Solar Lamps Field Test Uganda
FINAL REPORT

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This report presents the findings of a research project that was launched in 2009 under the guidance of Kilian Reiche, whose insightful instructions have been pivotal to the generation of relevant results. The research in the first phase of the project, including the focus groups and the set-up of the lamp sale model, was led by Marek Harsdorff.

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Content

SUMMARY

One quarter of the world population still lacks access to modern energy today, and prospects for the situation to change over the next decades are bleak given limited government funds and little private sector interest to serve low income households, especially in remote rural areas. For these, "PicoPV" products (i.e. small solar lamps, including flashlights and lanterns, or home systems which provide bright LED or CFL lighting and charge radios and cell phones at end-user prices of US$ 10-200 and extremely low maintenance costs) are a promising new technology option.

However, important questions remain regarding the best way towards a fast but sustainable large-scale diffusion of PicoPV solutions. More than 100 firms produce PicoPV products for dissemination in developing countries today, but most products are of very low quality, with serious implications for consumer trust in the new technology. Early lab tests have focused the awareness of governments and donors on the importance of quality control and customer information however, field tests in different countries with sufficient sample sizes are needed for a better understanding of PicoPV performance under real-life conditions, and to identify gaps in the emerging draft lab test procedures. In addition, private sector actors lack basic market information on this new technology (such as national market potentials, local consumer preferences and willingness to pay) which they would need to decide if and how to enter this new market segment.

In order to help bridge these information gaps and support the development of the nascent PicoPV market, GIZ has launched a comprehensive PicoPV field test and survey in developing countries across continents, using a range of specially developed research tools.

Country-specific insights have been sought on the following four research questions:

1. Which lamp types/designs/features are preferred by local customers?
2. How do the lamps perform under real life conditions in typical target group households?
3. What are the socioeconomic impacts of the new lighting devices at household level?
4. How much are the target customers willing and able to pay?

Our five most interesting results from the Uganda Field Test & Survey are:

- In order to better match users' charging and lighting habits and increase the impact of the lamps, manufacturers need to improve products' solar fraction (i.e. design lamps with sufficient panel and battery capacities, to meet users' needs in terms of light output and burn time), equip lamps only with advanced charge controllers, and work on the robustness of the products, in particular the connection parts.

- The Uganda data highlight the urgent need to introduce quality labelling mechanisms, based on proven test procedures, on international as well as local levels: Almost all lamp models, including top end products with high quality claims by manufacturers, did not meet expectations in terms of durability and robustness in spite of the fact that they had been picked as "best of class" in the previous lab test (which in turn was based on the lab test draft methodology currently in use by GIZ as well as the World Bank's Lighting Africa Initiative).

- Data on usage of traditional lighting alternatives in households with and without solar lamps showed somewhat sobering results regarding amounts of replaced kerosene: Only for one of the lamps tested, we can assume that one kerosene lantern per household has been fully replaced; all other lamps "saved" (substituted) less than one kerosene lamp (hurricane type). This is in part due to the low solar fraction and/or poor technical performance (e.g. rapidly declining light output due to low battery quality or poor design of LED bulbs) of most solar lamps but it remains an issue even when looking only at fully functional lamps with sufficient burning time. Systems which provide more than one lighting point per household may allow for substitution of more than one kerosene lantern, as they illuminate more than one room at a time (most households in our Uganda field survey use more than one room after dark).

- Users may well be willing to pay considerably more than suggested in recent international publications on PicoPV, which assumed less than 10 US$ as an average willingness to pay (WTP) among consumers in Sub-Sahara Africa (derived from general household surveys): based on the Uganda results, sales prices up to 90 US$ may be acceptable for high quality PicoPV lanterns and kits (less than that will be paid for flash-lights). Current sales prices of high quality products need to come down by about 50 % for a massive diffusion.

- Absolute and relative WTP for different products changes significantly depending on the level and nature of information that consumers have about the lamps: before trying out different solar lamps, users were willing to pay more for the brightest lamps (maximum lumen at full charge) yet, after several weeks of using them, they preferred the more robust lamps which gave the maximum lighting service over time (total lumen hours as determined by brightness times de facto hours of usability over time).

- PicoPV systems can help achieve social benefits in terms of improved studying conditions for children.
  By contrast, the data do not allow for clear conclusion regarding work load alleviation for women: While a deferral of domestic work from the morning to the evening hours has been observed, this seems to have cut down women's time for reading, socializing and productive work in the evening hours. Further field research will be needed to explore whether and under what conditions women actually benefit from the use of PicoPV systems.

1. INTRODUCTION

In Uganda, 97 % of the rural households have no access to grid electricity today. Population growth rates that are among the highest in Africa (3.5 % estimated for 2010) and limited public and private resources to invest in electricity infrastructure pose severe challenges to change the situation significantly over the next 2-3 decades. With these bleak outlooks to improving their energy access situation people are severely restricted in their economic and social development prospects.

Improved lighting is recognized as a key lever to help people improve their living conditions: Modern lighting technologies can not only help reduce households' significant expenditures on lighting fuels and batteries, but it also widens the scope of possible evening and early morning activities, thereby promoting better educational outcomes, making domestic work easier and more efficient, encouraging social interactions, improving security, and enabling new income generating activities.

Under the Energising Development Programme, GIZ has started to explore low cost solutions to meet the basic energy needs of the rural poor in Uganda and many other countries. "PicoPV" products, i.e. small low cost solar PV systems that provide lighting and ICT services, have been given special attention as an off-grid solution that has become affordable for the bottom of the income pyramid, due to falling prices for LED and solar cells. However, a number of market barriers exist that will prevent large scale outreach of PicoPV markets to those consumers who will benefit most, i.e. low-income households in remote rural areas. GIZ has launched a broadly based initiative in 2008 to address some of the most important inhibiting factors and help the evolution of the nascent PicoPV market over the medium term. Bridging various information gaps between actors along the supply chain and end-consumers was identified as one of the key entry points.

After a comprehensive screening of the global PicoPV products market in 2008, a pre-selection of promising lamp models were taken for a lab test (developed jointly by Fraunhofer Institute for Solar Energy Systems (ISE) Freiburg, Germany, and GIZ) in order to identify a set of lamp models that meet minimum quality standards.

The lamp models that passed the lab test were taken for field tests in different developing countries in order to gain insights on the following four questions:

I. Which lamp types/designs/features are preferred by local customers?

II. How do the lamps perform under real life conditions in typical target group households?

III. What are the socioeconomic impacts of the new lighting devices at household level?

IV. How much are the target customers willing and able to pay?

A field test methodology was developed to be applied in parallel in different countries, with small adjustments to local contexts, to allow for a cross country comparison of the results.

The consolidated results from all GIZ PicoPV field test countries will help identify demand patterns that are universal across developing countries on different continents, but also to find out in which areas national and regional specificities exist.

The results of the field test in Uganda, launched in 2009 and completed in 2010, are presented in the following chapters.

Figure 1: Various solar lamp models for test-charging in the GIZ office in Arua.

Chapter 2 provides a summary of the Uganda survey methodology and the three methods of lamp distribution that were tested (free distribution, sales and lending), chapter 3 presents the selected solar lamps, chapter 4 draws some lessons from the lamp sales implementation, chapter 5 illustrates the baseline situation, chapter 6 analyzes the field survey results for each of the four research questions, chapter 7 summarizes these results and chapter 8 concludes with some policy recommendations which can be drawn from the field test results.

2. CONVENTIONAL LIGHTING TECHNOLOGIES

The most common lighting technologies used in Uganda are covered kerosene lamps (so called 'hurricane' lanterns), kerosene wick lamps, battery powered flashlights and lanterns, and candles. For data on the respective importance of these different lighting technologies see chapter 6.6.

Figure 2: Hurricane lamp for sale in a general store.

Figure 3: Simple wick lamp, used by Ugandan households traditionally in the kitchen.

3. METHODOLOGY AND FIELD TEST SET-UP

3.1 Overview of research instruments employed

The Uganda solar lamps field test was carried out in different districts of Northern Uganda, namely in 4 districts in West Nile (Arua, Maracha, Nebbi and Koboko) and in Lira. In West Nile, 7 different lamp models were tested to find out about relative strengths and weaknesses of the different lamps, as well as socioeconomic impacts depending on the lamp model; in Lira district, one lamp model was distributed to a sample of particularly marginalized households to analyse which socioeconomic benefits the lamps could offer.

The following research instruments were employed:

- focus group discussions on different solar lamp models (West Nile);
- test use of solar lamps by unelectrified rural households, with ex-ante and ex-post (after 3 months) standardized interviews (West Nile and Lira);
- Dutch auctions to assess willingness to pay for different solar lamp models (West Nile); and
- expert interviews with solar dealers and other business persons, technicians, incl. Technicians who acted as sales agents for the test, local authorities, spiritual leaders, a representative of a local savings and credit cooperative, a local micro-finance expert and a local consultant with sound knowledge of the solar market in the area (West Nile).

Figure 4: Households were interviewed before starting to use a solar lamp and 3 months later.

The focus groups and some of the expert interviews, where people were presented different lamp models and asked for their comparative assessments, allowed for conclusions regarding consumer preferences for different lamp models and certain lamp features; they also gave insights into the question which lamp features eventually guide consumers' purchasing decisions.
The household survey, by contrast, provided an ideal instrument to analyze users' experience with the lamps in their everyday life, socioeconomic impacts of the use of different solar lamp models, and the technical performance of different lamp models under real-life conditions.

The qualitative survey methods (focus groups, semi-structured expert interviews) were also considered a vital complement to the largely quantitative household surveys, because they are better suited to elicit frank disclosures of emotive opinions and/or social or cultural reservations against the use of new products. The focus group discussions have yielded valuable insights into user preferences in Uganda.

3.2 Focus groups methodology

Focus group discussions with five groups of 10 to 14 participants were conducted in May 2009 at the GIZ PREEEP office in Arua. Groups were kept homogeneous in terms of gender, occupation and social backgrounds in order to encourage outspoken discussions. Focus groups with farmers, women group members, business people and teachers yielded the perceptions of different potential solar lamp user groups; one focus group with solar technicians revealed views of potential vendors of solar lamps. A moderator guided the 3 hours discussions along a set of predetermined questions. Participants were requested to discuss about their everyday lighting needs, their aspirations and day-to-day challenges, and share their preferences and opinions with regard to the five different lamp models **(see Table 1 on page 14)** that were presented to them during the discussions. The focus group was organized in a 3 step approach: In the introductory phase, the objectives and procedure of the focus group was introduced, and people were asked to present themselves to the group. In the second phase, the solar lamps were presented, and participants were asked to share their first (visual) impressions. In the third phase people were allowed and encouraged to explore the lamps by touching them, picking them up, and switching them on and off. In order to give people a realistic impression of the light output, the room was dimmed through curtains.

3.3 Lamp distribution models

The core part of the solar lamps field test in Uganda were user surveys taken from households before they started to use a solar lamp and after they had tested it for a period of 3 months. The interviews were based on standardized questionnaires developed for cross-country application under the GIZ PicoPV field test programme. They were conducted by local enumerators who were trained and supervised by the international consultants that coordinated the field test.

The main challenge in organizing the user survey was to find ways to distribute the lamps to households so that they could be tracked for follow up interviews after 3 months. A guiding principle for the field test was to avoid system distribution free of cost for households, in favour of distribution on a sales basis, in order to ensure due valuation of the lamps by test users. Three different lamp distribution models were developed accordingly:

- distribution of 50 pieces of one lamp model at a highly subsidized price to a special user group: members of the NGO National Community of Women Living with HIV/AIDS (NACWOLA) in Lira (April 2009);
- sale of different lamp models to rural households at slightly subsidized prices in 3 districts in West Nile (April 2009-april 2010);
- lending of different lamp models to low-income households in selected villages for a test period of 3 months in West Nile (April– July 2010).

While the test setup in Lira was chosen primarily to analyze socioeconomic impacts of the use of a solar lamp, the focus of the test in Arua was on comparing consumer satisfaction, performance and impacts across the different lamp models.

i) Highly subsidized distribution of lamps to members of the NGO National Community of Women Living with HIV/AIDS (NACWOLA) in Lira

50 pieces of the Ammini Sun Lite solar lamp were distributed to members of the NGO National Community of Women Living with HIV/AIDS (NACWOLA) in Lira district in December 2008. In order to get a lamp, NACWOLA members had to register on a list to express their interest. Lamp recipients had to pay a contribution of USH 20,000 (8.5 US$). As the number of women interested in receiving a lamp exceeded the number of available lamps, lamp distribution was restricted to the first 100 women on the list. Interviews were taken from 47 lamp recipients after they had used the lamps for 3 months, and from a control group of 48 NACWOLA members without a solar lamp. A special standardized questionnaire was developed for this part of the field test to cover the underlying research questions with a focus on socioeconomic impacts of lamp use and health issues. The key results of this analysis as well as the technical performance of the Ammini lamps in the test are presented in the respective chapters of this report; a separate report is available that contains the results of the NACWOLA field test in detail.

Figure 5: Distribution of Ammini lamps to NACWOLA members in Lira: Function held in June 2009 to celebrate lamp hand-over to the women.

ii) Sale of different lamp models to rural households in 3 districts in West Nile (April 2009-April 2010);

- For the sale of solar lamps to the targeted households in West Nile, starting in April 2009, it was considered most efficient to harness an existing sales channel for solar products in the area. Matrix Electronics Ltd., which is an electronics retailer with its main shop in Arua town (district capital) and a franchisee of the Kampala-based solar products importer UltraTec Ltd., was chosen as a sales partner. Matrix Electronics received approx. 25 pieces of each of the lamp models for testing on a commission basis from GIZ. Ten technicians working for Matrix Electronics on a freelance basis and representatives of 3 local SACCOs were instructed to promote and sell the test lamps to households on the occasion of business visits to villages. They were advised to always carry one piece of each of the test models with them so that customers could choose from the full range of products.
  The lamps were sold at the following prices :
- Aishwarya – USH 120,000 (~ US$ 52)
- Solar 2007-1 (Freilassing) – USH 277,000 (~US$ 120);
  optional radio connectable to Freilassing – USH 39,000 (US$ 17)
- Solux LED 100 – USH 280,000 (~US$ 121)
- Solar LED 50 – USH 90,000 (~US$ 39)
- Solata – USH 35,000 (~US$ 15)
- Mighty Light – USH 75,000 (~US$ 32); optional phone charging pin for Mighty Light – USH 10,000 (US$ 4).

Technicians would attain the lamps from the Matrix shop in Arua against signature of a formal agreement; they had to hand in the cash payment to Matrix only upon sale and after households had made their payments. Both Matrix Electronics and the technicians received a commission of 10,000 USH for each lamp piece that had been sold. For Matrix Electronics, an additional motivation to engage in the sale experiment was that it was perceived as a valuable learning opportunity for distribution of solar products through freelancing sales agents.

A downside of this lamp distribution approach for the purposes of the study was that it did not allow for controlled sampling. As the focus of the study was on rural, unelectrified consumers, Matrix Electronics was instructed not to sell any of the field test lamps directly through the shop; a few lamp pieces were nevertheless sold directly to inhabitants of Arua town, some of which are connected to the electricity grid and used the lamps as backup devices. Among the unelectrified households that bought the test lamps, there was a bias towards the higher income strata in the rural population of West Nile. Contrary to instructions that were communicated to the sales agents at the outset, some relatively wealthy households bought two or even more solar lamps, which further reduced the scope of generated lamp user data.

In the first 5 months after the launch of the lamp sale, several technicians were quite successful at selling the more affordable lamp models (Aishwarya, Mighty Light, Solux 50 and Solata); the more expensive models, however, were difficult to promote among the (rural poor) target consumers, and sales began to stagnate. In response to this, the sale model was complemented through a simple consumer credit scheme: Clients were offered the possibility of paying off the lamps in installments over a period of 6 months. The responsibility for enforcing payments lay with the technicians. Technicians were given some flexibility in setting the exact number of installments as well as the down payment; a 50 % down payment and 4 installments was the standard scheme.

iii) Lending of lamps to selected low-income households for a 3 months test period

As sales of the more expensive lamps were still too slow to complete the field test in a reasonable time frame, it was decided in April 2010, 12 months after the test had been launched, to close down the sale of lamps and to distribute the remaining lamps (plus an appropriate number of pieces of a new test model, namely d.light Kiran) to households through a new model: The lamps were lent to selected low-income households in 3 villages in Arua district over a period of 3 months. This approach allowed for strategic sampling and fast and efficient distribution of lamps in combination with baseline and follow-up user surveys. Households who received a lamp for testing under the lending model were given the option to buy the lamp after the test period at a reduced price.

In order to ensure that lamps were only lent to trustworthy households, recommendations from the local enumerators and local GIZ staff were harnessed for the selection of households. Before lamps were handed over to test users, meetings were arranged with the Local Chairmen LC1 (elected political leader at village level) of each of the selected villages to present the project, explain its objectives and seek his support for the further proceedings. As a second step, the selected community members were called for a meeting in which the project was presented jointly through the project staff and the LC1, followed by a short community discussion about the new solar products, expectations by the households and possible impacts. The meeting was also used to give detailed instructions on the use of the lamps and for a sensitization towards careful handling of the GIZ property.

