying a solar pump. It is very instructive to compare the costs of solar powered irrigation to the costs of i) buying and running a diesel or electric pump or ii) buying water from an irrigation service provider. Both alternatives are readily available to the farmers in the test area and shall be analyzed hereafter.

### 7.3.2. First alternative: buying and running a diesel or electric pump

In chapter 7.2.1. it has been shown that the electric and diesel pumps that are available in Bangladesh are often oversized in relation to what the farmers would need. Still, there is a booming market for new and second hand pump systems and spare parts. A visit at the local market in Rangpur has shown that one can buy a new electric four horse power water pump at a price of BDT 18'500 (see tables 7 and 8).

Contrary to the solar pump, where the farmer faces a high upfront investment but very low maintenance costs, using a diesel or electric pump causes high fuel or electricity costs. In recent years, and especially within the last year, fuel prices in Bangladesh have been on the rise. The government had to increase the electricity tariffs and fuel prices several times because the heavily-subsidized power sector has become an unbearable financial burden. The subsidy cuts made the diesel price rise from BDT 45 per liter to BDT 65 within one year. The electricity cost, as of May 2012, was at BDT 2.85 per kWh. Both prices are expected to further rise in the future, making the use of electric and diesel pumps more and more costly. At the same time, the prices of solar panels – the most expensive part of the solar pump – will probably continue to come down, making solar pumping an increasingly attractive alternative. But, for the time being and under the still existing subsidies, using a diesel or electric pump makes economic sense for many farmers – not least because they can generate additional income by offering irrigation services.

### 7.3.3. Second alternative: buying water from an irrigation service provider

A second alternative that the farmer has is to buy water from an irrigation service provider. The advantages and disadvantages of this option were already discussed in chapter 6.5. Regarding the costs, this alternative seems to be a better choice for a farmer than buying a solar pump. This statement is based on information that can be found in table 11 hereafter:

**Table 11: Production cost, irrigation cost and ROI of different crops for a farmer that buys water from an irrigation service provider**

| Crop | Prod. cost BDT/dec | Irrig. cost BDT/dec | Irrig. cost % of prod. cost | Yield kg/dec | Net income BDT/dec | ROI |
|---|---|---|---|---|---|---|
| Rice | 128 | 39 | 30 | 21 | 68 | 1.74 |
| Maize | 119 | 27 | 23 | 26 | 131 | 4.85 |
| Potato | 385 | 19 | 5 | 56 | 201 | 10.58 |
| Brinjal | 273 | 56 | 21 | 111 | 955 | 17.05 |
| Tomato | 384 | 27 | 7 | 116 | 649 | 24.04 |
| Cabbage | 152 | 15 | 10 | 265 | 379 | 25.27 |
| Chili | 178 | 13 | 7 | 26 | 373 | 28.69 |
| Bitter gourd | 176 | 9 | 5 | 68 | 742 | 82.44 |

Source: iDE 2009, p. 23

Of particular interest, at this point, is the irrigation cost per decimal for different crops given in the third column. For vegetables, the average irrigation cost per decimal and season is BDT 20.5. Accordingly, the cost of irrigating 25 or 50 decimals is BDT 512 or BDT 1'025 respectively. Because table 11 is based on data gathered in 2009, we make the same calculations again, but generously assume that the irrigation charges have doubled since then. This means that the irrigation service charge is estimated to be at BDT 1'024 for 25 decimals, and at BDT 2'050 for 50 decimals per season.

This compares to an investment of BDT 32’000 for a micro solar water pump. Hence, the farmer can buy water from an irrigation service provider during 16 seasons until he has spent the same amount of money as for a solar pump. Under the aspect of costs, it is therefore doubtful whether a farmer would invest his money into a solar pump if, for the same price, he can get his fields irrigated by a service provider. Especially because buying the irrigation service means that the farmer does not have to spend his time irrigating fields and does not have to worry about such things as where to find a technician who can repair the pump in case of a technical problem, or where to get spare parts from.

### 7.4. Concluding remarks

The purpose of chapter four was to assess the market viability of the micro solar water pump on the basis of three criteria: the technical reliability, the desirability of the system and its affordability.

As of the first criteria, the field testing delivered a lot of valuable information. By testing the pump system under real conditions, a range of technical problems could be discovered and most of them solved. The feedback from the users was mostly positive. The farmers found it a good idea to use the sun, a source of power that is inexhaustible, clean and for free, to drive a water pump. They further liked the fact that such a technology would make them independent from water sellers or would free them from the drudgery of treadling for several hours a day. They however, do not have enough confidence in the system yet and fear that it does not deliver enough water to cover their needs. The farmers are also concerned about the fact that the pump does not run on cloudy or foggy days.

The analysis of the desirability of the solar pump, in terms of the amount of water it supplies, has shown that it would deliver enough to cover the needs of the millions of small-scale farmers in Bangladesh. It has, however, become clear that the pump is not suitable to irrigate rice crops. It also is not designed for flood irrigation and should be used in combination with some sort of water saving technology (e.g. shower or drip irrigation) in order to make maximum use of every drop of water pumped.

Overall, the irrigation sector in Bangladesh seems to be a difficult environment for the micro solar water pump at the current time. For those farmers who own a large diesel or electric pump, which in many cases allows them to offer an irrigation service to other farmers, the micro solar water pump is not an attractive alternative because the amount of water pumped is insufficient. Potential customers are farmers who want to irrigate small vegetable plots. Those mainly poor farmers are, however, very cost and risk averse and have the option to buy water from one of the numerous water sellers at a comparatively cheap rate. The micro solar water pump is therefore not an ideal one-for-one replacement of existing irrigation technologies in Bangladesh. It might, on the other hand, have great potential if it is sold as part of a comprehensive solar system that offers other amenities as well – light, for example. Potential avenues for the micro solar water pump project will be presented in the following chapter.