A written agreement between the test household, GIZ and the LC1 was signed at the point of lamp handover, which specified the terms of the lending scheme and the liabilities of the parties. At the end of the test period, about one quarter of the test households bought their test lamps; about three quarters of the households handed back the lamps (several of which were sold at this occasion to interested households in the village who had not been selected as test households but who had seen the lamp in use by neighbours); 4 lamps were reported to be stolen during the test period, but the responsible households paid for them.

Figure 6: Test users were lent the lamps for a period of 3 months and could either buy them or hand them back to GIZ afterwards.

4. Selection of lamps for the field test

Six lamp models were selected for the Uganda field test based on the results of a first of its kind lab test conducted in 2008-2009 for GIZ by the Fraunhofer Institute for Solar Energy Systems (ISE), Germany .

In addition, two D.light products (Solata and Kiran) were included in the field test as they were among the relatively successful low-cost models available on the Ugandan market.

	Aishwarya	Mightylight 3040	Solar 2007-1 (Freilassing)	Solux LE
				
Manufacturer	Noble Energy Solar Technologies Ltd. (India)	Cosmos Ignite Innovations (India)	Solarprojekt Freilassing e.V. (Germany)	Solux (Germar
Lamp type	lantern	multi-purpose	lantern	task light
Light cone	360° horizontal	90°	360° horizontal, 180° vertical	180° horizonta
Weight	1.2 kg	0.5 kg	0.58 kg	1.15 kg
Bulb type	CFL	LED	LED	LED
luminous flux according to producer's specification				80-100 lumen
Battery type	lead-acid	NiMH	NiMH	NiMH
Lighting duration as per manufacturer's specific.	7-9h	8h	>8h	7.5h
Battery capacity/voltage	4000 mAh/6V	2000 mAh/3.6 V	4500 mAh, 3.6 V	3500mAh/3.6 V
Charge controller		deep-discharge protection, but no overcharge protection	overcharge protection, but no deep-discharge protection	no deep-discha protection, no protection
Complementary functions	radio built into the lamp	phone charging pin (one piece) available at additional cost	external radio can be connected (optional)	phone chargin available
Price	52 US$ (~118,000 USH) (Purchase price CIF in Germany, 2008)	US$ 45 (~102,000 USH) (Purchase price CIF in Germany, 2008)	93 US$(~211,000 USH) (Purchase price CIF in Germany, 2008)	63 US$ (143,0 (Purchase pric Germany, 2008

Table 1: Overview of solar lamps in the Uganda field test.

Table 1 provides an overview of the key technical details and features of the lamps.

D 100	Solux LED 50	Solata	Kiran	Ammini
				
ny)	Solux (Germany)	d.light	d.light	Ammini Solar Pvt. Ltd. (India)
	flashlight	task light	lantern	lantern
l	90°	90°	360° horizontal, 180° vertical	360° horizontal
	0.13 kg	0.35 kg (incl. module)	0.31 kg	1.3 kg
	LED	LED	LED	CFL
	60-80 lumen			380 lumen
	NiMH	NiCd	Ni MH	lad-acid
	4h	4h	5h/8h	3h
V	1800 mAh/3,6V	400 mAh/3.6 V	300mAh/3.6V	7200mAh/12 V
arge overcharge		overcharge protection	overcharge protection	
g pins	phone charging pins available			
00 USH) e CIF in 8)	62 US$ (140,000 USH) (Retail price on Ugandan market, 2010)	18 US$ (40,000 USH) (Retail price on Ugandan market, 2010)	20 US$ (45,000 USH) (Retail price on Ugandan market, 2010)	125 US$ (300,000 USH) (Retail price on Ugandan market, 2010)

5. LESSONS FROM THE PILOT LAMP SALES MODEL

The lamp sales channel established for the first phase of the field test in West Nile provided an opportunity for pilot testing a locally appropriate distribution model for PicoPV lamps. The experience has rendered some interesting lessons on what works and what does not work when building up supply chains for low-cost solar products that reach out to rural households in Uganda. These lessons are relevant in the context of potential future market development sup-port through government, NGOs or international donors.

Lesson 1: Active marketing efforts are needed to create awareness about the new kind of products among the target customer base.

The West Nile experience shows that awareness about the new kind of solar products has not yet cut through to low income rural consumers in the area. A massive marketing and promotion effort is needed to successfully sell solar lamps at large scale. The challenge is to identify which actors are best placed to take an active role in such efforts. For most electronics dealers, e.g., active promotion efforts at field level do not fit into their working patterns and schedules. They do not have appropriate staff, equipment needed, etc.

Figure 7: Solar lamp promotion event held in a rural trading centre in Arua district in August 2010.

Lesson 2: Building trust in the new kind of products among the target consumer base is a challenge.

Employing locally based technicians as sales agents is in principle an excellent approach to bridge target consumers' lack of confidence . Several lamp clients stated that their purchasing decision was driven by the personal relationship they had with the technician who promoted the lamps. People also felt assured that they could call the same technician in case of technical problems or defaults.

For this reason it is vital that the sales agents dispose of sound product know-how. They should be well informed about appropriate product handling, particularly optimal charging, battery properties, and availability of spare parts. Ideally, they should be capable of doing simple repairs, and should know where to turn to in order to claim warranties. Sales agents should also be able to give persuasive explanations about the potential economic and social benefits of the lamps to interested clients.

In order to increase knowledge on small solar products like solar lamps, half-day training may be sufficient for electronics dealers and other dealers. Alternatively, technical product know-how sheets, i.e. generic fact sheets about properties of certain components (tailored to the level of expertise of local technicians) could be an effective tool to help convey such knowledge to a scattered network of local sales agents.

Several sales agents also emphasized the importance and effectiveness of warranties for building trust among consumers. Especially in a model of direct marketing of lamps to households through sales agents, a printed warranty with label and contact details of the manufacturer or master dealer to be handed over when a lamp is sold can help to create confidence that the product is of good quality. For such printed warranties, a well-established brand of a local dealer (even if he is only an intermediate actor who passes warranty claims on to the manufacturer like UltraTec Ltd. In the Uganda case) can be more effective than a widely unknown brand of the manufacturer himself.

The savings potential and the higher quality of life that the solar lamps offer were reported to be important selling points. The successful sales agents would take their time to discuss these benefits with interested customers.

Lesson 3: Avoid confidence-based supply chain relations.

The freelancing technicians were each handed out 5 to 6 pieces of solar lamps on credit with minimum formalities required (they had to sign a form). This model was chosen in due consideration of the limited working capital local technicians have at their disposal. Sadly, this confidence-based approach performed very poorly: When GIZ took stock after the sale had been going on for 11 months, a number of 46 solar lamps were reported to be remaining with technicians who had taken them away for sale and never showed up with the money. It was extremely difficult, both for the Matrix management and for GIZ, to track the technicians in debt, many of them would refuse to pick up their mobile phones, and even in personal meetings payments could not be enforced .

Several factors have contributed to the lack of accountability on the side of the technicians acting as sales agents, and could be addressed in any similar future model as follows:

- The selection of freelance sales agents should be rigorously based on long-standing business relations with the sales hub (Matrix) or on sound personal references. Only persons who have sufficient proof of their trustworthiness should be considered for a confidence-based sales channel with limited enforcement mechanisms.
- In addition, guarantors (e.g. at least 2 guarantors) could be identified for each sales agent, preferably persons with close personal relations both to the sales agent and the sales hub.
- Technicians knew that the lamps had been given to Matrix on credit basis and that GIZ would possibly not hold Matrix accountable for lamps that were reported to be “lost” further down the distribution chain. It should be avoided to create a perception (both on customer and retailer side) that losses or non-payments will cause damage only to “remote” actors several steps up the supply chain. Anonymity inhibits payment morale.

Overall, qualitative interviews with dealers, wholesalers and other experts have shown that models where sales agents are handed over products on credit basis have proven not to be viable in Uganda. By contrast, if sales agents have to pay for products in advance, this requires an effort on their side to raise the necessary working capital, and ultimately leads to a self-selection of motivated and capable sellers who seriously expect to make a profit from the business.

It should be noted that the sobering outcomes of the sales pilot should not be attributed to a general lack of trustworthiness among the local people due to a certain cultural disposition, as often brought forward by foreign business people operating in the area. Rather, it must be taken into consideration that the technicians who volunteered as sales agents are poor and have no financial backups, with only their extended family networks as social security mechanisms.

In cases of financial emergencies, including through sickness or death of family members, it comes as an obvious solution to resort to financial buffers like those created through the solar lamps sale. Several technicians who had not handed back money for lamps reported about such emergencies on the side of their clients or within their own families, and most probably not all of these stories were mere excuses.

Lesson 4 (on project management): When involving dealers in a research project or a distribution model pilot, incentives must be set out for private partners to contribute to successful outcomes.

A high level of responsibility for the overall management and supervision of the lamp sale was transferred to Matrix Electronics, which was given an incentive to distribute the highest possible number of solar lamps, but had obviously no direct interest in the successful completion of the study. Even though repeated efforts were made to convey the research objective, the methodology employed and the potential utility of the study outcomes for marketing purposes to the Matrix management, collaboration on the implementation of the survey was sometimes unsatisfactory. Contrary to instructions given by the project team, Matrix sold several lamps to customers who live in electrified houses in Arua town and to customers in South Sudan which could not be tracked for interviews. In addition, poor records were kept of technical problems with which lamp users addressed themselves to the shop.

Figure 8: Solar lamp for sale in Matrix Electronics shop in Arua town.

Further observations regarding promotion of solar lamps through established institutions and targeted promotion activities

5.1 Distribution through SACCOs

Savings and Credit Cooperatives (SACCOs) are very wide-spread in Uganda (as well as in other East African countries). They vary in size, membership and organizational structures, and have a remarkable outreach to low-income sections of the population, often neglected by commercial finance institutions, in particular in remote rural areas far from district capitals. The membership networks that SACCOs have created, make them an ideal platform for the sale of consumer goods to poor rural households. GIZ and their local partners have been working with SACCOs for several years for the promotion of solar products. On the one hand, the unique outreach potential of these institutions has been ascertained through this experience; on the other hand, it has emerged that building effective relationships with SACCOs requires a well-planned and long-term effort on the side of the dealer who seeks to tap markets through SACCO networks, including prudent selection and analysis of the specific management and incentive structures within the SACCO.

Accordingly, as regards the promotion of PicoPV systems through SACCOs, different solar product dealers report positive and negative experiences. For instance, promotion of solar lamps through the West Nile Teachers' SACCO which offers loans between 25,000 and 500,000 USH was not very successful because most teachers had open loans at the time when solar lamps were introduced as a new product eligible for SACCO financing. Stable business relations could also not be established with the management of MP Uganda Farmers' SACCO. By contrast, successful collaboration for promoting solar lamps can be reported in case of the Pakwach Nam SACCO, through which 10 lamps were sold in a first round and 15 lamps in the second round.

Overall, expert interviews yielded that successful collaboration with SACCOs for promoting consumer products depends on SACCO management structures and internal dynamics which vary from group to group. The best approach is to seek information and references for individual SACCOs and decide thereupon which ones are promising partners.

5.2 Promotional events

- Customers living in close proximity to the district capital Arua are better informed about solar products than people in the villages and tend to make highly informed purchasing decisions. They would not buy the lamps on the occasion of a particular promotion event, but rather collect detailed information about the products promoted and later compare them with the full range of offers available with retailers in Arua.
  It can be concluded, therefore, that for a customer base that has access to a settled dealer, promotion events at market places can help for awareness creation, but not to boost sales numbers.

Figure 9: Local market day in a village in Arua district.

- Experts' views deviated about the effectiveness of lamp demonstrations in public places after dark. On the one hand, the demonstration effect for lamps in the dark can help to raise interest. On the other hand, market places are usually also spots where people gather for drinking in the evenings; the presence of many drunken people was perceived as a risk factor by solar dealers.

- Seasonal timing is crucial for successful promotion events. In Arua, where tobacco is an important source of income for many people, it was recommended to schedule solar lamp promotion events according to the tobacco season. Tobacco is harvested once a year between June and August, which is when people have cash available after selling their annual produce to a big local tobacco processing company.

- Another success factor for any promotion activity has been found to be active involvement of the Local Chairman (LC 1; village mayor). For product information and demonstration events at public places, it emerged as good practice to contact the LC in advance of the planned event, explain the objectives of the lamps promotion to him and seek his support for the project. It has proven highly effective to let the LC himself announce the lamps demonstration per megaphone and be present throughout the product demonstrations, in order to enhance people's confidence and interest.

5.3 Using Catalysers

- Demonstrations in schools to students and parents, upon agreement with school principals, are another possibility for lamps promotion. Teachers who are already familiar with these products could be used as catalysers.

- In an interview with the retired Arua diocese Bishop, he suggested Sundays after church to be a good occasion for solar lamps demonstrations and promotion (Figure 10). In the Ugandan context, it may be conducive to seek support by spiritual leaders like priests and bishops for the promotion of solar lamps. In Arua, several top-end solar lamps were purchased by the orphanage centre of the Arua diocese, which were much appreciated by the spiritual and other staff.

Figure 10: Good occasion for solar lamps promotion: After the church service on a Sunday morning in Arua town.

5.4 Financing options/Consumer credit scheme

Initial feedback from the innovative consumer credit scheme was very positive as the number of sales of more expensive lamps increased immediately. However, the final conclusion for some of the technicians was that transaction costs for enforcement of repayments had been too high. One technician also reported that open loans had interfered with their personal relations to the customers.

In Uganda, getting credit from a MFI is difficult for households who have no regular monthly income, like farmers. Teachers and civil servants, for whom access to financial services is relatively easy, usually make extensive use of these opportunities, and take up loans e.g. to pay school fees for their children. As a result, however, a large part of the middle income strata is effectively without access to new loans for consumption of small household appliances like solar lamps, as MFI refuse to grant credit to clients while repayment of previous loans is pending.

Solar dealers have also stated that as per their experience, for an investment in a household item in the price range below 200,000 USH, families can often tap informal financial services, as it is common practice to borrow money from family members for such purposes.

There are several potential entry points for the design of financing opportunities for small solar products.

- Village Savings and Loan Associations, initiated by the West Nile Private Sector Development Promotion Centre, are community-based organisations and much less formalized than SACCOS (but can serve as a predecessor for a SACCO). These groups engage in regular savings, usually on a weekly basis, and provide affordable small loans to members. Such loans could enable people to acquire PicoPV products in the lower price ranges. Around 1000 of such groups exist already in West Nile.
  The groups are being supported by Community-Based Trainers (CBTs), who attend and provide inputs to the village level group meetings on a regular basis. One possible approach would accordingly be to offer product knowledge and marketing training to these CBTs and encourage them, possibly through an incentive scheme, to promote the lamps in the group meetings.
- FINCA (regulated micro-finance institution with nation-wide branches in many district capitals like Arua) has already developed a special loan product for the purchase of solar home systems eligible for a government subsidy disbursed through the Rural Electrification Agency . A local solar dealer arranged for a meeting with the FINCA Arua branch to present solar lamps to their staff and to discuss possibilities for FINCA field staff to act also as promoters and sales agents for solar lamps. In principle the idea was supported by the FINCA team. However there has been no follow-up effort from the side of FINCA so far, indicating a lack of interest, which has also discouraged the solar lamp dealer who has not yet reverted to this idea.

6. SOLAR LAMPS USER SURVEY – BASELINE SITUATION

6.1 The sample

In the solar lamp user survey in West Nile, a total number of 100 lamp users were interviewed, of which 42 had purchased one or several solar lamps in the first phase of the project, and 58 households had been given a lamp for a lending period of 3 months in the second phase.

The large majority of the households reside in Arua district, and few in other districts of West Nile, namely Alengo, Koboko, and Nebbi. Two test lamps had been sold to households from South Sudan, which were also included in the survey .

Households in West Nile are frequently composed of extended families with several members described as "dependants", which may be nieces, nephews or distant relatives of the household head, or grandparents staying with their adult children. The average size of households interviewed for the survey was 7.4 members (std. dev. = 3.8), ranging from 1 to 19 members. The average number of children below 16 in these households was 3.5, and the average number of adult men and women per household was equal.

Six lamp clients were clerics or priests of the Arua Diocese, and one lamp client stays in the Arua diocese orphanage centre as staff; as these large living communities are of a very different nature than the conventional family households in the area, these cases were excluded from the analysis of basic household parameters (chapter 5). Their experience with using the solar lamps was however considered equally valid, so that they were included in the analysis of the solar lamp specific sections of the ex-post interviews.

6.2 Housing situation

Traditional housing in rural West Nile is characterized by each family inhabiting a small cluster of grass-roofed mud or brick houses, which usually have 1 to 4 rooms each, with a one-room house serving as a kitchen. Within the survey sample, more than 80 % of households inhabit more than one house, with 63 % of them living in either 2 or 3 houses. The average number of houses belonging to one household was 2.6, with the maximum number of houses being 8. The average number of rooms inhabited by one household was 6.3%.

Of the sample households' dwellings, 28 % are built of mud, 35 % of burnt bricks, and 37 % are cement houses.
About 40 % of the houses are roofed with straw and 40 % with corrugated iron sheets.

6.3 Education, occupation and income

The level of education of the male heads of household is distinctly higher than that of their spouses or female heads of households. While only 15 % of males have no or only primary level education, 28 % of women have dropped out before secondary, or never gone to school. Only 11 % of females are university degree holders, as opposed to 32 % of males. Diplomas from tertiary institutions or vocational schools or teachers diplomas are also more frequent among men (29 %) than among women (22 %).

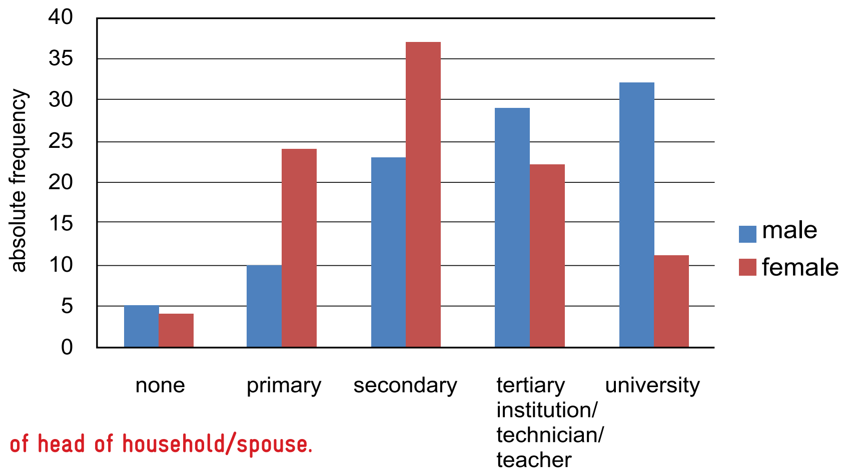


Figure 11: Level of education of head of household/spouse.

The large majority of households in the sample cultivate at least a small patch of land, usually around their houses, to grow food, often only for their own consumption. Agriculture is either a primary or a secondary occupation for all surveyed households, but only 20 % of the households depend completely on agriculture for their livelihoods. Commerce, teaching and government jobs are the most important sources of income in the sample apart from agriculture. 30 % of men and 24 % of women make an income from commerce; 18 % of men and 11 % of women work as teachers.

Seven percent of the households state that their children under 16 help in the family's agriculture, but it can be assumed that the rate of children helping with agricultural work is much higher. When respondents were asked (in the margins of the standardized interview) whether the children also helped in agriculture, the answer was usually "yes", with a connotation of it being too self-evident to be mentioned explicitly. The large majority (91 %) of households with children below 16 states that their children go to school .

Box 1: Observation on methodology: Assessing household income

> **Observation on methodology: Assessing household income**
>
> Assessing **household income** through survey instruments is a tedious undertaking. There are various reasons why respondents' specifications of monthly household income can be distorted: People who run small and informal businesses may be suspicious that information may leak through to tax authorities; respondents may not be informed of other household members' incomes; or they may simply not keep book of average monthly revenues from irregular income sources like agriculture, small businesses or commerce. By contrast, households' capacity and readiness to accurately disclose monthly expenditures for specific consumption categories is usually higher.
>
> **Solution:** Therefore, households in the solar lamps field test were asked to specify both their monthly income and their monthly expenditures on food, energy, clothes, school fees, health, water, housing (incl. renovation), and other major expenditures. For the analysis of income, those cases were excluded where monthly income as specified by respondents fell short of monthly expenditures on the most basic and easiest to assess consumption purposes (i.e. food, energy, clothes, health, water and other expenditures) by more than 100,000 USH.

After exclusion of cases in the sample where reported monthly income deviates significantly from reported monthly expenditure (see Box 1 above), 81 households remained for analysis. The average monthly income was 478,000 USH, ranging from 18,000 to 3 million USH. Figure 12 shows the average distribution of monthly income .

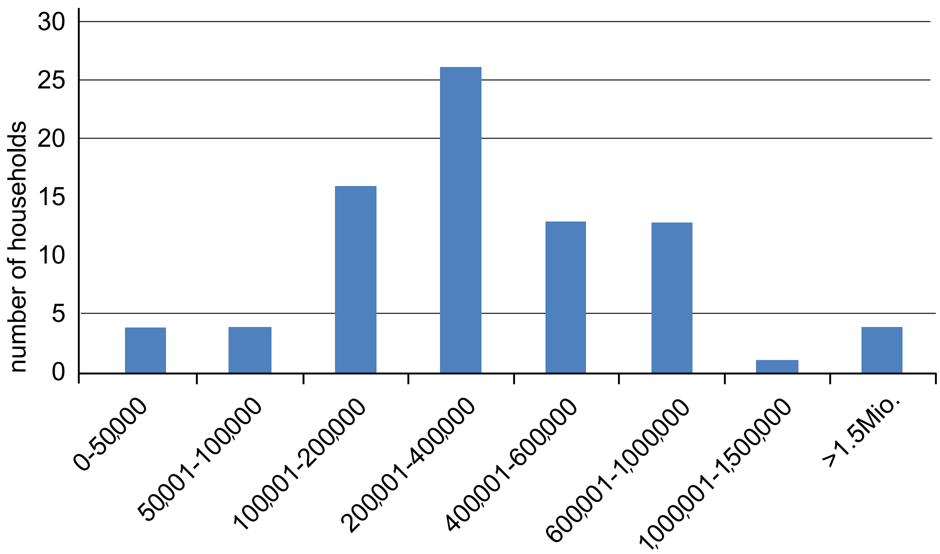


Figure 12: Monthly income (in USH) – frequency.

6.4 Household expenditures

The **largest item in households' average spending is school fees,** which make up almost one third of households' total monthly expenditures (approx. 126,000 USH). Expenditures for food average around 95,000 USH and therewith constitute the second largest item in households' budgets. Average **expenditures on household energy** (for the most part fuel for cooking and lighting) fall far behind clothes and housing costs, but are also **substantial at an average of 30,000 USH,** making up roughly 7 **% of total household budgets.** Table 2 below provides an overview of average spending on different items.

Table 2: Overview of average spending on different items.

	Valid cases	**mean** (in USH)	**std. deviation** (in USH)
Food	90	~95,300	11,894
Energy	92	~30,400	30,737
Clothes	67	~43,000	30737
School fees	80	~126,400	170,376
Health	81	~23,800	17,574
Water	66	~11,100	17,404
Housing (incl. maintenance, renovation)	31	~41,600	66,581
Other	23	~48,000	43,017
Total	**93**	**~317,000**	**279,712**

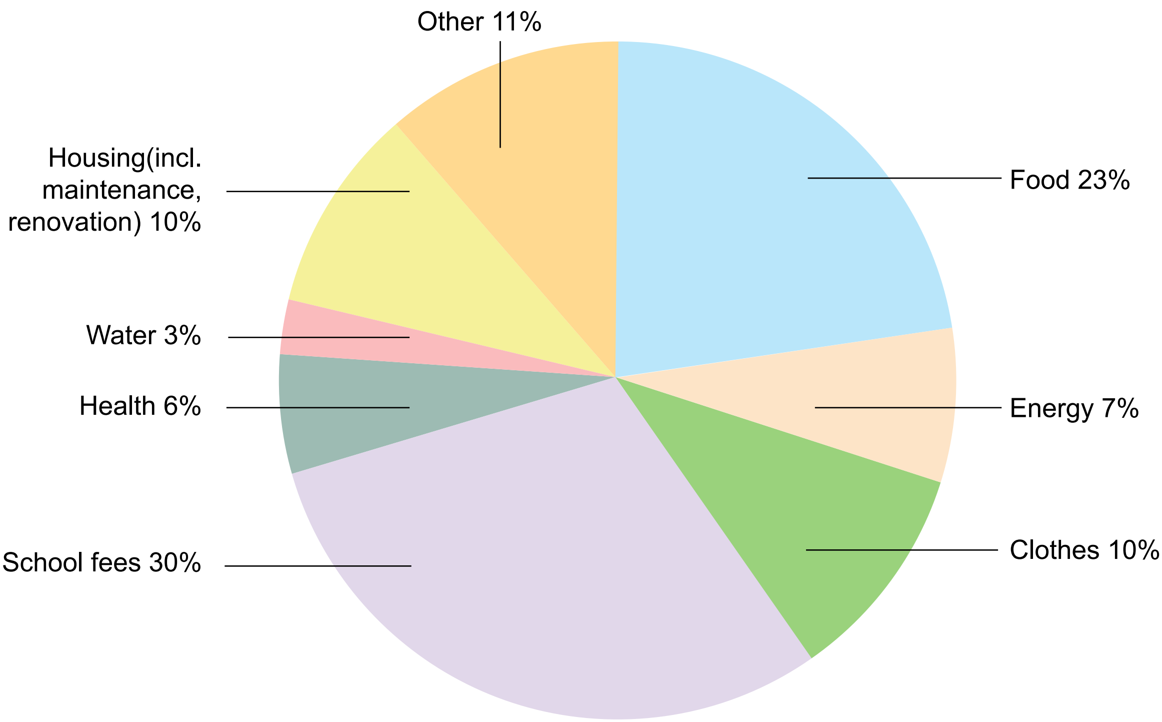


Figure 13: Average distribution of household budget.

6.5 Energy supply and consumption

Electricity supply in West Nile

In the West Nile Region of Uganda an isolated grid network is operated and fed through a heavy-fuel oil thermal power plant in Arua (1.44 MW) by the West Nile Rural Electrification Company (WENRECo). The grid extends from Arua to Oko and Wandi in the North, and southwards from Arua to Eruba with one line continuing to Vurra and the other one via Nebbi to Paidha. This grid is currently faced with steadily growing demand, which the currently existing power generator cannot meet, all the more as it is operated only during daytime. Load shedding and numerous outages of the power supply are the consequence. These will only end once the mini hydro power plant at Nyagak with an initial power generation capacity of 3.5 MW will be commissioned. Construction started in 2006, and the plant is expected to be commissioned in August 2011. Through an extension of the existing power lines from Arua through Maracha to Koboko in the North (approx. 60 km), from Nebbi to Pakwach in the South (58 km), a branch off from Nebbi to Parombo and Panyimur for power supply in Pakwach (17 km) and an extension from Phaida to Vurra (76 km) currently unelectrified regions in North-West Uganda will be connected to the WENRECO grid by 2012. The construction of the power plant and extension of the grid is supported by the German Development Cooperation through KfW. In the survey sample, roughly **10 % of the respondents stated that they had heard of concrete plans that their household would benefit from grid extension** or densification efforts.

Electricity consumption

At the time of the baseline interview, 7 % of the households in the sample (including lamp users staying in the Arua Diocese), were connected to the WENRECO **electricity grid.** In addition, 5 % of the households owned a **solar home system.** **Generators** were used by 9 % of households; of these, only 2 households used the generator on a daily basis, whereas the other 7 households used the generator 1-3 times a week. In summary, a total of **89 % of households in the sample have no regular power supply** through grid or solar home system, and **83 % of households have no access to any form of modern energy supply** (i.e. no grid power, no SHS and no generator).

A zero electrification rate in the sample of solar lamp test users, even though aimed for initially, could not be realized as the lamp sale model employed during the first phase of the project did not allow for a perfect control over the sample composition: Some lamps were bought by rather rich households who used them as lighting back-up devices for the frequent power outages and as alternatives to costly operation of generators.

Household energy for cooking

Of the overall household energy consumption portfolio, energy for cooking is the most important component. All households in the sample cook on charcoal and firewood stoves, none of the households uses LPG for cooking . Some households use one of the improved stoves that have been promoted under the GIZ PREEEP stoves component in the area. Households spend on average approx. 7,660 USH for cooking fuels per week, of which charcoal constitutes the larger part. Accordingly, charcoal is perceived as the most important energy source by most households: When asked to rank the different energy sources by importance, by far the largest share (60 %) of households said that charcoal was number one at the time of the baseline interview (followed by firewood with 18 %).

Dry cell batteries make up the second largest part of households' energy expenses. Apart from running flashlights or lanterns (by 79 % of households, more details in chapter 5.6), dry cell batteries are also used to run radios by 54 % of households (on average a bit more than 2 pairs per week). Households' expenditures for dry cell batteries per week average around 2,800 USH.

6.6 Household lighting economics and lighting behaviour

Lighting devices used and lighting expenditures

At the time of the baseline interview, people lit a lamp in the evening at 7 p.m. on average and switched off the last light at 10.30 p.m. The average lighting duration in the evening was 3 hours and 30 minutes. Only two thirds of the households use a light also in the morning, mostly between 6 a.m. and 7 a.m. The average morning lighting duration was 1 hour and 20 minutes.

Kerosene was the most important lighting energy source for households in the sample, used by 90 % of households before they started using solar lamps. More than half of the respondents named it as the second most important energy source in their house. The average weekly house hold consumption of kerosene for lighting was 1.3 litres, with 95 % of households using a maximum of 3 litres, and the maximum weekly consumption being 7 litres. The baseline average expenditure for kerosene was a sum of approx. 2,750 USH/week.

83 % of households used hurricane lamps, and 26 % of households used (also) simple kerosene wick lamps , all of them on a daily basis, at the time of the baseline interview. Hurricane lamps were the main lighting device in 86 % of families' living rooms at the time of the baseline interview (followed by simple wick lamps, 7 %). Most households (70 %) use only 1 hurricane lamp, some households use two (18 %), and the remaining 12 % use 3 or 4 of them. The average lighting duration of a hurricane lamp was 4 hours and 20 minutes per day. Simple wick lamps, which most households use to light the kitchen while cooking and some also use in children's rooms or bedrooms, were burning for a bit longer than three hours on an average day.

Dry cell batteries were the second most important lighting energy source, used in flashlights or battery-run lanterns on a daily basis by 79% of households, before starting to use a solar lamp. The average weekly consumption of batteries for lighting was slightly less than 2 pairs. At baseline, for a majority of 58% of respondents flashlights were the main lighting device used outside the house (followed by hurricane lamps, used outside the house by 19% of households).

A substantial share of households (38%) also used candles, whereby 80% of these households use candles on a daily basis, and 20% rather as a "backup lighting device" for days when they had run out of kerosene. The average weekly consumption of candles (by those households that use them) was 6 pieces, for which they spent on average roughly 1,600 USH. Pressure lamps and lamps running on gas were not used by any of the households in the sample.

It can be derived from the data that if households were to fully replace the lighting device they use in their main room, which is a hurricane lamp in most cases, through a solar lamp, this would result in weekly savings in lighting expenditures of roughly 2,000 USH.

Table 3: Sample household energy consumption and expenditures.

Energy source	Used by xy % of households	Average weekly consumption per household	Average weekly expenditure for running costs per household
Kerosene for lighting	90 %	1.26 litres	2,740 USH
Hurricane lamps	83 %		
Simple wick lamp	[min. 26 %]	20	
Dry cell batteries for lighting	79 %	1.8 pairs	1,540 USH
Flashlights	72 %		
Battery-run lanterns	8 %		
Dry cell batteries for radio	54 %	2.2 pairs	1,980 USH
Candles	38 %	6 pieces	1.570 USH
Firewood	40 %	[difficult to assess]	5.970 USH
Charcoal	77 %	[difficult to assess]	6.390 USH
Generator	9 %	2.9 litres of diesel	16.400 USH

Notably, households in the sample have a marked **habit of placing their traditional lighting devices on tables rather than hanging them up:** 90 % of households using a hurricane lamp usually place them on the table when it is lit; so do 80 % of users of candles and 65 % of users of simple wick lamps. The latter are often used in the kitchen for cooking and are placed on the table or on the oven in one third of cases.

In addition to costs, **acquisition of lighting fuels is also a burden** for households. Most people (79 %) buy kerosene from their nearest petrol station, and only 13 % get it in their local trading centre. People travel on average 2.6 km (one way) to purchase kerosene (households reported that the price for kerosene is lower at the petrol station than when purchased in bottles on markets or in shops).

The distribution networks for candles and for dry cell batteries seem to be more efficient: The large majority (88 %) of households buy candles in nearby shops or their nearest trading centre; for only about 30 % of users of candles, the purchase place is 1 km or further away from their home (the average distance being 900 meters).

Batteries are also mostly bought in peoples' nearby shops or trading centres, but almost 40 % of consumers in the sample report that they buy batteries in town, also because of price advantages. The average distance to the place of purchase of batteries was 1.5 km.

Energy consumption behaviour of the average household in the sample:

A representative household in the sample lights their 6 rooms home with…

- hurricane lamp placed on the table in the main room, burning for 4 hours/day
- simple wick lamp used in the kitchen
- flashlight used mainly outdoors

Kerosene is purchased at a distance of 2.6 km from home; batteries at a distance of 1.5 km.

A representative household spends around 6,000 USH per week for lighting.