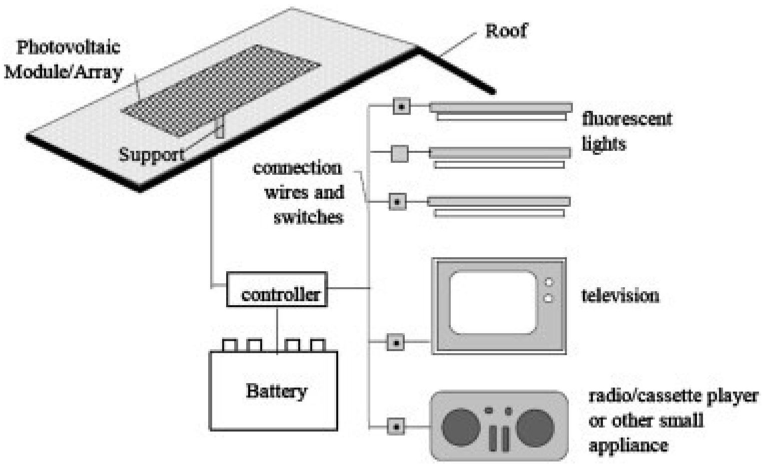
## 8. Potential avenues for the micro solar water pump project

### 8.1. Combination with the solar home system

In the previous chapter it was argued that the micro solar water pump will probably not be a one-to-one replacement of an existing fuel powered irrigation technology – at least for the time being. If the pump is sold as part of a comprehensive solar system, on the other hand, it might have great potential.

In the local context of Bangladesh, one could make use of the huge demand for solar light and the booming market for solar home systems (SHS). A typical SHS, as illustrated in Figure 6, comes with a 20W to 100W photovoltaic (PV) panel. The hardware includes a rechargeable battery for energy storage, a battery charge controller, switches, and interconnecting wires. A SHS can power one or several (usually fluorescent) lights and may include outlets for a television, radio or other low power consuming appliances (Mondal 2010, p. 1126).

**Figure 6: Components of a typical solar home system (SHS)**




Source: Mondal 2010, p. 1126

It was in December 2002, with the establishment of the Rural Electrification and Renewable Energy Development Program (RERRED), that the support of the government of Bangladesh and international organizations for off-grid solar projects “coalesced into a formalized program” (Siegel and Rahman 2011, p. 7). Since then, the program has been implemented through the Infrastructure Development Company Limited (IDCOL), a state-owned non-banking financial institution that was established in 1997 (Uddin and Taplin 2009, p. 282).

The project initially aimed to install 50’000 SHS by 2008. IDCOL achieved this target already in 2005, three years ahead of the completion date and USD 2 million below the estimated cost. Therefore, the target was revised to 2.5 million SHS by 2014. Up to 29 April 2012, IDCOL has installed 1’429’440 SHS through its thirty partner organizations. The biggest partner is Grameen Shakti which has already installed about 800’000 SHSs.

People who intend to buy a SHS are required to pay at least ten percent of the total costs as down payment. For the rest of the outstanding amount, they receive a loan financed by the partner organizations (20 percent) and IDCOL (80 percent). This loan is paid back via a series of monthly installments over a period of 12, 24 or 36 months (Siegel and Rahman 2011, p. 7). The grant that IDCOL provides to its partners for every SHS sold has been gradually reduced from USD 90 to Euro 22 (IDCOL 2011, p. 4). This goes in line with IDCOL’s objective to further the commercialization of the SHS and to “facilitate the transition from a sector that relied upon subsidies to one that could stand alone” (Siegel and Rahman 2011, p. 8). The question that remains to be answered is how the micro solar water pump can be combined with such a SHS.

One possibility would be to market the water pump as an “add-on” to the solar system. Already today, SHS owners can choose from a range of options in terms of the size of the panel and the appliances they want to power. Table 12 gives an overview of the packages offered by Grameen Shakti.

**Table 12: SHS packages offered by Grameen Shakti for out of grid areas**

| Load | Package includes | Using Time per day | Package Price (BDT) |
|---|---|---|---|
| 11 x 7 watt tube light and a 17-20” TV (Black/White) | A 135 watt panel, 11 x 7 watt CFL, a 100AH deep discharge battery, a charge controller, a frame and cables | 4 Hours | 72‘900 |
| 11 x 7 watt tube light and a 17-20” TV (Black/White) | A 130 watt panel, 11 x 7 watt CFL, a 100AH deep discharge battery, a charge controller, a frame and cables | 4 Hours | 72‘000 |
| 10 x 7 watt tube light and a 17-20” TV (Black/White) | A 120 watt panel, 10 x 7 watt CFL, a 100AH deep discharge battery, a charge controller, a frame and cables | 4 Hours | 69‘200 |
| 8 x 7 watt tube light and a 17” TV (Black/White) | A 85 watt panel, 8 x 7 watt CFL, a 130AH deep discharge battery, a charge controller, a frame and cables | 4 Hours | 44‘800 |
| 7 x 7 watt tube light and a 17” TV (Black/White) | A 83 watt panel, 8 x 7 watt CFL, a 100AH deep discharge battery, a charge controller, a frame and cables | 4 Hours | 44‘500 |
| 7 x 7 watt tube light and a 17” TV (Black/White) | A 80 watt panel, 7 x 7 watt CFL, a 100AH deep discharge battery, a charge controller, a frame and cables | 4 Hours | 42‘200 |
| 6 x 7 watt tube light and a 17” TV (Black/White) | A 75 watt panel, 6 x 7 watt CFL, a 100AH deep discharge battery, a charge controller, a frame and cables | 4 Hours | 40‘500 |
| 5 x 7 watt tube light and a 17” TV (Black/White) | A 65 watt panel, 5 x 7 watt CFL, a 100AH deep discharge battery, a charge controller, a frame and cables | 4 Hours | 36‘000 |