Activities done when using light

In those households of the sample that depend completely on traditional lighting devices, men's activities before and after sunset are largely confined to entertainment and recreation, while women's reported morning activities reflect their roles as housekeepers (82 % of women who use a light in the morning hours do so to do domestic work). By contrast, only one quarter of women report that they use the light for domestic work in the evening hours, while almost half of the women report that socialising or reunions are among their main evening activities. However, talks at the margins of the interviews revealed that women usually start cooking and doing kitchen work before dark inside their windowless kitchen houses, which is why they do not necessarily declare cooking as a domestic work done after dark. Children use light predominantly for studying and reading: 80 % of children at school age use the morning hours (before sunrise) and 67 % the evening hours for studying.

Productive work before and after sunset is low on the agenda of men, but much higher on that of women: While a rather negligible share of men do productive work at home when it is dark, 19 % of women use the evening hours for income generating activities like running a shop, doing tailor work or other handcrafts, or preparing lessons (see Figure 14 and Figure 15).

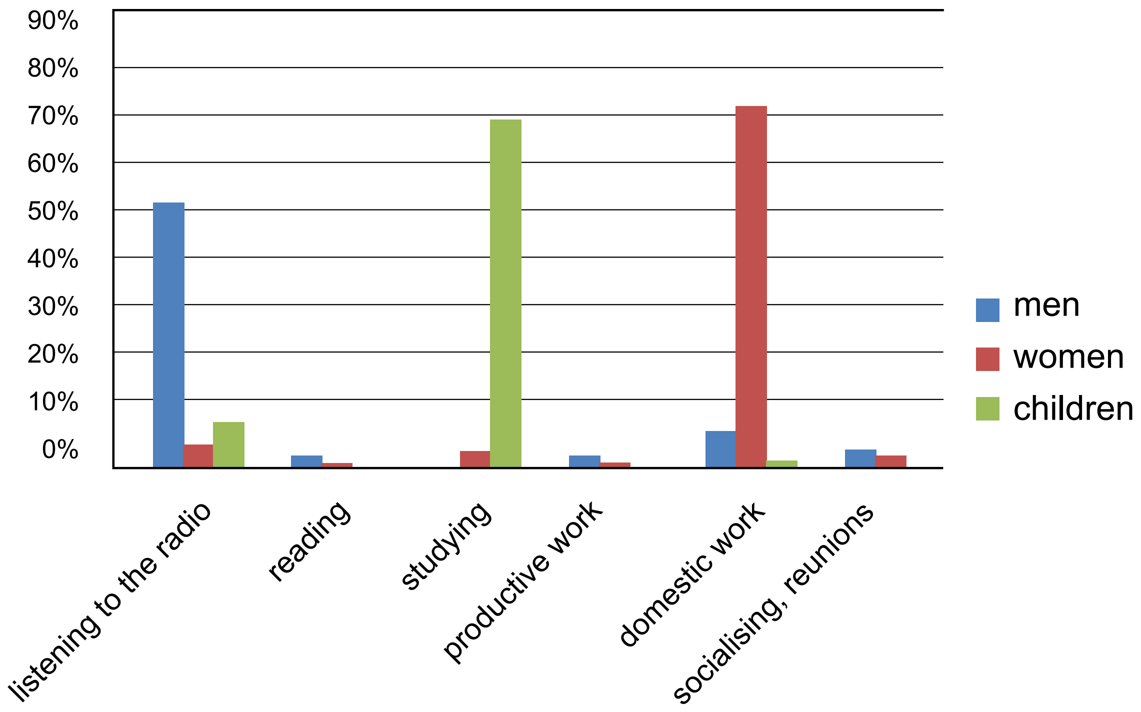


Figure 14: Morning activities by household members
(only households depending completely on traditional lighting devices).

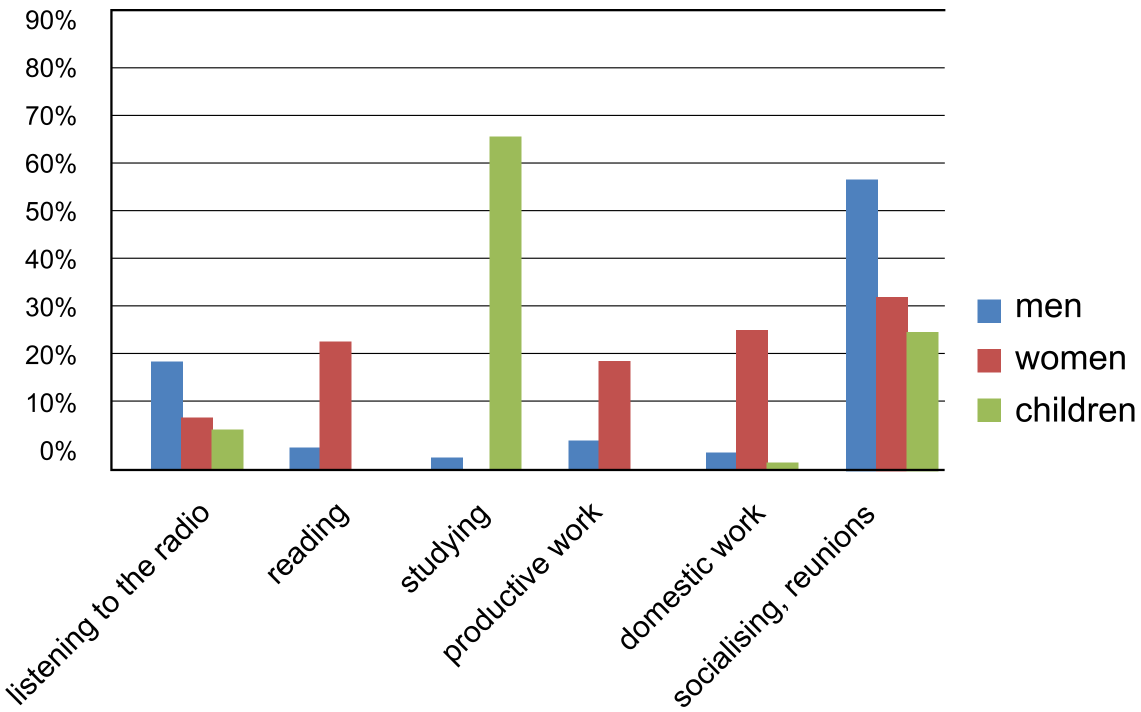


Figure 15: Evening activities by household members
(only households depending completely on traditional lighting devices).

6.7 Priority needs to improve living conditions

Households were requested (in an open question) to name and prioritize the three most important things they would like to improve about their housing conditions. Better lighting was the desire that was mentioned most often (by 80 % of households), and was even ranked as top priority by 65 % of households. This result should however be interpreted with care, as such overwhelming dominance of lighting as a priority need may rather be testament to respondents' awareness that the survey was part of a programme to promote solar lighting solutions.

The expressed desire for better lighting was followed (by a distance) by the desire for better access to water (mentioned by 49 % and top priority for 5 % of households). A better structure of the house itself (a rather broad category comprising any improvements on roof, walls, windows, doors etc.) achieved position no. 3 in the ranking, mentioned by 28 % of households and ranked top priority by 5 % of households.

The importance attached to each option for housing improvements were condensed into a single ordinal variable (Ranging from 0 to 3) which allows for an overall ranking of households' priority needs, presented in Figure 16.

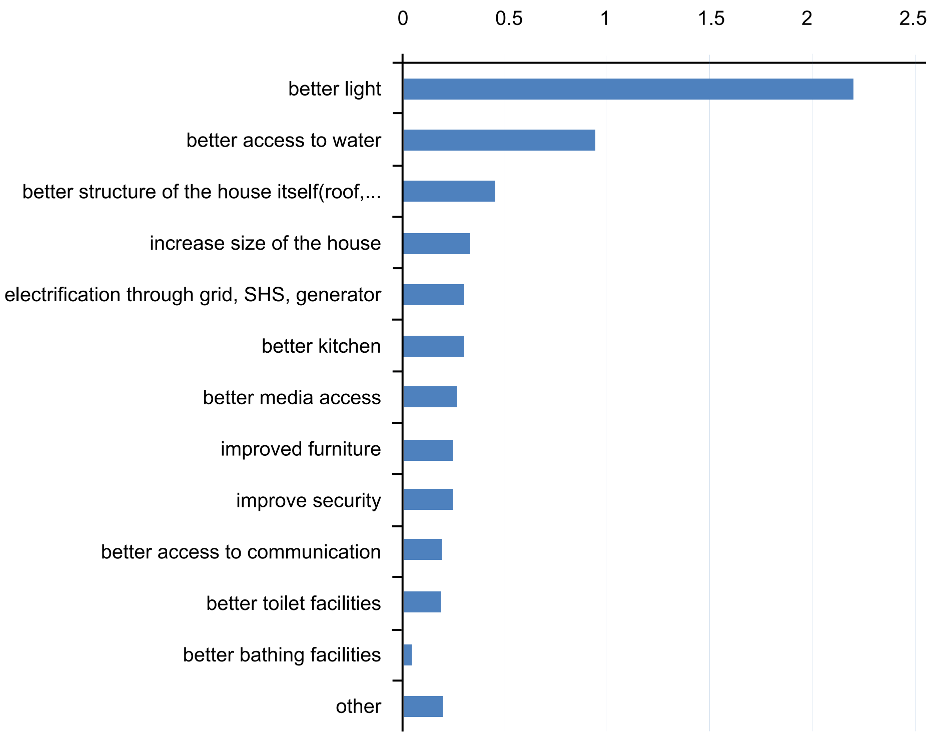


Figure 16: Ranking of households' priority needs for improvements on housing situation; average score on an ordinal scale ranging from 0 to 3.

The main reason why people wanted to improve the lighting situation in their houses was that they felt they were hampered in doing certain activities at night (noted by 50 % of respondents). Lack of security or risk of accidents were the second most important inconveniences (32 % of respondents).

For only 5 % of households, indoor air pollution was the most important inconvenience associated with their (baseline) lighting situation. Given the widely discussed concerns about detrimental impacts of fuel-based lighting systems, households were also asked explicitly whether they ever worried about health effects due to the use of kerosene lamps. An overwhelming majority of respondents (94 %) affirmed that they did. Most people (63 %) specified that kerosene poses risks to the respiratory system, and one quarter of respondents noted that it caused harm to their eyes.

Altogether, 37 % of households reported that there had been accidents in their houses associated with the use of lighting devices (90 % of which were caused by kerosene lamps or candles). Interestingly, more than 50 % of these accidents happened as someone cut themselves on broken glass from a hurricane lamp. One third of accidents were related to burns or objects catching fire.

Box 3: Observation on methodology: Blurred concepts of lighting and electricity.

At the top of the list of **activities that unelectrified households hoped to do (more conveniently) with better lighting was reading or studying** (named by 88 % of respondents). Socialising was as important as watching TV (67 %) and domestic work (named by 65 % of households, whereby 58 % of families mentioned it under "what the women would be able to do better"; 11 % of households described it also as a men's activity, and 9 % as a children's activity).

18 % of unelectrified households stated that **productive activities** (including e.g. sewing and tailoring; running a shop; teachers preparing lessons; doing paper work related to daytime business activities) were hampered due to the lack of light in their houses. When screening out those households that were already doing productive activities after dark, it emerges that **4.5 % of men and 5.6 % of women in the sample households had ambitions to take up productive activities after dark.**

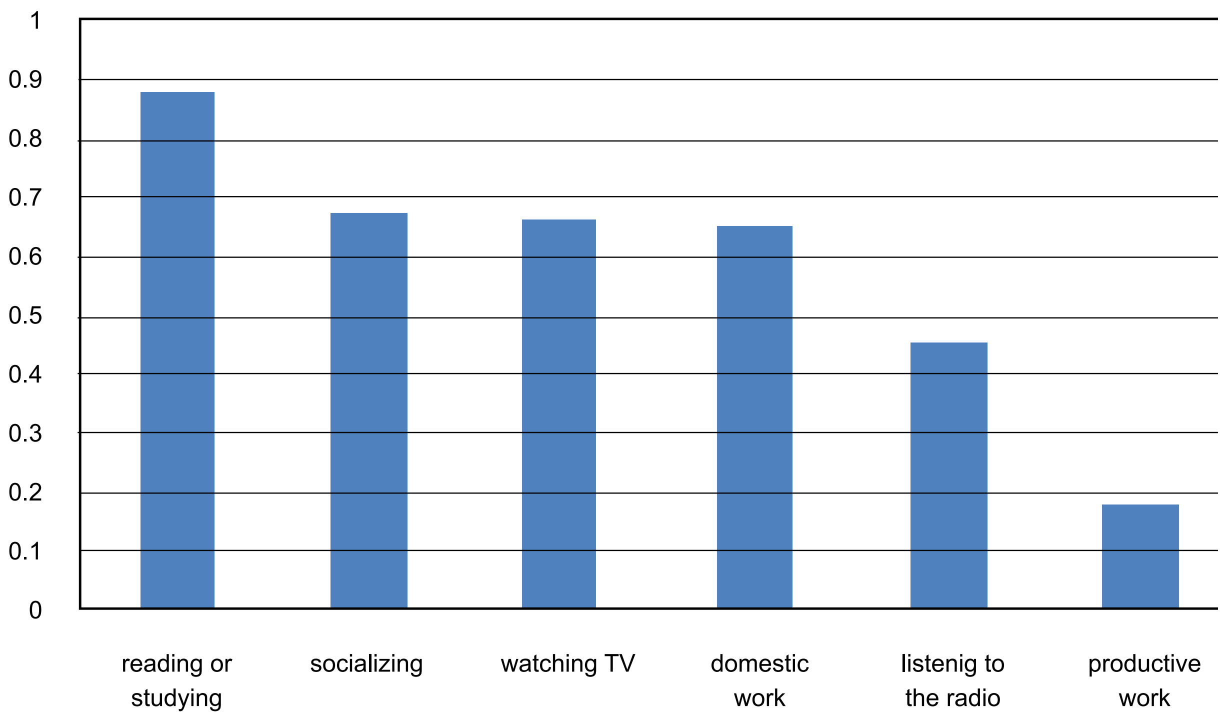


Figure 17: Which activities are hampered by lack of light? (% Of unelectrified households; multiple answers possible).

Further, households were asked (in an open question) to name the most important strength and the most important weakness of the lighting devices that they use. At the time of the baseline interview, the main reason why people appreciated hurricane lamps was simply that they gave good light (mentioned by 80 % of households); other factors mentioned as key advantages were that the hurricane lamp is not blown off by the wind, and that it is portable and easy to use. On the other hand, when it came to disadvantages of hurricane lamps, insufficient light intensity or coverage was also the most frequently noted weakness (22 %). The second most mentioned weakness of hurricane lamps was their high running cost (20 %), followed closely by air pollution (18 %).

Flashlights are appreciated primarily because they provide good light (mentioned by 55 % of respondents); their cost of operation is the most frequently cited downside.

When asked to rate the light quality of the various lighting devices that people used (as very poor= 1, poor=2, good=3 or very good=4), battery-run flashlights scored best of all conventional off-grid lighting devices, with a mean evaluation of 3.7, falling under "very good". The hurricane lamp was rated as "good" (average rate = 2.8), and the simple wick lamp as "poor" (mean rate = 2). CFL bulbs, used by only 5 households, achieved the highest rate (mean=3.8).

6.8 Use of radios

In Uganda, the most prominent medium of mass communication is still the radio (Economist Intelligence Unit 2009).
In the sample, 84 % of households have a radio. One third of these households use even more than one radio (23 % two radios, 12 % 3 to 6 radios). Radios are almost exclusively run on dry-cell batteries, even in households that are connected to the grid, that have a SHS or that use a generator.

Women and children listened to the radio for more hours per day (on average 5 hours and 20 minutes at baseline) than men (A bit more than 4 hours at baseline), basically because they are out for work during most of the day. The data clearly point to the importance of the radio as a channel for information for the population in rural West Nile: 70 % of men and 39 % of women state that they primarily listen to news and information broadcasts (rather than to music or entertainment).

6.9 Use of mobile phones

Mobile phones are widely spread in the survey area: 90 % of the sample households used at least one mobile phone, whereby 75 % of households used more than one, and 40 % of the families had even 3 or more phones in use.
The average number of mobile phones per family was 2.7.

There are substantial "running costs" associated with the use of mobile phones: At the time of the baseline interview, 85 % of households paid a fee to have their phones charged, in most cases 500 USH per phone. However, these charging costs are relatively small as compared to airtime expenses: The mean amount that heads of households spend on airtime per week is approx. 18,300 USH. This value is however strongly driven by some outliers at the upper end of the scale, who use their phones a lot for work-related calls; the median expense of household heads for airtime is 10,000 USH.

Women spend substantially less on airtime, 7,200 USH on average (median = 5,000). Mobile phones have apparently taken an important role in underpinning people's economic activities: 61 % of men and 26 % of women report that they use their phones for work.

7. SOLAR LAMPS FIELD TEST – QUALITATIVE AND QUANTITATIVE FIELD RESULTS

The remainder of this report presents the findings of the solar lamps field test generated through qualitative research methods and the mainly quantitative test user survey. It is structured along the central research questions guiding the field test.

7.1 Which lamp model do users prefer?

7.1a Which lamp model would unacquainted clients choose?

The following section analyses which lamp models would raise the interest of potential clients with no previous solar lamps experience and product knowledge, and on which basis such clients make their purchasing decision. Conclusions on these questions are drawn from the focus groups, expert interviews with technicians and solar dealers, and the community meetings to introduce the lamps lending model. In addition, the sales numbers from the first phase of the field test tell a story of their own.

Overall, the new kind of lighting product was received with keen interest and excitement by the target user group, as could be observed when the solar lamps were presented to focus groups and at community meetings. A large share of respondents of the user survey, when asked about their first impression of the solar lamp, stated that they considered it "a solution to the household's lighting problems". However, the qualitative research also revealed that the large majority of people in the survey area had no previous experience with solar lamps. Hardly any of the test users interviewed had ever seen them in shops or in use by other households. Most people were unfamiliar with the concept of solar power altogether: People frequently asked where to buy and change the batteries, even after they had been told that the batteries were rechargeable through solar power.

During the focus group discussions, several people hesitated to touch the lamps. While the group of technicians remarked that some of the lamps seemed to be of high quality, teachers feared that they were fragile and needed a lot of sensitization before they could be used. Farmers were concerned that the lamps were designed for urban areas and might easily get spoilt in rural households.

Quality was unanimously regarded as the most important aspect upon which a lamp would be assessed. Several focus group members commented on the low quality of Chinese products and stated that the place of manufacturing was a factor that they took into consideration when making purchasing decisions. When products were labelled as "made in Germany", people said they expected them to be of high quality, while they generally avoided buying Chinese products in fear of short life spans.

Further, the focus group results as well as the sales proceedings point to a strong preference for multi-purpose lamps with a 360° horizontal light cone and luminance levels which are sufficient to light a whole room. People want a lamp that is useful for all family members to pursue their evening activities. The lamp should be suited for reading and studying, ideally for several students at a time, domestic work, reunions, socializing or ceremonies. Aishwarya was found to best fulfil this key criterion. It was also the lamp for which demand was highest and that sold fastest during the first phase of the field test . Freilassing was also considered a multi-purpose lamp, however, during the lamp sale, it could not compete with Aishwarya due to its much higher price; sales were very slow, and less than one third of the pieces were actually purchased. Solata was unanimously perceived as a mono-functional student lamp which was not suited to meet a household's lighting needs.

In general, people appreciated a lamp design that resembles the traditional hurricane lamps and that can be used in the same manner. Aishwarya was described as the "most familiar, beautiful and attractive lamp" and "exactly like the one we use". It was also found easiest to operate. For Freilassing, focus groups participants proposed it should be equipped with a handle at the top so that it can easily be picked up and moved around. It may be concluded that for a lamp to be perceived by rural clients in Africa as versatile and suitable for their everyday needs, a "classic" lamp design will be most successful, while clients find it difficult to imagine how innovative and exotic lamp designs will fit with their everyday activities.

Figure 18: Women exploring different lamp models in a focus group.

Focus group participants were also asked to evaluate the lamps with regard to specific criteria. When asked how easy or difficult to operate the different lamp models were, Aishwarya was deemed easiest, as the switch was clearly visible. By contrast, people had major difficulties in discerning the switch on Solux 50 and therefore said it was the least user-friendly model.

When asked to rate the light quality of the different lamps, Aishwarya with its CFL bulb was found to give the "clearest" light, while the light of the LED lamps was perceived as "dim". One participant asked if it was possible to remove the "dimming" cover of the Freilassing for a better light output. On the other hand, the Freilassing was appreciated for its semi-globular light cone, while the 180° horizontal light cone of the Solux 100 was considered insufficient.

In terms of durability and robustness attributed to different lamp models, interestingly, all focus group participants were able to immediately distinguish top-end products from the cheaper lamps (which are less robust, as proved later). Solux 100 and the Freilassing were identified as the most solid models, and also the best protected against damage, dust and water. Aishwarya was considered rather fragile; it was proposed that it should be equipped with a metal protection for the glass cover, like a hurricane lamp. However, technicians reckoned that the Aishwarya was probably the model that was easiest to repair. Solata was also considered to be fragile.

As regards the weight of the lamps, the discussions produced inconsistent results. On the one hand, business people reckoned that "when people feel the weight they see that there is quality inside". Several comments suggested that heavy weight and big size of the lamps enhanced people's estimation of the value of the product. In addition, very small lamps like the Solux 50 were seen as easy prey for thieves. On the other hand, several participants noted that portability of the lamps was important and appreciated.

The colours of the lamps were not given too much importance during the focus group discussions, and peoples' taste and preferences varied. For instance, some focus group participants expressed reservations against the white colour of Aishwarya. They considered white an inappropriate colour for a lamp within their cultural context, as white objects were used in spiritual and religious ceremonies such as funerals. Other people had a more practical approach to assessing lamp colours: Some commented that a white lamp would attract dirt and dust; in contrast, others reckoned that a white lamp would be particularly easy to clean. No conclusions can be drawn with regard to preferred lamp colours in the area.

7.1b Which lamp models would a client choose after having tested the lamps?

The preferences and key purchasing criteria of well-informed clients may vary distinctly from those of inexperienced clients (analyzed in the previous section), as illustrated in Figure 19 on the sales success in the first vs. the second phase of the field test: It shows that demand for the top-end lamp models (Solux 100 and Freilassing) as well as for the small and unimposing, but very bright and robust Solux 50, was higher in the second phase, when people had a chance to test the lamps for 3 months before making a purchasing decision. For Solata, by contrast, the figure suggests that it was rather disappointing, and that people were less interested to buy it (in spite of the very affordable price) after having tested it than when deciding upon first impression.

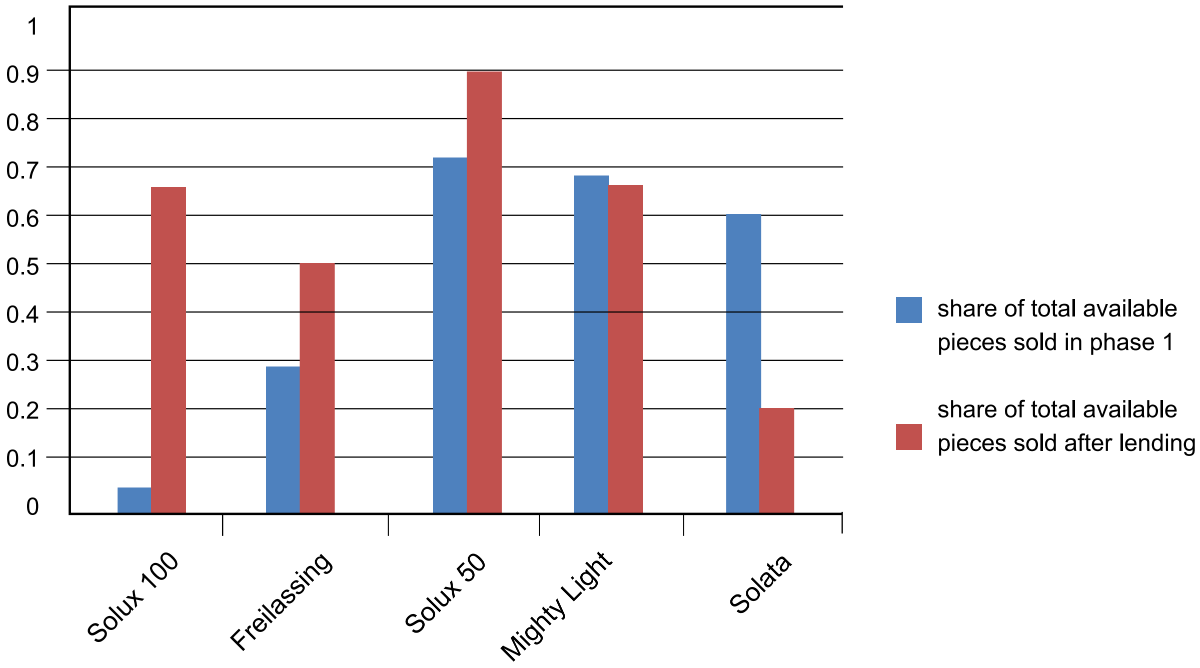


Figure 19: Sale success of different lamp models, sale through technicians (phase I) vs. sale after 3 months testing (phase II).

The results of the user survey in Uganda allow only for limited conclusions with regard to preferences of well-informed consumers, as in the given set-up users tested only one particular lamp model in their everyday lives and were usually not able to compare it with other models. Some observations from the data are nevertheless worth mentioning.

In general, what people appreciated most about the solar lamps after having used them for 3 months was the good luminance that they provided. "Good light quality" was the aspect that spontaneously came to the mind of almost three quarters of respondents when asked about the main strength of their solar lamp. The saving potential of the solar lamp was what almost all the remaining respondents first thought of. Other aspects like reduced air pollution, portability and robustness of the lamps were mentioned very rarely as core advantages of the solar lamps.

When it comes to weaknesses of the solar lamps, the main concern shared by 85 % of the inter-viewed households was that absence of sunshine hampered the usefulness of the lamps.

Figure 20: Focus group members looking at different solar lamp models.

For a comparative analysis of user satisfaction with different lamp models, households were asked to rate different aspects of their lamps on a scale from 1 ("very bad") to 4 ("excellent"). The two aspects where the data show at least some variation between different lamp models, thus allowing for a meaningful interpretation, are the light quality and the robustness of the lamps (Figure 21). Interestingly, Solux 50 achieved the best rating in terms of light quality; this evaluation may reflect the positive surprise that users experienced with the small lamp from which they had not expected such a good light output (provided through the power-LED). Aishwarya, Freilassing and Solux 100 all achieved similar average ratings of around 3.85 on the 1-4 scale, while Kiran, Mighty Light and Solata were all at a level of approx. 3.75 on average. The overall high ratings of light quality for all solar lamps, including the small student light Solata, is remarkable and probably reflects the relatively better light output in comparison to that of the traditional lighting devices.

The rating diverges much more when it comes to robustness of the lamps. Aishwarya received a rather poor rating (3.2 on a 1-4 scale), which is not surprising given the high default rates during the test. Mighty Light and Solata achieved medium ratings, and the two Solux models are the clear winners of the robustness rating.

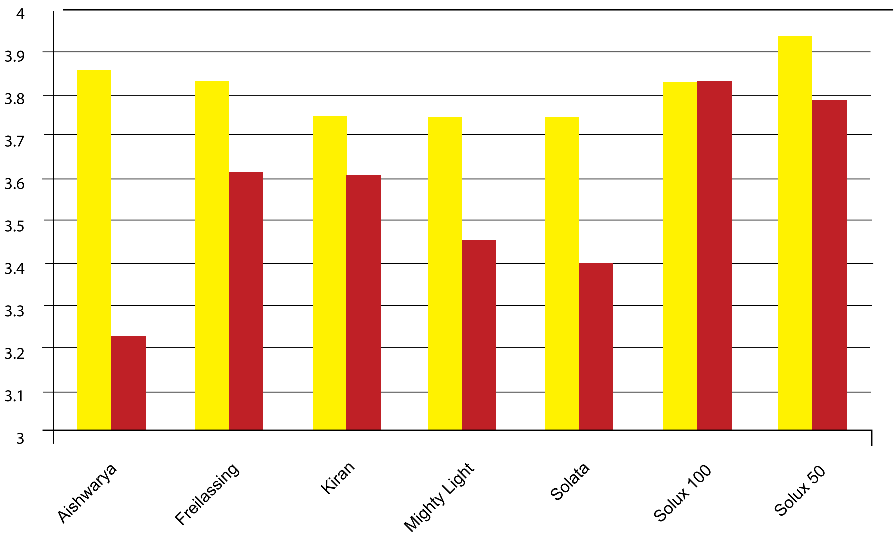


Figure 21: User rating of light quality and robustness of different lamp models.

Another important observation was that users had no preference for a specific light colour in the literal sense. Even though no further explanation of the word "light colour" was given in the standardized interview, several conversations in the margins of the data collection pointed out that people had a preference for white light over yellowish ("warm") light. Apparently, the only thing that matters for people is that the light is bright, and the white light of the solar lamps is perceived as superior in terms of brightness as compared to the light from kerosene lamps or non-LED flashlights.

Box 4 provides a summary of the most important, i.e. the most unanimously expressed consumer preferences.

Box 4: Summary of the most important consumer preferences.

Users appreciate:

- versatile lamps with 360° horizontal light cone and high luminance level
- lamp design that resembles the traditional hurricane lamps and that can be used in the same manner
- handle at the top of the lamp
- indication whether the switch is in on or off position
- different luminance levels

Users dislike:

- poor quality, usually expected from products "made in China"
- switches that are not clearly visible
- products with low light output and short burn time / low solar fraction.

Further observation: Most people in the survey area have no previous experience with solar lamps; lamps should therefore come with detailed and easily understandable user instructions, e.g. stickers on the lamps.

7.1c Which specific lamp features do users prefer and appreciate?

Portability of the lamps is important, and users found lamps with a handle on top most convenient. Aishwarya, in spite of its heavy weight, was described as portable (“can be carried around like a hurricane lamp”) while for Freilassing people proposed it should be equipped with a handle at the top so that it can easily be picked up and moved around. For Solux 50, people suggested that it should be equipped with a clip so that it can be attached to trousers.

For moving outside, people said that a lamp with a spotlight (or a max. 90° light cone) was preferred because it hides the person carrying the lamp in darkness: “One is invisible and cannot be recognized by strangers or militaries”. This statement points to people’s continuing wariness to perils when moving outside after dark in Northern Uganda, a region that is still scarred by the long lasting conflict.

Box 5: Observation on methodology: User preference for certain lamp features are best revealed through qualitative methods.

Observation on methodology: User preferences for certain lamp features are best revealed through qualitative methods

Observations during the survey data collection and the analysis of the data have shown that a standardized interview is not an ideal instrument to gain insights into which aspects and features of the lamps were most important for test users. Respondents tended to be puzzled by the question “Which aspects of the lamp do you consider important?”, and had no idea what to answer initially.

However, the qualitative methods, notably the focus groups and qualitative interviews, yielded some interesting results with regard to specific lamp features that users prefer and appreciate.

Respondents of the user survey and the focus group participants came up with the following concrete suggestions for changes on the lamps to make them more practicable and suited to their everyday needs:

- Aishwarya could be equipped with a metal protection for the glass cover, like a hurricane lamp, to make it more robust.
- For the external radio of Freilassing, the cable should be longer so that lamp can be moved even when connected to the radio.
- Users of Kiran and Solata stated that the lamp was too small and that its light output was not sufficient for their everyday needs.
- The different brightness modes on the two Solux models, Kiran and Solata were considered a very useful feature; other lamps should also be equipped with this feature (only possible for LED lamps).
- On all lamps, there should be an indication whether the switch was in on- or off-position.
- Teachers suggested that the lamps should be equipped with stickers containing important user information, such as charging instructions and the maximum lighting duration. Lamps with a radio should furthermore carry an attention notice saying “the use of radio diminishes the duration of light”.
- Users of Solata reckoned that the lamp’s “neck should be stronger” or fixed; they would have preferred a stiff construction instead of the flexible but instable neck.
- The phone chargers of the Solux models should be combined in one single piece, as the small loose pieces can easily get lost.

7.2. How do lamps perform under real-life conditions?

7.2a Where and how do people use their solar lamps?

In the large majority of households (87 %), the solar lamps were used primarily in the main room. 8 % of families have used their lamps in a bedroom. Not surprisingly, it was the smaller lamp models, namely Kiran, Solata and Solux 50 that were used in bedrooms rather than in main rooms.

One family uses their Solata lamp to light a shop that the family runs in a small booth next to their main house.
The family reported that the lamp had helped attract customers after dark, and it has encouraged customers to stay and sit around the shop and have soft drinks in the evening hours.

Overall, people have largely retained their habit of placing their lamps on the table when they use them in their main rooms. For two lamp models, however, people have developed different practices of placing the lamps indoors: A substantial share of Kiran users found that when placed on the table a large share of light was absorbed rather than spread throughout the room; they therefore preferred to hang the lamp up on the ceiling or at a wall. In case of the Solux 50, the first striking observation is that it was still placed on the table by 70 % of its users, even though the design of the flashlight model does not at all favour this way of using it. However, Solux 50 is also the lamp that is carried around by the largest share of people (50 %) when in use indoors.

Figure 22: People most often place their solar lamp on a table in their main room, even if this inhibits optimal light distribution, like in the case of the Kiran lamp.

It has been observed in several cases that people have hung up their solar lamps at the ceiling of their huts in a manner that allows for the light to spread across several rooms, as in the traditional architecture the walls do not go all the way up to the roof (Figure 24).