| | | | |
|---|---|---|---|
| 5 x 7 watt tube light and a 17" TV (Black/White) | A 63 watt panel, 5 x 7 watt CFL, a 100AH deep discharge battery, a charge controller, a frame and cables | 4 Hours | 35'700 |
| 5 x 7 watt tube light and a 17" TV (Black/White) | A 60 watt panel, 5 x 7 watt CFL, a 80AH deep discharge battery, a charge controller, a frame and cables | 4 Hours | 34'400 |
| 4 x 7 watt tube light and a 17" TV (Black/White) | A 50 watt panel, 4 x 7 watt CFL, a 80AH deep discharge battery, a charge controller, a frame and cables | 4 Hours | 29'500 |
| 3 x 7 watt tube light and a 14" TV (Black/White) | A 40/42 watt panel, 3 x 7 watt CFL, a 55/60AH deep discharge battery, a charge controller, a frame and cables | 4 Hours | 23'600 |
| 2 x 5 watt CFL or a 5watt CFL and a tube light | A 20/21 watt panel, 2 x 5 watt CFL or a 3watt CFL and a tube light, a 30AH deep discharge battery, a charge controller, a frame and cables | 4 Hours | 13'100 |

Source: Grameen Shakti 2012, n.p.

In a meeting with Grameen Shakti in June 2012, Senior Manager Firoj Molik Ali revealed that when Grameen Shakti started its SHS piloting project in 1996, they had no experience in this field. From the beginning on, the goal was to offer different packages and financial support to the client. The target group was not defined in relation to a certain level of income, but seen as all people living in off-grid areas. While Firoj Molik Ali admits that it is still difficult to reach the poorest people in Bangladesh, he is confident that not only the wealthiest social stratum can afford a SHS. This is illustrated by the fact that 70 percent of the SHSs sold are small systems in the range of 20W to 50W. Furthermore, through spreading the cost of the system over several months and by the fact that the monthly installments are in the range of what the family previously spent on kerosene, also poorer people can become SHS owners. Another advantage of the SHS is that people can, by adding another solar panel, gradually upgrade their installation and power more and more appliances (e.g. fan, TV etc.) (Meeting with Grameen Shakti, Dhaka, 13 June 2012).

As of today, Grameen does not offer a solar pump "add-on" to its clients. Firoj Molik Ali, however, is convinced that there is a demand for a small-scale water pump on the part of the solar home owners. By upgrading the existing panels from 40W to 80W, the SHS owners could get water delivered into their houses, without having to manually operate a hand pump like it is the case today. The pump could lift water into a tank on the roof where it would be stored and used to cover the drinking and household water needs of the family. Having in-house water facilities, e.g. a shower, adds to the comfort and quality of life and, a factor that is not to be underestimated, is an object of prestige. The water pump could be used to irrigate a homestead garden or fruit trees near the house, as well. The advantage of this option, in comparison to taking the irrigation device to the field, is that the panel and the pump are set at the house where they are safe from stealing and do not need to be installed every day. Further, this water supply would allow growing high value crops in a kitchen garden, which would be an opportunity for poor families to generate additional income.

The fact that SHSs not only improve people's quality of life by giving them access to electricity, but also create income opportunities, is certainly one of the secrets of success of this technology. Women, for example, are getting extra time for activities like sewing or poultry farming. Shop owners have been able to increase their sales because the improved light attracts customers (IDCOL 2011, p. 10). Furthermore, many households and businesses have been able to "generate income by charging people a small fee to charge their mobile phones with the electricity generated by their SHSs" (Siegel and Rahman 2011, p. 8). The monthly installments can therefore be seen as an investment, rather than a cost, and the SHS as the foundation of a business that can lift a Bangladeshi family out of poverty.

Before the micro solar water pump can be offered as an add-on to SHS owners, this combination will have to be tested extensively. The challenge will be to find a comprehensive system that makes efficient use of the electricity generated, that is easy to handle and that covers the needs of the users (e.g. in terms of hours of light delivered, liters of water pumped etc.). Therefore, another field test should be considered to find out how the solar pump, from a technical point of view, could be connected to the SHS and what potential customers think about this idea.

Another idea, which will be presented in the following chapter, is to sell the micro solar water pump in combination with the so-called power box.

### 8.2. Combination with the power box

The power box is a simple off-grid solar charger and LED light that was designed by students from BUAS. The goal is to improve the quality of life of people living in areas without access to the electricity grid. The power box, which can be connected to any 1W to 5W solar panel available on the market, delivers hours of bright light to family homes, schoolchildren or street vendors. If the costs of the system are spread over a longer period of time, the monthly expense will be in the range of what a family previously spent on kerosene. Currently, the students at BUAS are developing a prepaid solution for the power box that will allow the users to pay for the system only when they use it. By replacing their kerosene lamps, people will not only enjoy brighter LED light, but also cleaner indoor air and a reduced risk of fire. Another feature of the power box is the universal charge interface that allows charging cell phones, torch lights or other appliances (BUAS n.d., pp. 1-12).

The combination with the micro solar water pump makes sense because it could be a source of income for the owner. As has been elaborated before, the micro solar water pump comes with a 80W solar panel. The power box, on the other hand, only with a 1W to 5W panel. The system owner could therefore use the panel to power the pump for several hours a day to lift water into a tank. During the rest of the day, the panel could be used to charge one, or ideally several, power boxes. This means that the owner of such a system could generate additional income by charging the power boxes or electric appliances of other people for a small fee. Further, if the amount of water pumped is bigger than what he needs for his own use, the owner of such a system could also become a water seller. Hence, through the combination of solar pump and power box, the owner would not only benefit from the light and water that is delivered, but also from the additional income opportunities that are created.

### 8.3. Concluding remarks

Before such comprehensive systems can be sold to the customer, they need to be tested under real conditions. In the case of Bangladesh, it is further recommended to conduct a market study to assess the demand for such systems and to compare them to the solutions offered by potential competitors. There is a huge demand for solar powered technologies, especially solar light, in Bangladesh. It should, however, not be underestimated that there are already big players competing for the customers in this sector. Grameen Shakti, for example, plans to expand and deepen its activities in the solar power sector. During the United Nations Conference on Sustainable Development in June 2012, Grameen Shakti signed a deal with Schneider Electric, an energy specialist with 130'000 employees worldwide. The plan is to create a social business called Grameen Schneider Electric to develop innovative solar-powered solutions for water pumping and off-grid power generation (The Daily Star 2012).

In sum, it is recommended to test the combination of the micro solar water pump with the solar home system and the power box in order to find the optimal design. Further, it is considered important to thoroughly analyze the market environment and the customer base for such a comprehensive system.

## 9. Conclusion

In recent years, it has become more and more evident that traditional development strategies or charity alone will not solve the complex problems of poverty, inequity and unsustainability that humankind faces today. Increasingly, the private sector is called upon to use its know-how, influence and innovations to sustainably serve those billions of poor people that have been neglected by global markets until this day. This is the central quest of the BoP theory brought to prominence by C.K. Prahalad. Despite a vast amount of academic articles and lively discussions about the topic, many aspects of the BoP theory still need to be studied more thoroughly. The present master thesis tried to contribute to the closing of one such knowledge gap by broaching the issue of *design for the BoP*.

The three central questions that guided the theoretical research were: *why*, *how* and *what* should a private company design for people living at the base of the economic pyramid. Concerning the question of why a company should design products and services for poor customers, it was argued that, despite major challenges, there are huge financial benefits and competitive advantages waiting at the BoP. In the chapters addressing the question of how a design process should look like, it was said that the people, not technologies, should be in the center of attention. Thus, in order to design innovations that have a real impact on poor people's lives, the focus of the research team needs to be on the exploration and understanding of the social, cultural and economic context of the customers. It was further argued that, in order to be desirable and appropriate for the needs of poor people, these innovations need to be affordable, customized to their needs and environmentally sustainable.

Against the background of these theoretical information, the case of the micro solar water pump was discussed. It was shown that it can be difficult to bring into balance the aspects of feasibility, desirability and economic viability – like it is suggested in the design thinking theory. The solar pump proofed to be technically reliable and desirable to the smallholder farmers it was designed for. However, taking into account the social and economic context and the broader irrigation market in Bangladesh, it was discovered that the micro solar water pump might not be able to enter the market as a one-to-one replacement of existing fuel powered irrigation technologies.

Human-centered design, rather than a sequence of orderly steps, has to be seen as a creative and iterative process. Hence, the lessons learnt during this first field testing yield new opportunities and solutions and will inspire further design changes to make the solar pump more compelling and affordable for potential customers. One idea that will be pursued in the future is to test the solar pump as part of a comprehensive system that offers also other amenities – light, for example.

The micro solar water pump project is very ambitious, not only because of the complexity of the technology, but because it stands at the intersection of some of the most urgent development issues in Bangladesh: the need for reliable and affordable irrigation to ensure food security, the rampant energy crisis and tangible effects of climate change, the struggle of small farm holders to feed their families and the effort to create income opportunities for the millions that still live in poverty. In this thesis it was demonstrated that, in order to produce revolutionary innovations that address such complex problems, designers sometimes need to leave the well-known path and venture out to discover radically new solutions.

In conclusion, the main takeaway from this thesis is that if an innovation is to have a real impact on poor people's lives, the design process needs to be human-centered and context-driven and should be understood as trial-and-error process and not as a sequence of orderly steps. The insights gained during the field testing of the solar pump in Bangladesh are therefore seen as contributions to an iterative design process which is not yet finished.

There are still a number of aspects of the BoP theory, notably the question of how BoP ventures can reach scale, that need to be further explored. Due to the limited scope of this study, these questions have to be left to future research. As of the future of the solar pump project, the search for the ideal design is still in progress. After all, it can only be hoped that all the people involved in the project will keep up their inspiring work in the spirit of John F. Kennedy, who once said:

> *The problems of the world cannot possibly be solved by skeptics or cynics whose horizons are limited by the obvious realities. We need people who can dream of things that never were.*

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## Appendix A: Pictures of the micro solar water pump

Measuring the amount of water pumped

Picture taken by author in Rangpur, 19 March 2012

Micro solar water pump installed in rice field

Picture taken by author in Rangpur, 19 March 2012

Micro solar water pump and solar panel

Picture taken by author in Rangpur, 20 March 2012

## Appendix B: Interviews with farmers that are testing the solar pump

**Ten of the farmers** that are testing the solar pump have been interviewed on April 19 and 20. The farmers live in the villages of Ranipukur and Buzrok Santosphur, Mithapukur upazila, Rangpur district.