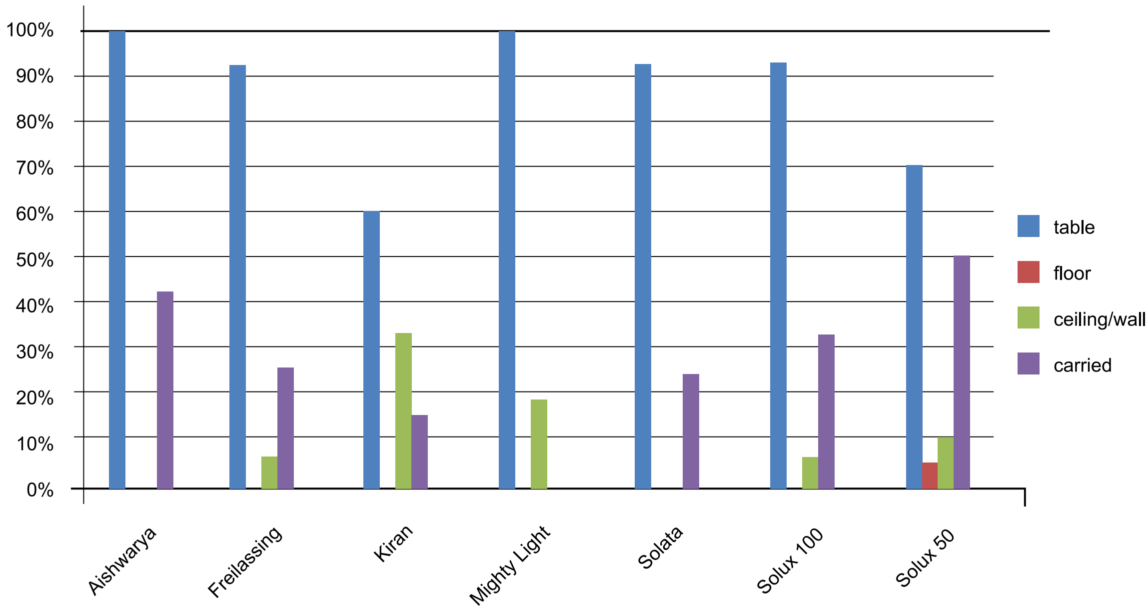


Figure 23: How people use their solar lamps indoors.

Figure 24: People hang up their solar lamps at the ceiling of their traditional huts so that the light spreads across several rooms.

Overall, less than one quarter of households have taken their lamps to the field or to other places outside their houses. Solux 50 was the only lamp model of which a substantial share of users (more than 50 %) reported that they used it also away from home. For outdoor usage around the house, lamps are predominantly used for moving around. If fixed in one place outdoors, lamps are put down on a table or hung up at walls rather than put down on the floor.

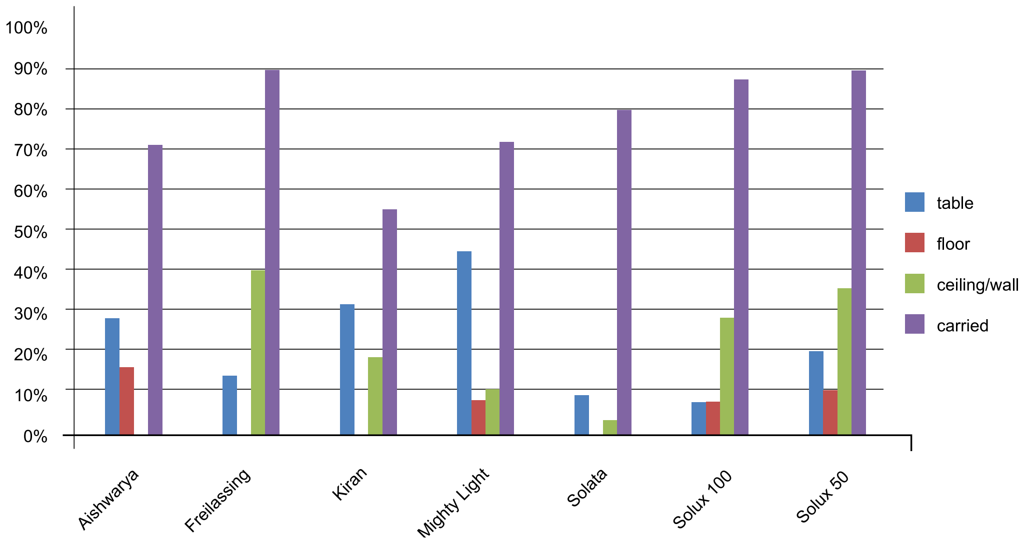


Figure 25: How people use their solar lamps outdoors.

7.2b How do people charge their lamps?

When charging the lamp during daytime, most families put down the module somewhere in their courtyard, mostly on the floor. Only one quarter of households have the habit of putting the module up on the roof (usually with the cable running through the window inside the house where the lamp is kept safe). 9 % of households place the panel in the window for charging. This kind of usage during charging points to a strong exposure of the panels, cables and connection parts to rough handling and risk of damage, as people move around the courtyard and children play and may easily step on the panels or stumble over cables. The technical inspections of lamps after 3 months of field test have shown that indeed connection parts are the most vulnerable components of the solar lamps, independent of the model, and caused (next to batteries) the bulk of

Figure 26: Panels are usually put down on the ground of the courtyard for charging the system during daytime, with children playing around the loose cable.

Overall, lamp users' reports on how often and for how long they charge their lamps point to a high prevalence of **poorly informed and inappropriate handling of the systems,** probably due to a **low general level of experience with and understanding of solar systems technology.** Among those households that use their lamp every day of the week, only two thirds stated that they charged their lamp every day of the week. More than 20 % of everyday solar lamp users charged them 4 or less times a week. The share of households that would not charge the lamp every day even though they used it on daily basis was particularly high (50 %) for Freilassing and Solux 50, which indicates an excellent solar fraction for these models. Of those respondents who charge the lamp daily, more than one third stated that they put the module in the sun for the whole day; on average, these households charged their lamps for more than 7.3 hours per day.

It can be concluded that more elaborate and consumer friendly instructions on appropriate lamp use and charging should be provided to users that are not familiar with solar PV, e.g. in the form of brochures that come with the solar lamps, or, maybe even more effective, through thorough user training given by the dealer.

7.2c For how many hours do people use light, and how long do the lamps last?

Households who use their lamps on a daily basis light them for 3 hours and 40 minutes on average in the evening, and for almost 2 hours in the morning. The field test thus reveals that the required daily "burn time" (the number of hours per night that a lighting system must provide light) is substantially higher than what is often assumed for technical assessments of lamps (e.g. the ISE lab test bases its conclusions on whether lamps fulfil minimum technical standards on an assumption of a daily burn time between 3 and 4 hours).

The everyday average lighting duration of the solar lamps in the test households does vary quite a lot by lamp model, as can be seen in Figure 26. Solux 100 is used longest, on average close to 7 hours per day, followed by Kiran, which is used almost 6 hours per day on average (taking into account only households who use their lamps daily). Aishwarya stands at the low end of the range, which corresponds to the higher power consumption of CFLs and the poor battery performance of a high share of Aishwarya lamps in the field test. It must be added here that these data do not indicate the maximum lighting duration of each lamp model; households were asked for how long they lit the lamps in their everyday life, but not whether they had tried to leave the lamp on until the light went off or became too weak to be useful.

From technical inspections of a limited number of lamps (3 Solata, 1 Mighty Light, 4 Freilassing, 2 Solux 50 and 3 Solux 100) after 3 months of usage, the following information can be added here:

- Solata performed worst: brightness of 2 out of 3 pieces decreased recognizably after 4 hours
- Mighty Light switched off after 5 hours (the lamp is equipped with a deep discharge protection)

- Freilassing: brightness of all 4 pieces decreased recognizably after 5 hours
- Solux 50: brightness of both pieces decreased recognizably after 5 hours
- Solux 100 performed best in terms of light output: one piece was still perfectly bright (as far as visible to the eye) after 6 hours, two decreased in brightness after 5 hours.

Box 6. Observation on methodology: Analysing technical field performance.

Observation on methodology: Analysing technical field performance

For conclusions on technical performance of lamps in the field, it must be noted that it is imperative to complement a user survey with technical inspections of the lamps, conducted e.g. by a technician/electrician equipped with a multi-meter that allows for proper a quick trouble shooting and identification of dysfunctional components. Households' statements on when and how technical problems occurred are not necessarily reliable and usually not precise enough.

Figure 27: Technical inspection of a used solar lamp during a household visit.

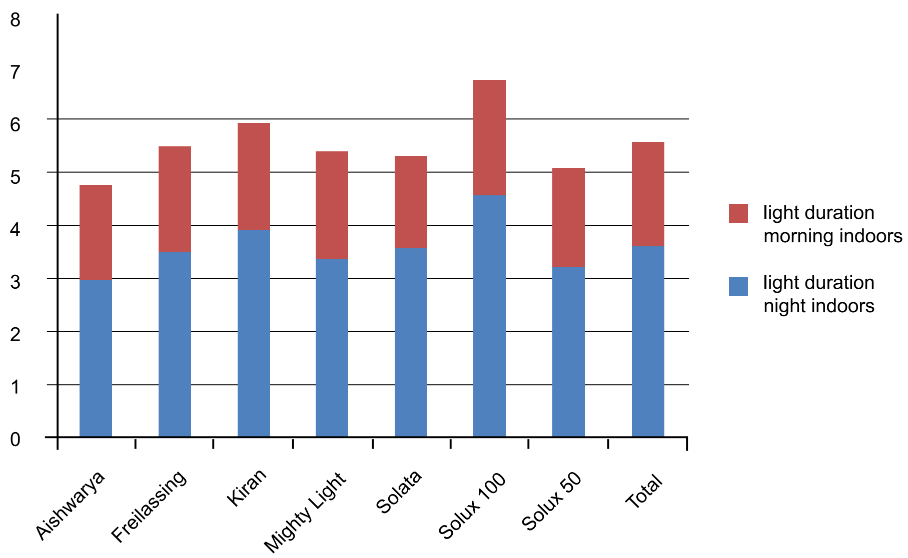


Figure 28: How many hours per day people use their solar lamps.

7.2d How do the solar lamps perform technically?

Overall, the field test has underpinned that in order to come to valid conclusions regarding aptness of technical lamp design and robustness, lab testing does need to be complemented with long-term testing under real-life conditions. The field test has shed light on certain technical strengths and weaknesses of some lamp models that were beyond the scope of what could be assessed by the lab test methodology developed by Fraunhofer Institute for Solar Energy Systems for GIZ.

It should be noted upfront that the two d.light products in the field test, namely Kiran and Solata, had not undergone the ISE lab test, but were selected as they were already available and had a rather good position in the Ugandan market at the time when the decision was taken.

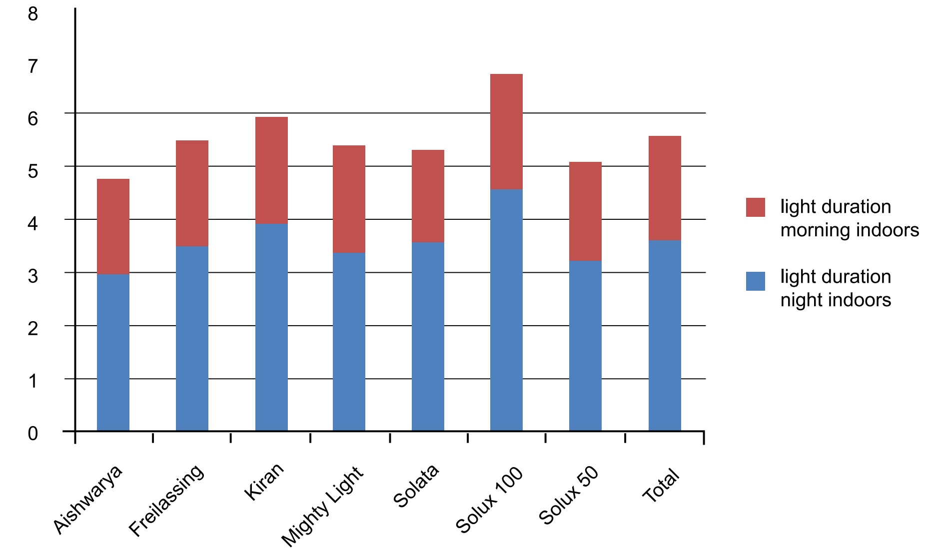


Figure 29: Shows the rates of occurrence of technical problems of each lamp model during the 3 months field test.

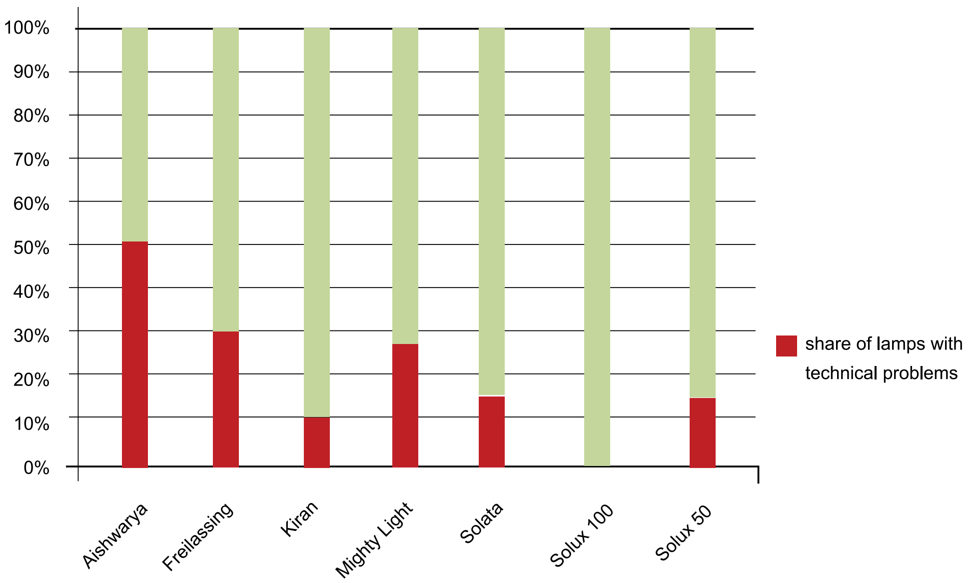


Figure 30: Occurrence of technical problems during the 3 months field test.

Solux 100

Figure 31: Cable connection box on module of Solux 100.

Solux LED 100 is the clear winner in Uganda in terms of robustness. Out of 15 lamps in the test, not a single piece has been reported to have failed or disappointed in performance. All 3 lamps that have been taken for a technical inspection after 3 months usage by test households comply with the manufacturer's specifications on lighting duration (more than 5 hours at the highest luminance level).

However, the technical inspection has detected that input jacks on 2 lamps had become loose in the course of the 3 months test period, and that inside the connection box of one of the modules the cable connection had become weak and the cable might soon come off (Figure 31).

Improvements of the robustness of these parts are recommended for future design revisions of the Solux 100.

Overall, user feedback on the design and robustness of Solux 100 was exceptionally positive. Only one user remarked that "the paper stuff on the bulb should be removed so that the light can spread to all directions". By contrast, another user found that "if placed strategically, the lamp will fill the whole room with light".

Kiran

The second best performing lamp in the test was Kiran, with only 2 pieces out of 18 having technical problems. One lamp failed completely during the first couple of days when the household started using it; the technical inspection revealed that the output from the solar module built into the lamp was too low, which had probably damaged the battery. The second technical problem that occurred was a failed switch on one Kiran lamp: The switch got stuck when pressed, which left the lamp very difficult to operate.

Other observations with regard to the technical design of Kiran was that the switch on the lamp does not indicate whether it is in on- or off-position, which can be a problem in case of deep discharge of the battery: The user would not know in which position to put the switch while charging. It was also noted that the battery inside the lamp is not labelled; neither does the packaging provide any specification on the battery type. Finally, an important conclusion from the technical inspection was that the lamp is not suited for repair or battery exchange, as it can easily break when one tries to open it.

Overall, a positive remark on the Kiran design is that typical weak parts like cables and connections between module, cable and lamp are completely avoided through the in-built panel on top of the lamp. There is however also a downside to this special feature: The fact that the full system needs to be placed outside for charging makes it an easy quarry for thieves; in fact, two households reported that their lamp was stolen during the 3 months test period while it was outside for charging. Also, three households remarked that the battery and module part on top of the lamp prevented the light from spreading throughout the room; another two households found the lamp not bright enough and proposed to improve the design for a better light output.

Solux 50

Solux 50 gave a very positive impression in terms of robustness and life span. Only three out of 20 lamps had technical problems, all of which were related to cables and connecting parts. Of the lamps that were taken for technical inspection, a loose input jack was found on one lamp, and the other lamp had a defect plug to connect the module cable to the lamp. On two lamps, the cable on the module had broken close to the plug to be connected to the lamp. The field test results thus suggest that the lamp would benefit greatly from higher quality components on cables, plugs and input jacks, to better match the overall high quality standard of the rest of the lamp.