### Personal details:

| Name of the farmer | Village | Age | People within household | Average annual net income of the household * | Source of income |
|---|---|---|---|---|---|
| 1. Md. Edrish Ali | Ranipukur | 50 | 4 | 20'000 Taka | Farming |
| 2. Md. Fattarul Islam | Ranipukur | 43 | 3 | 5'000 Taka | Farming |
| 3. Md. Mostafizar Rahman | Ranipukur | 22 | 5 | 3'000 Taka | Farming |
| 4. Md. Abdus Salam | Ranipukur | 38 | 5 | 25'000 Taka | Farming |
| 5. Md. Wajad Ali | Ranipukur | 43 | 5 | 10'000 Taka | Farming |
| 6. Md. Sadek Ali | Ranipukur | 30 | 2 | 2'000 Taka | Farming |
| 7. Md. Abu Talha | Buzrok Santoshpur | 58 | 5 | 5'000 Taka | Farming / bicycle repair |
| 8. Md. Abdul Monnaf | Buzrok Santoshpur | 50 | 5 | 10'000 Taka | Farming |
| 9. Md. Edrish Ali | Buzrok Santoshpur | 45 | 4 | 40'000 Taka | Farming |
| 10. Md. Lovelu Mirah | Buzrok Santoshpur | 37 | 4 | 25'000 Taka | Farming |

* Average annual net income of the household = income minus expenses for housing, food, clothing and medical treatments

** As of 25 April 2012: 1 Bangladeshi Taka (BDT) = 0.01202 US Dollar (USD)

### Questions related to the cultivation of land:

() = number of farmers that gave this answer

| | |
|---|---|
| 1. Total area under cultivation by the farmer | - Between 36 and 600 decimals[1]<br>- Average: 183 decimals |
| 2. Type of crops | □ Rice (8)<br>Between 25 and 450 decimals<br>Average: 164 decimals<br><br>□ Vegetables (9)<br>Between 20 and 150 decimals<br>Average: 57 decimals |

[1] 100 decimals = 1 acre = 4046m2

| | |
|---|---|
| 3. Is it your own land or sharecropping? | ☐ Own land only (5)<br>☐ Sharecropping only (2)<br>☐ Both, own land and sharecropping (3) |
| 4. What are the conditions for the sharecropping? | ☐ Rice: between 33% and 50% of the harvest have to be given to the landowner<br>☐ Vegetables: 33% have to be given to the landowner<br>☐ The farmer has to provide all inputs (including seeds, fertilizer, pesticide, water etc.) |
| 5. How much do you earn (net benefit) per decimal of rice/vegetables? | The farmers could not answer this question |
| 6. Do you have a homestead garden? | ☐ No (7)<br>☐ Yes (3)<br>Surface: 5, 10, 35 decimals<br>Crop: vegetables<br>Irrigated with hand pump or treadle pump |

## Questions related to irrigation BEFORE solar water pump was used:

| | |
|---|---|
| 7. What kind of pump did you use? | ☐ Treadle pump (2)<br>☐ Diesel pump (7)<br>☐ Electric pump (6)<br>☐ Other (0) |
| 8. Did you purchase water or use your own engine and pump? | ☐ Purchase water from water seller (9)<br>☐ Use own manual pump (2)<br>☐ Use own engine (1) |
| 9. How often did you have to irrigate your fields? | ☐ Boro rice: every 5 days<br>☐ Vegetables: once a week (sandy soil), every two weeks (clay soil) |
| 10. Did you use any irrigation technologies in order to save water e.g. shower / drip irrigation or AWD[2]? | ☐ Yes (0)<br>☐ No (10), flood irrigation.<br><br>➡ One farmer said that he has seen AWD in other fields. He thinks that for him it does not make sense to use AWD because he pays a fixed rate (per acre and season) for water. There is no pressure to save water.<br><br>➡ Another farmer said that he already saves as much water as he can. He is not flooding his rice fields and only applies a minimum amount of water. He cannot save more water by using AWD. Result: he is getting better yield than other farmers that flood their fields. |

[2] AWD = Alternate Wetting and Drying

| | |
|---|---|
| 11. What type of contract did you have with the water seller? | ☐ Rice: - 2500 Tk per acre and season from DTW[3] with electric engine<br>- 4000 Tk per acre and season from STW[4] with electric engine<br>- 6000-7000 Tk per acre and season from STW with diesel engine<br>☐ Vegetables: between 75-100 Tk per hour |
| 12. Was water always available when you needed it? | ☐ Yes (2)<br>☐ No (8), because: - regular power cuts<br>- water level went down and reduced water output by about 20%<br>- high demand for water, often farmers have to “wait in line” |
| 13. Have you ever used a prepaid device to pay for your water? | ☐ Yes (0)<br>☐ No (10) |
| 14. What are the major problems, related to irrigation, that you face? | – Regular power cuts → and therefore electric engines cannot be used<br>– It is hard physical work<br>– Water is not always available in time |

### Questions related to irrigation NOW that the solar water pump is used:

| | |
|---|---|
| 15. What kind of crops do you irrigate with the solar pump? | ☐ Rice (1)<br>☐ Vegetables (10) |
| 16. What surface can be irrigated with the solar pump? | ☐ Rice: up to 15 decimals (clay soil)<br>☐ Vegetables: between 10-34 decimals<br>➔ One farmer tested the solar pump in a rice field. He was able to irrigate 32 decimals of vegetables and 15 decimals of rice with one solar pump. This is only possible because it is clay and not sandy soil.<br>➔ One farmer can only irrigate 10 decimals of vegetables because the soil is very sandy and because it is very hot during dry season (lot of water evaporates). |

[3] DTW = deep tube well
[4] STW = shallow tube well

| | |
|---|---|
| 17. Do you use any kind of irrigation technology in combination with the solar pump (e.g. shower / drip irrigation or AWD)? | ☐ No (1)<br>☐ Yes (9): shower irrigation technology<br><br>➡ Generally speaking, the farmers liked the shower irrigation technology because it needs less water than furrow/flood irrigation.<br><br>➡ They, however, also said that it takes them more time (and for some of them causes additional labor cost) when they irrigate their fields with the shower irrigation technology compared to flood irrigation.<br><br>➡ Some of the farmers let their children use the shower irrigation technology because for them it is fun.<br><br>➡ One farmer said that the shower irrigation technology has another positive side-effect: there are fewer insects on his crops and he does use less pesticide. |
| 18. Where do you see the advantages of the solar water pump? | – No expenses for fuel and oil<br>– Farmers do not depend on electricity and are not affected by the frequent power cuts<br>– No operating costs<br>– Solar is a good thing for Bangladesh<br>– Those farmers, who used a treadle pump previously, said that they can save time. While their small children could not operate a treadle pump, they can make them use the shower irrigation technology.<br>– The farmer does not have to wait until the water seller has time to irrigate his field<br>– Solar pump = freedom<br>– The farmer can irrigate whenever he wants to |
| 19. Where do you see problems with the solar water pump? | – The water discharge is not sufficient<br>– The farmers want at least 1 to 1.5 inch delivery<br>– Irrigation is more time consuming<br>– The pump does not run on cloudy days<br>– Sometimes there are technical problems and therefore, even though the sun is shining, the pump does not run<br>– Two farmers said they had to pay for the additional labor that was necessary to irrigate the field. For the money they had to invest, they could have bought water from a water seller.<br>– One farmer said, the priming pump is not good because it is leaking |

| | |
|---|---|
| 20. Do you save any time by using the solar water pump? | ☐ No (8)<br>☐ Yes (2 treadle pump users) |
| 21. Can you irrigate a larger field because of the solar pump? | ☐ No (10)<br>☐ Yes (0) |
| 22. Would you want to own a solar water pump? | ☐ No (1)<br>☐ Yes (9), if it pumps more water |
| 23. How much money (Taka) would you be willing to pay for the solar water pump? | – 0 Taka (1)<br>– 7'000 Taka (1)<br>– 10'000-12'000 Taka (2)<br>– 15'000 Taka (2)<br>– 15'000-16'000 Taka (1)<br>– 15'000-20'000 Taka (1)<br>– 20'000 Taka (2)<br><br>Average: 14'666 Taka |

## Appendix C: Interviews with engine owners/water sellers

**Five engine owners/water sellers** have been interviewed on April 20 in the villages of Ranipukur and Buzrok Santosphur, Mithapukur upazila, Rangpur district.

### Personal details:

| Name | Village | Age | Average annual net income* |
|---|---|---|---|
| 1. Md. Edrish Ali | Ranipukur | 50 | 20‘000 Taka |
| 2. Md. Selwar Hossain | Ranipukur | 33 | 30‘000 Taka |
| 3. Md. Abu Bakkar Siddik | Buzrok Santoshpur | 30 | 25‘000 Taka |
| 4. Md. Tajbar Hossain | Buzrok Santoshpur | 32 | 25‘000 Taka |
| 5. Abu Bakkar | Buzrok Santoshpur | 70 | 20‘000 Taka |

* Average annual net income = income minus expenses for housing, food, clothing and medical treatments

** As of 25 April 2012: 1 Bangladeshi Taka (BDT) = 0.01202 US Dollar (USD)

### Questions related to the pump they use:

() = number of farmers that gave this answer

| | |
|---|---|
| 1. What kind of pump do you own? | ☐ Diesel (3)<br>☐ Electric (2)<br>☐ Other (0) |
| 2. How old is your pump? | ☐ Diesel: 5, 22, 25 years<br>☐ Electric: 22, 25 years |
| 3. Did you buy the pump on the local market? | ☐ No (0)<br>☐ Yes (5) |
| 4. Are spare parts easily available on the local market? | ☐ No (0)<br>☐ Yes (5) |
| 5. What is the capacity of the pump? | ☐ Diesel pumps: 4 HP with a discharge of about 10-12 liters/sec<br>☐ Electric pumps: 5 HP with a discharge of about 14 liters/sec |
| 6. What kinds of problems do you have with the pump? | - No problems with the pump itself<br>- Frequent power cuts are a problem for the owners of electric pumps |

| | |
|---|---|
| 7. What are the advantages of your pump? | - Very reliable<br>- Delivers a lot of water |
| 8. How many acres do you irrigate with one pump? | - 5 HP electric: 15-20 acres (very efficient pump)<br>- 4 HP diesel: 5-8 acres |

**Questions related to the water selling business:**

| | |
|---|---|
| 9. Do you sell water to other farmers? | ☐ No (1)<br>☐ Yes (4) |
| 10. How many months a year do you sell water | - Above all during dry season (from November to May)<br>- Sometimes also during Aman season |
| 11. Did you buy the pump on a credit? | ☐ No (5)<br>☐ Yes (0) |
| 12. How much are the maintenance costs of the pump per year? | - On average about 3000 Taka per year (more if bigger parts have to be replaced) |
| 13. How much does one liter of diesel cost? | - 65 Taka |
| 14. How much does one liter of diesel cost one year ago? | - 45 Taka |
| 15. How does the rising diesel price affect you? | - The cost for irrigation increases<br>- Amount charged to the farmer is 80-100 Tk/hour - one year ago it was 50-60 Tk/hour |
| 16. Is diesel always available? | ☐ No (0)<br>☐ Yes (5) |
| 17. Who bears the cost for the diesel, repairing / maintenance of the engine etc.? | ☐ Water seller (5)<br>☐ Water buyer (0) |
| 18. If you have an electric pump, is electricity always available when you need it? | ☐ No (5): there are frequent power cuts, only avail about 8-12hours/day<br>☐ Yes (0)<br>➡ Users of electric engines get 20% government subsidy on electricity. The price for electricity is 2.85 Taka per kWH, but is expected to go up by about 20% within the next few months. |
| 19. Do you use the engine for other activities apart from irrigation? | ☐ No (3)<br>☐ Yes (2): threshing |
| 20. Have you seen the solar water pump in the field? Or heard about the project? | ☐ No (0)<br>☐ Yes (5) |