In addition, a design feature that was identified as unfavourable was the cable length of only 3 meters, which makes it difficult for people to keep the lamp safely inside the house while putting the module out for charging; in fact at least 3 households reported that their Solux 50 had been stolen while charging. Two households also remarked that they would prefer the phone chargers to come in one piece instead of a loose set of pins, of which single pieces can easily get lost. Another minor flaw on one lamp was that a metal clip fixed on the backside of the lamp for hanging it up had come off. Overall, user feedback about the Solux 50 was very positive. Many households stated that the lamp had exceeded their expectations of brightness, and that they were extremely satisfied with the durability of the lamp. The lamps that were taken for inspection after 3 months usage had a burn time of 5 hours at the highest level of brightness and thus met the manufacturer's specifications.

Solata

Solata was less convincing in terms of robustness and durability: 4 pieces out of 21 had serious technical problems. One lamp provided only very dim light after only 1 week; on 2 lamps batteries failed completely after few weeks of usage, and on another lamp after 3 months. Presumably these defaults occurred due to very low quality of the battery, or due to an inappropriate charge controller: the lamp is equipped with a NiCa battery which is highly prone to damage through overcharging, and it should also be fully discharged every now and then to maintain the capacity over the long run. Apart from that, NiCa batteries are extremely poisonous and therefore not recommendable for distribution in developing countries, notably in rural areas, where there are no appropriate disposal systems in place.

Like the other D.light product in the test, the switch of Solata does not indicate whether it is in on- or off-position, which can be problematic in case of deep-discharge of the batteries. Another weakness of the lamp was the mechanical fatigue of the metal "neck" of the lamp. Several households complained that it was no longer possible to orient the light cone to a specific direction, and that a lamp with a stiff neck would have served them better. General user satisfaction with the lamp was rather modest, many households stated that the lamp was simply too small and the light output too little for their lighting needs.

Overall, the technical inspection revealed a general weak mechanical design of the Solata lamp. The Solata lamps that were tested after 3 months of usage also performed poorest in terms of burn time: brightness of 2 out of 3 pieces decreased recognizably after 4 hours.

Mighty Light

With 2 lamps and 2 phone chargers out of 11 having technical problems, Mighty Light also falls under the poor performers in the field test (although the sample size was smallest for this lamp). On both failed lamps, the plugs had come off from the cables after 3 months of usage. As the lamp shell and overall technical design of the lamp gave a robust impression and users were very satisfied with its stable burn time and luminance level, it would be warranted to equip the lamp with a higher quality cable to match the general level of quality of the product. Short circuits had occurred on the two phone charging pins, whereby the technical inspection revealed that the circuit board inside the charger was so poorly designed that a short circuit was very likely to happen.

Mighty Light was the only lamp in the test that had no LED charge indicator, which, as users noted, made it even more difficult for them to localize technical problems. Another unfavourable design feature was that the switch on the lamp does not indicate on- or off-position.

Two households remarked that they wished the lamp had a better light coverage and suggested to work on the design of the light cone. However, several households emphasized that the lamp was very bright and fully satisfactory for their lighting needs; some families even used the lamp to light several rooms at a time (Figure 24).

Some users regretted also that the red colour of the plastic shell had faded over the course of only a few weeks, leaving the lamp in a light orange shade, which people found less attractive than the original colour.

One Mighty Light that was taken for technical inspection had a burn time of 5 hours; it was the only LED lamp in the test that switched off automatically to protect the battery from deep-discharge.

Freilassing

In terms of value for money, Freilassing was the most disappointing lamp in the field test, with 5 lamps out of 17 having technical problems. The most frequent problem was that batteries were found to be dysfunctional when the lamps were to be taken in use, whereby it was not possible to determine whether the batteries had already been dysfunctional by the time of delivery, or whether they had been damaged through storage over several months before they were sold. Given that the lamp is not equipped with a deep-discharge protection, it may be assumed that the latter was the case. Even though the lab test evaluation has not predicted any failures to result from the missing deep-discharge protection, the field test has shown that under real circumstances (e.g. long storage) it can emerge as a problem.

One lamp in the field test failed because of a loose contact on the circuit board inside the lamp due to bad soldering; however, the technical inspection after three months of usage confirmed the overall impression from the lab test that the lamp is very robust and characterized by high quality workmanship, so that this deficit is most probably an exceptional case.

One of the lamps came with a dysfunctional module, which was sent back to the manufacturer for inspection and immediately exchanged free of charge. On one module, the plug on the cable was broken after 3 months of usage. Figure 32 shows a cable with knots and twists as found on several lamps, which can easily lead to fractions inside the cable.

Figure 32: Freilassing cable after several months of usage.

Even though the overall failure rate was high among the Freilassing lamps in the test, it should be noted that those users that encountered no technical problems were highly satisfied with their lamps in terms of burn time, brightness, and particularly robustness of the lamp.

Aishwarya

Aishwarya was by far the poorest performer in the Uganda field test with a failure rate of 50 %. Seven lamps out of 14 had battery problems after less than 3 months of usage. Several families reported that the burn time of their lamp had decreased constantly over the first 3 months of usage and had come down to less than 2 hours, in some cases half an hour or even less. Technical inspection yielded that this problem was due to an inappropriate dimensioning of the components: It is equipped with a 5 Watts CFL bulb, a 5 Watts module and a 7 Ah battery, which means that by design a full day charging will only provide enough power to run the lamp for approx. 3 hours. Given the average lighting needs of the test users and their habit of also playing the in-built radio for several hours, the lamp will suffer from daily deep-discharge, which damages the lead-acid battery within a short time. Thus, the composition of components on the Aishwarya model in the test was found to be unsuitable for the Ugandan rural context. In other words, the poor solar fraction that was already marked in the lab test results has emerged as a true factor for inaptness of the lamp under real-life conditions in Uganda.

Apart from the sizing problem, poor workmanship on the switches of the radio was another reason for complaints:
The switches had come off in several cases, but could be fixed with glue when the users brought the lamps back to the electronics dealer. Some households also remarked that they were disappointed by the overall lack of robustness of the lamp, notably the cable and connection parts.

Ammini SunLite

The Ammini lamp that was tested by approx. 50 households in Lira district in a separate chapter of the Uganda field test can only be evaluated based on the self-reporting by users at the time of ex-post interviews, as well as a rather qualitative assessment of used lamps (without keeping precise statistics of how often certain problems occurred) undertaken by NACWOLA. The used Ammini lamps in Lira were not taken for a technical inspection as in the Arua field test.

According to users' reporting, only one lantern had a serious technical problem after a three months period of usage, namely a dysfunctional connection of the panel to the lamp (plug or input jack), which prohibited proper charging.

In addition, the following technical weaknesses were observed and reported by NACWOLA one year after lamps had been taken into use by their members:

Cables have become stiff and are prone to break after repeated winding and bending, notably at the cable section close to the plug.

The connection parts (plugs and input jacks) are exposed to dust and corrosion which can lead to a transition resistance causing losses in charging.

The socket for connecting the cable to the lamp is fragile and poorly designed. The switch is not protected against dust and can easily get spoiled.

7.3. Which economic and social impacts have households experienced due to the use of solar lamps?

7.3a What is the potential of solar lamps to meet a household's basic lighting needs?

The field test results highlight that only solar lamps with high luminance levels have the potential to meet the lighting needs of rural households. In the first instance, it was observed that almost all households continued to use some of their formerly used conventional lights in parallel with the solar lamps. Even in the separate section of the field test implemented in Lira, where the average household income in the sample was even considerably lower than in the Arua sample, solar lamp users continued to use traditional lighting sources such as candles, dry cells for torches and kerosene . This raises a sequence of questions with regard to the actual lighting service capacity of PicoPV products. First and foremost, it is important to emphasize that the survey instruments employed cannot measure to what degree people have scaled up their lighting consumption through the use of solar lamps; when solar lamps do not replace but rather complement formerly used lighting devices in a household, this can mean simply that the household is willing and able to pay for a superior lighting service.

However, for the low-income households which constitute the majority of the sample, we can expect that they would actually seek to compensate the investment in the solar lamp through savings on running costs for (conventional) lighting.

Even under this assumption, it may be due to various factors that households are not ready to abandon the use of kerosene lamps and flashlights once they have started to use a solar lamp. First, solar lamps in many households only service one room at a time, but families are used to spreading across several rooms in the early morning and evening hours. Second, solar lamps may not provide a sufficient daily burn time, so that after the solar light has gone off, people light their kerosene lamps or flashlights. A third scenario is that the luminance of the solar lamp is actually too poor to allow for several people pursuing their evening activities in a single room. It may be that luminance of a system even with fully charged batteries has decreased substantially after 3 months of usage, or that it has started to decrease over time in the course of an evening.

It is not possible with the data set at hand to fully disentangle these different factors and find a solid quantitative measure for the lighting service that each lamp provided under real-life conditions. We therefore resort to a proxy: To **assess *the degree* to which different solar lamps meet people's lighting needs, we count the traditional lighting devices each solar lamp has replaced.** We analyze both the **overall number of conventional off-grid lighting devices used** by a household before and after starting to use solar lamps, and the **number of hurricane lamps** one solar lamp has replaced. Each of these two measures accounts for different aspects of how light can be shared between rooms and people and across time, but neither is fully satisfying to resolve the uncertainties discussed above. Figure 30 below shows that for some of the lamps both measures lead to different results ; however, in the first place, it demonstrates that the potential to replace formerly used lighting devices varies distinctly across the different lamp models, and that only for a few lamp models the results confirm a satisfactory service level.

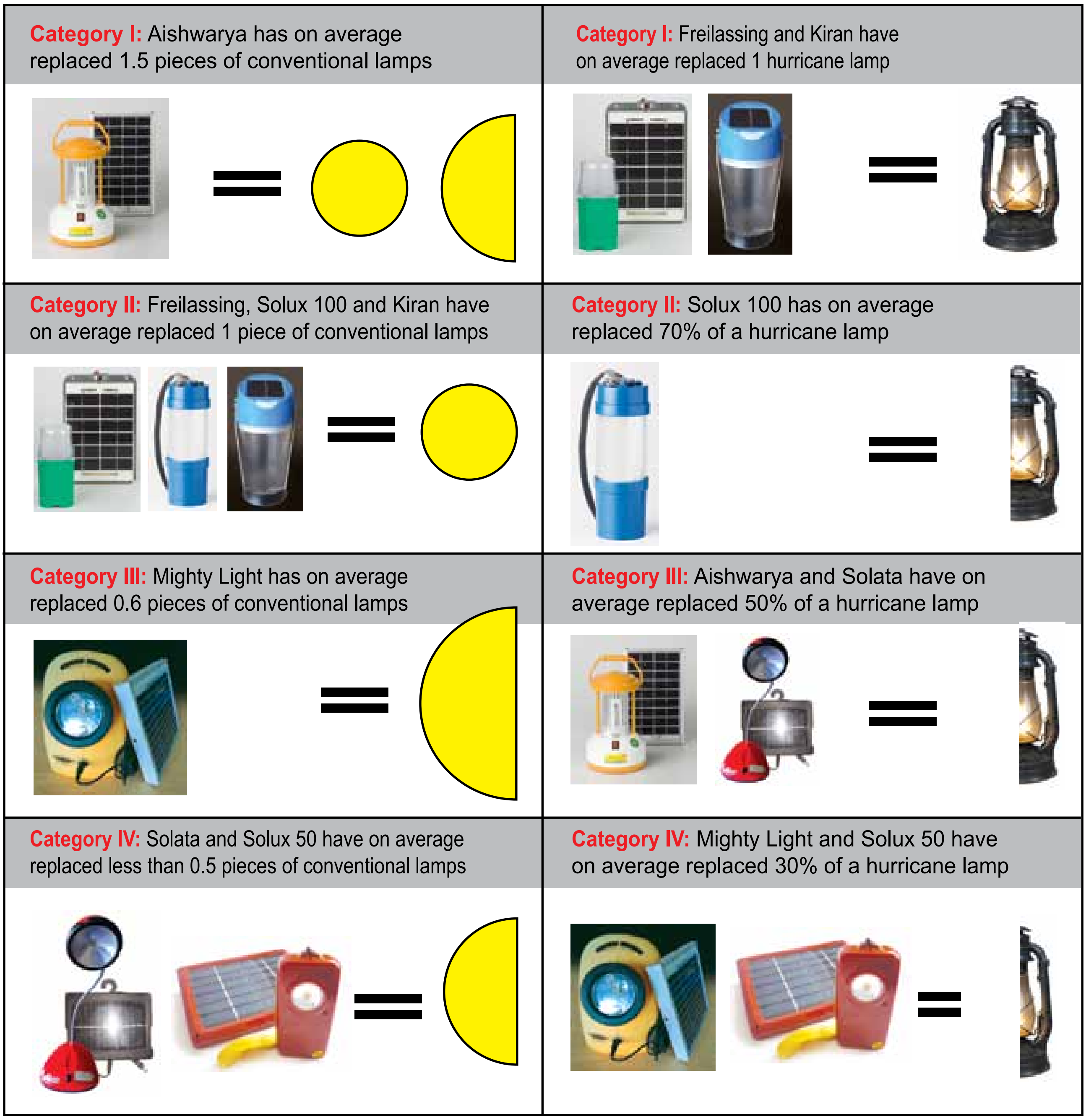


Figure 33: Different lamp models fall into different categories when measuring their potential to replace conventional lighting devices. In the left column, the yellow rounds indicate the total number of conventional lamps (hurricane lamps, simple wick lamps, flashlights, battery run lanterns) that were replaced through one piece of a solar lamp; in the right column, only the numbers of hurricane lamps replaced through one solar lamp are counted.
Different categories emerge for each of the two measures.

The results roughly confirm the ex-ante assumption: Lamps with higher luminance levels replace more conventional lighting devices than lamps with relatively poorer light output. The potential to replace different traditional lighting devices was highest for Aishwarya (taking into account only those households where no technical problems occurred with the solar lamps): On average, one Aishwarya replaced 1.5 conventional lamps, and every second Aishwarya replaced a hurricane lamp. Other lamp models that (if operational) replaced one conventional lighting device on average were Freilassing, Solux 100 and Kiran. For Solata, Solux 50, and Mighty Light the data suggest a lower potential to completely replace formerly used lighting devices, whereby Solata achieved the lowest value of mean replacements. For Mighty Light it must be noted that the sample size was very small and the result is therefore of limited validity. The mean difference is significant, i.e. it can be excluded that this results has occurred by chance, for Freilassing (total number of replaced lamps/replaced hurricane lamps) and Kiran (replaced hurricane lamps).

In order to check whether the replacement of conventional lighting devices through solar lamps was statistically significant, a paired samples test was conducted. A mean difference of 0.68 in the number of conventional lighting devices used per household before and after the introduction of solar lamps was established, and this difference is significant at the 0.001 level (std deviation= 2.03, std error = 0.19). In conclusion, on average almost 2 out of 3 households can be expected to fully replace one of their formerly used lamps when they start using a solar lamp. Table 4 provides an overview of the results in detail.

Table 4: Potential of solar lamps to replace traditional lighting devices. To measure this potential, the number of conventional lighting devices households used at baseline was compared to how many they used in parallel with a solar lamp. The analysis was done (i) with the total number of kerosene and battery-run lamps used per household (left column) and (ii) the number of hurricane lamps used per household (right column). Only lamps reported to be fully functional were considered.

Type of Solar Lamp	Mean difference in numbers of conventional lamps **(hurricane, simple wick, flashlight, battery run lantern)** used before and after starting to use solar lamp	**Mean difference in numbers of hurricane lamps (i.e., no other lamps) used before and after starting to use solar lamp**
Aishwarya	**1.5714** n=7, Std. Deviation=2.64	**0.5** n=4, Std. Deviation=0.577
Freilassing	**1.071*** n=14, Std. Deviation=1.542	**1.083**** n=12, Std. Deviation=1.084
Kiran	**1.118** n=17, Std. Deviation=2.342	**1*** n=17, Std. Deviation=1.369
Mighty Light	**0.625** n=8, Std. Deviation=1.923	**0.333** n=3, Std. Deviation=0.577
Solata	**0.4118** n=17, Std. Deviation=1.543	**0.25** n=12, Std. Deviation=1.087
Solux 100	**1.133** n=15, Std. Deviation=3.021	**0.636** n=11, Std. Deviation=0.924
Solux 50	**0.444** n=18, Std. Deviation=1.423	**0.176** n=17, Std. Deviation=0.951

* Significant at the 0.01 level
** Significant at the 0,05 level

Box 7: Observation on methodology: How to measure the quality of the lighting service offered by a solar lamp

Observation on methodology: How to measure the quality of the lighting service offered by a solar lamp

For future field tests, instruments need to be developed to better measure the level of lighting service that PicoPV systems actually provide and to examine how this lighting service alters over time when lamps are in everyday use. A two-track approach will be most effective: First, luminance measures should be taken from fully charged lamps in regular short intervals over up to five hours (either lamps have to be taken back to the lab or a luminance meter needs to be applied onsite, whereby the use of an Ulbricht sphere in the lab will allow for better comparability of illuminance levels between lamps with different light cones); second, survey instruments need to be fine-tuned to better grasp users' perception of the lighting service offered by different lamp models; this will be a multi-facetted variable that covers various aspects such as luminance, light distribution in the room, possibility to spread light across different rooms, and whether luminance remained constant or decreased over time. Respondents in the survey had difficulties to disentangle these aspects in terms of suggested measures like "brightness", "light colour", "light cone", "lighting duration", etc. Possibly the standardized survey should also be complemented through qualitative interview techniques, e.g. by letting people describe the lighting service in their own words.