| | |
|---|---|
| 21. Where do you see the advantage of the solar water pump? | - No fuel costs<br>- Not dependent on electricity supply<br>- Could be used for nursery or homestead garden<br>- A combination with light would be good |
| 22. Where do you see the problems of the solar water pump? | - Not enough water pumped |

## Appendix D: Interviews with farmers that buy water from irrigation service providers

**Eleven farmers that buy water from irrigation service providers** have been interviewed between 20-24 May 2012 in the villages of Ranipukur, Chilakhat, Motorpur, Binbiniyachao, Pochim Binbiniya, Modho Binbiniya and Anazihonishawar, Rangpur district.

### Personal details:

| Name of the farmer | Village | Age |
|---|---|---|
| 1. Md. Mashtribizar Rahman | Ranipukur | 48 |
| 2. Md. Fantarul Islam | Ranipukur | 48 |
| 3. Wazed Ali | Ranipukur | 40 |
| 4. Md. Sader Ali | Ranipukur | 36 |
| 5. Md. Shomser Ali | Chilakhat | 50 |
| 6. Md. Sharibul | Motorpur | 32 |
| 7. Md. Bondsa | Binbiniyachao | 30 |
| 8. Md. Atiyar Rhaman | Binbiniyachao | 30 |
| 9. Md. Motlubor Rahman | Pochim Binbiniya | 62 |
| 10. Md. Suza | Modho Binbiniya | 28 |
| 11. M.A. Hamid | Anazihonishawar | 55 |

### Questions related to water selling service:

() = number farmers that gave this answer

| | |
|---|---|
| 1. Do you always get water in time? | ☐ Yes (0)<br>☐ No (11) |
| 2. IF NO, why don't you get water in time? | – Water sellers do not come to irrigate very small plots of land<br>– Water seller is busy<br>– Farmer does not have enough money to pay for the service<br>– For farmers, cash payment in advance is difficult<br>– The diesel price is very high<br>– Fuel sometimes not available<br>– Sometimes, STW inactive<br>– A lot of people wanting to buy irrigation service compared to a decreasing number of water sellers |

| | |
|---|---|
| 3. Do you buy water from different sellers? If yes, from how many? | ☐ 2 different sellers (4)<br>☐ 2-3 different sellers (2)<br>☐ Only from one seller (5) |
| 4. How long do you usually have to wait for the water (days)? | ☐ 2 days (2)<br>☐ 2-3 days (3)<br>☐ 3 days (1)<br>☐ 3-4 days (2)<br>☐ 3-5 days (1)<br>☐ 4-6 days (1)<br>☐ 5-6 days (1)<br>Average: 3.3 days |
| 5. How often (per season) does it happen that you don't get the water in time? | ☐ 2 times (3)<br>☐ 3 times (1)<br>☐ 3-4 times (2)<br>☐ 4-5 times (1)<br>☐ 5-6 times (4) |
| 6. How is the water selling organized? Is there a fixed order? Does the water seller stick to that order? | Yes, there is a fixed order |
| 7. Do some people get a preferential treatment from the water seller? If yes, why? | – Yes, because they have personal relations with the water seller (6)<br>– People that pay in advance get a preferential treatment (2)<br>– People that pay a higher price get water first (1)<br>– No preferential treatment (4) |
| 8. What are the consequences for you if you do not get water in time? | – Bad feeling for the farmer<br>– Yield is reduced<br>– Crop damage<br>– More insects and diseases<br>– More labor in the field needed<br>– Late harvest / flowering<br>– Price of output reduced |
| 9. By how much (%) is the yield of your crops reduced if you don't get water in time? | – 15-20% (3)<br>– 20% (4)<br>– 25% (2)<br>– 25-30% (1)<br>– 30% (1)<br>Average: 21% |
| 10. Where do you get your water from, if the water seller cannot deliver? | – From relatives (4)<br>– From a water seller at another village (3) |
| 11. Do you feel that you are dependent on the water seller? | ☐ Yes (11)<br>☐ No (0) |

## Appendix E: Interviews with water pump sellers

A total of **3 pump sellers** have been interviewed on April 18 in the city of Rangpur.

### Personal details:

| Name of the business | Proprietor | Address |
|---|---|---|
| 1. M/S. Krishi Seba | Md. Mahfuzur Rahman | Shallow tube well market<br>Station Road<br>Rangpur |
| 2. M/S. Krishi Gorh | Md. Selim Parvez Kamal | Shallow tube well market<br>Station Road<br>Rangpur |
| 3. Rashel Machineries | Md. Tarikul Islam | Shallow tube well market<br>Station Road<br>Rangpur |

### Questions related to their business:

() = number farmers that gave this answer

| | |
|---|---|
| 1. How many customers do you have? | – Engine: 500, Pump: 20<br>– Engine: 500, Pump :150<br>– Engine: 5'000, Pump: 2'500 |
| 2. How many of them grow rice/vegetables? | Rice: about 80% of them<br>Vegetables: about 10% of them |
| 3. Do you sell on credit? | No (3)<br>Yes (0) |
| 4. Do you sell any solar powered technologies? | No (3)<br>Yes (0) |
| 5. Where do you see the advantages of a solar powered water pump? | – No fuel costs<br>– Not dependent on electricity supply anymore |

**Water pumps available on the market in Rangpur:**

* As of 25 April 2012: 1 Bangladeshi Taka (BDT) = 0.01202 US Dollar (USD)

**Electric pumps:**

| Horse Power (HP) | Water discharge (l/sec) | Weight (kg) | Fuel consumption (l/hour) | Average Price engine+pump (Taka) | Longevity engine (years) |
|---|---|---|---|---|---|
| 0.5 | 0.5 | 5 | - | 2500 | 5-7 years |
| 0.75 | 0.75 | 7 | - | 4500 | „ |
| 1.5 | 1.5 | 8 | - | 5500 | „ |
| 2 | 8 | 10 | - | 12500 | „ |
| 3 | 10 | 10 | - | 15000 | „ |
| 4 | 14 | 14 | - | 18500 | „ |
| 5 | 19 | 16 | - | 25500 | „ |

**Diesel pumps:**

| Horse Power (HP) | Water discharge (l/sec) | Weight (kg) | Fuel consumption (l/hour) | Average Price engine only (Taka) | Longevity engine (years) |
|---|---|---|---|---|---|
| 4 | 8 | 45 | 0.5 | 12800 | 8-10 years |
| 6 | 10 | 70 | 0.75 | 13500 | „ |
| 8 | 14 | 80 | 1 | 15200 | „ |
| 12 | 20 | 110 | 1.5 | 26000 | „ |
| 16 | Not for irrigation | 120 | 1.65 | 27500 | „ |
| 20 | Not for irrigation | 130 | 2 | 30500 | „ |

## Appendix F: Interviews with solar home owners

**Five solar home owners** have been interviewed on April 20 in the village of Buzrok Santosphur, Mithapukur upazila, Rangpur district.

### Personal details:

| Name of person | Village | Age | Average annual net income* | Profession |
|---|---|---|---|---|
| 1. Md. Hannan Paikar | Buzrok Santoshpur | 45 | N.A. | Input seller |
| 2. Md. Hannan | Buzrok Santoshpur | 45 | 15‘000 Taka | Doctor |
| 3. Md. Johangir Paiker | Buzrok Santoshpur | 25 | 40 ‘000 Taka | Input seller |
| 4. Md. Mahbubur Rahman | Buzrok Santoshpur | 50 | 10‘000 Taka | Farmer |
| 5. Md. Mozaffer Hossain | Buzrok Santoshpur | 50 | 20‘000 Taka | Teacher |

* Average annual net income = income minus expenses for housing, food, clothing and medical treatments
** As of 25 April 2012: 1 Bangladeshi Taka (BDT) = 0.01202 US Dollar (USD)

### Questions related to solar home system:

() = number of solar home owners that gave this answer

| | |
|---|---|
| 1. How big is the solar panel you use? | 40 Watt (5) |
| 2. What do you use the electricity for? | □ Light (5)<br>□ Black/white TV (4)<br>□ Fan (1) |
| 3. From whom did you buy the solar home system? | BRAC (5) |
| 4. Did you get a credit? | □ No (0)<br>□ Yes (5) |
| 5. What are the repayment terms of the credit? | – Down-payment 3’000Tk and 845Tk/month over 24 months<br>– Down-payment 4’500Tk and 750Tk/month over 24 months<br>– Down-payment 5’000Tk, rest over 24 months with 12% interest<br>– Down-payment 8’000Tk and 500Tk/ month over 24 months |

| | |
|---|---|
| 6. Do you use a prepaid device to pay for the solar home? | ☐ No (5), they are not familiar with prepaid devices<br>☐ Yes (0) |
| 7. What is the advantage of having a solar home? | – Light is always available<br>– One can watch TV<br>– Students/children can study at night<br>– Not dependent on electricity grid (frequent power cuts) |
| 8. What are the problems that you have with the solar home system? | – No problems<br>– And if there ever is a problem: warranty for battery and other parts is 5 years, for panel 20 years |

**Questions related to the "solar water pump add on" to the solar home:**

| | |
|---|---|
| 9. Would it be useful if, in combination with the solar home system, you could also power a small water pump – e.g. to pump water into a tank on your roof? | – Yes, that is a good idea (5)<br>– The water could be used for household (drinking, cooking, washing etc.) and irrigation purposes (fruit trees, homestead garden)<br>– Today, they use hand tube wells to pump water used in the household |
| 10. How much would you be willing to pay for such a "solar water pump add on" to your solar home system (for the pump and the tank)? | – 3'000 Taka (only for pump, he would make tank himself) (1)<br>– 10-15'000 Taka (1)<br>– 15'000 Taka (2)<br>– Up to 25'000 Taka (1)<br>Average: 14'000 Taka |

**Acknowledgement**

I would like to express my deepest gratitude to all the people that supported me during the process of writing this master thesis.

Many thanks go to Prof. Andrea Vezzini, Alois Müller, Maja Huerlimann and Leslie Light for their valuable inputs.

Special thanks go to the team of iDE Bangladesh, especially Rajiv Pradhan and Badrul Alam, who made me a part of their team.

My sincere appreciation is extended to Ph.D. Urs Heierli for making the internship in Bangladesh possible and for his support and guidance throughout the research.

**Declaration of Authorship**

"I hereby declare

- that I have written this thesis without any help from others and without the use of documents and aids other than those stated above,
- that I have mentioned all used sources and that I have cited them correctly according to established academic citation rules."

Glis, 15 November 2012

Karin Imoberdorf