7.3b Economic impacts of solar lamps: How much can households save in lighting expenses?

Overall, the use of solar lamps has helped reduce the consumption of lighting fuels and dry cell batteries in the majority of households, as stated by an overwhelming majority of households (94 %). The baseline vs. Ex-post data on household expenditures for lighting confirms that the use of solar lamps has enabled households to save considerable expenses for both kerosene and dry cell batteries. Those households that encountered no technical problems with the solar lamps consumed on average almost half a litre of kerosene less per week when using solar lamps as compared to before. The average reduction in weekly kerosene expenditure was 1,300 USH as per household indications (which actually corresponds to a bit more than half a litre). The paired sample test for kerosene savings through using solar lamps shows that the effects are significant at the 0.000 level.

In the separate field test in Lira, average weekly kerosene expenditures of solar lamp users were 125 USH lower than those of the control group. Even though these "savings" seem small in absolute terms, it needs to be pointed out that in the Lira context, this figure points to a kerosene savings potential of solar lamps of around 60%. In Arua, the consumption of dry cell batteries for lighting went down by one pair in 3 weeks on average. The respective saving was an average of 450 USH per week as per household indications (both results are significant at the 0.05 level). In the Lira field test, expenditures for dry cell batteries were equally high in the group of solar lamp users as in the control group.

A lamp-wise analysis of savings potentials underscores that on principle, investing in a high quality lamp pays off.
The savings potential of different lamps diverges enormously (up to 400 %) between high and low luminance lamp models, but also between lamps with excellent and poor technical performance **(Figure 33)**. The average savings on kerosene were highest among households using a Solux 100 (almost 2,000 USH per week), followed by those using Freilassing (1,500 USH/week). Interestingly, Solux 50 ranks no. 3 in terms of kerosene savings potential and reaches almost the level of Freilassing (1,450 USH/week).

For some lamp models, the picture varies substantially depending on whether the entire sample is analyzed or whether the dysfunctional lamps are excluded from the analysis. In fact, Kiran users who did not encounter any technical problems were able to save almost the same amount of kerosene as the users of Freilassing and Solux 50. However, when not filtering out the dysfunctional lamps, Kiran performs not quite as good, but is still at one level with Mighty Light (approx. 1,200 USH/week). Not filtering out lamps with technical problems most significantly spoils the performance result for Aishwarya.

This does not come as a surprise, given that almost half of all Aishwarya users reported about substantial losses in lighting duration after a few weeks of usage. The "real" savings realized by the full sample of Aishwarya users were only 500 USH/week, while the "potential" savings, i.e. the savings of households where Aishwarya worked fine even after 3 months were double the amount (almost 1,000 USH/week). The "real" savings potential of the very bright Aishwarya lamp, appreciated initially by households because it spreads bright light throughout the room, ranks equally low as that of the weakest lamp in the test (in terms of luminance), the Solata lamp.

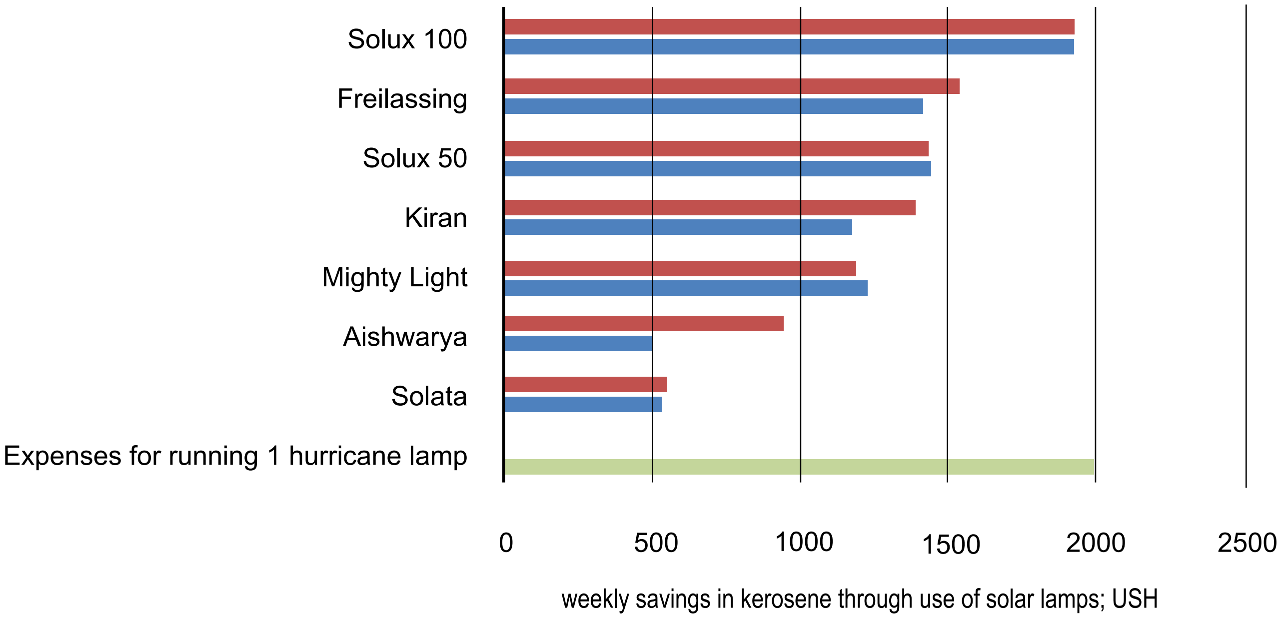


Figure 34: Savings realized through the use of solar lamps.

In conclusion, the projected saving potential of 2,000 USH established on the basis of baseline data, realized if a household fully replaces a hurricane lamp used in the main room, was reached by only one lamp model, i.e. the Solux 100.

7.3c Do people use light for more hours per day?

The use of solar lamps has had a more significant impact on people's light consumption in the morning hours than in the evening hours, and again the impact varies strongly between different lamp models. Notably, 50 % of those households that had no habit of using a light in the morning before they owned a solar lamp have started to do so; one third of these cases were users of Solux 100. In terms of lighting duration, however, the use of solar lamps has not increased the hours that people use a light in the evening. A lamp model-wise analysis of the impact on lighting duration, excluding households where lamps had technical problems, yields diverging results. For some lamps, the average lighting duration in the morning or in the evening actually decreased rather than increased after people started to use the solar lamps. For Solux 100, the average morning time lighting duration increased by more than 1 hour as compared to the baseline. Freilassing users have increased their lighting hours in the evening by an average of 25 minutes. The most notable increase in average lighting duration can be reported for Mighty Light, namely 40 minutes in the morning and 30 minutes in the evening. Of all these observations, only the morning time lighting increase of Mighty Light users is significant at the 0.1 level.

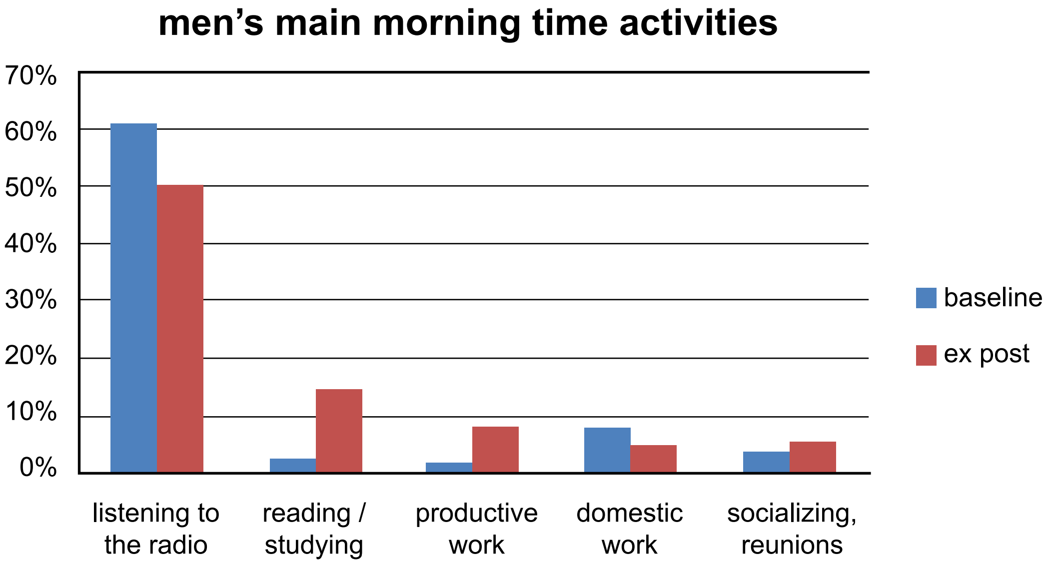
7.3d How have people's morning and evening activities changed?

When asked for which activity the lamps have been used primarily, more than half of all households state that it was studying or reading. Interestingly, socializing was the second most frequently mentioned activity (28 %).

Figure 35: The small Solata student lamp provides sufficient light for children to do homework; however, it is not bright enough and has a too limited light cone to replace a hurricane lamp for multiple uses.

When analyzing in detail which activities people pursued mainly before dawn and after sunset at baseline as compared to after the introduction of solar lamps in their houses, the data point to significant impacts of the solar lamps on people's everyday lives (Figure 36 to Figure 37). However, different household members have changed their habits in different ways. More than 10 % of men have started to use the morning hours and the evening hours for reading. Five and ten percent have taken up productive work in the morning and in the evening hours respectively, now that they have a solar lamp. By contrast, listening to the radio before dawn and after sunset and socializing in the evening has receded in importance for men.

In the separate field test carried out in Lira, men's main evening activity was socialising, irrespective of whether households own a solar lamp or not. However, the availability of solar light in the house seems to prompt men to read newspapers in the evening, while at the same time it decreases the probability of men helping with the domestic work (6% of men assist with domestic work in households with a solar lamp, as opposed to 10% in the control group).



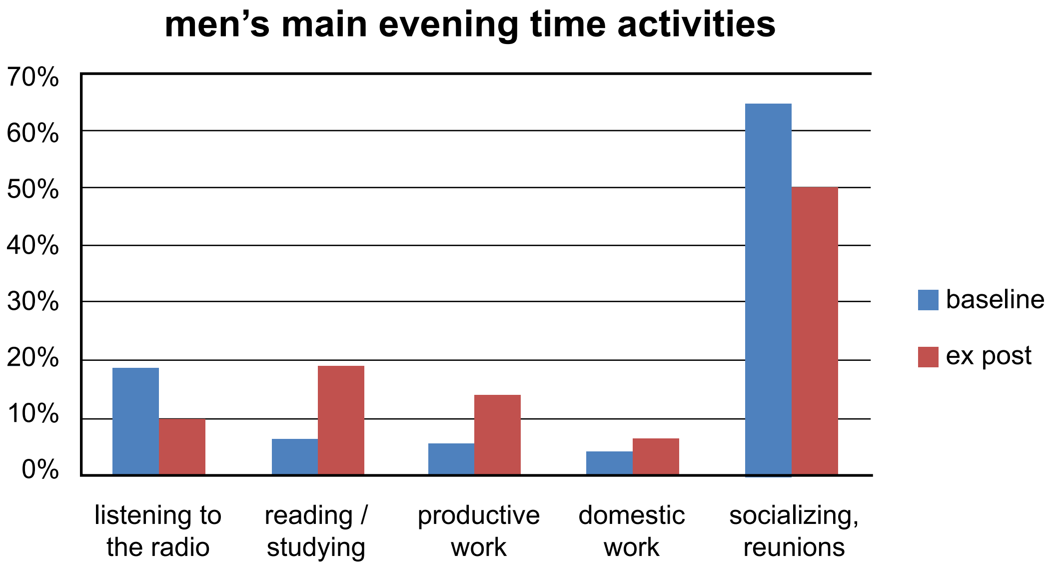
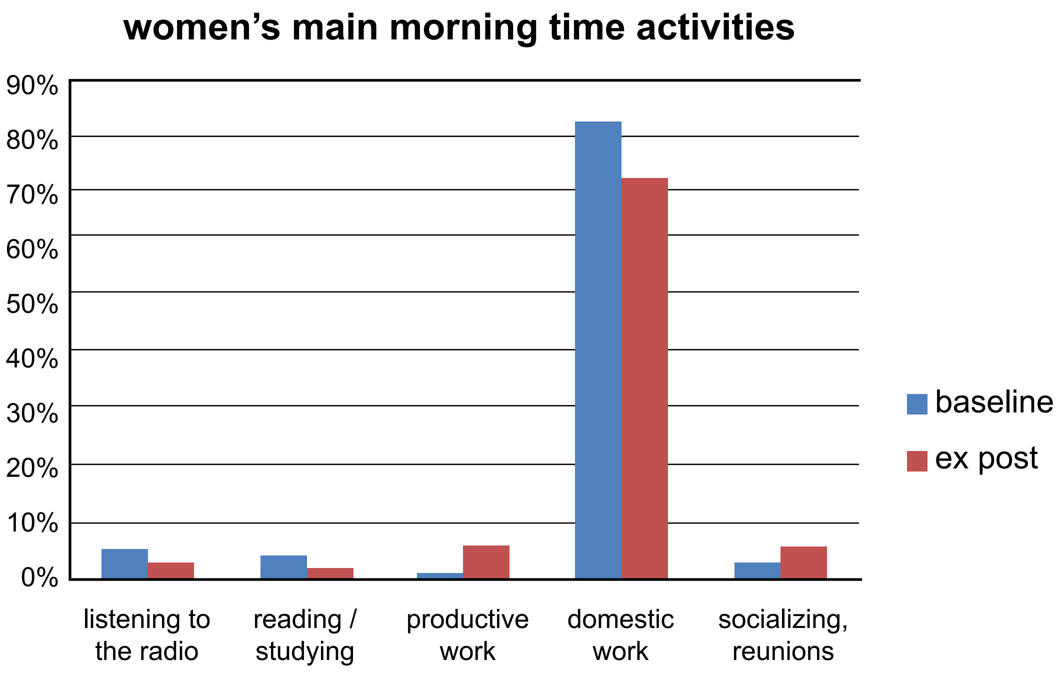


Figure 36: Men's morning and evening time activities before and after starting to use solar lamps.

A different picture emerges for women: The Arua data point to a deferral of domestic work from the morning to the evening hours. At the same time, domestic work seems to have cut down women's time for reading, socializing and productive work.

In Lira, while 54% of women with a solar lamp cite domestic work as their main evening activity, this is the case for only 45% of the women without a lamp.



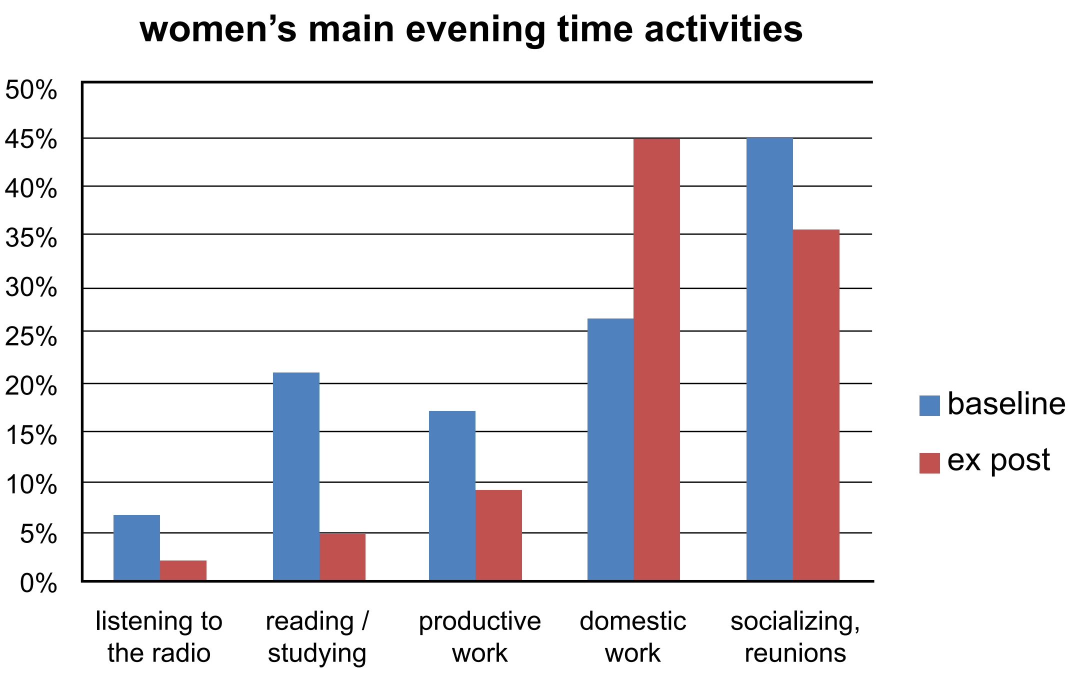
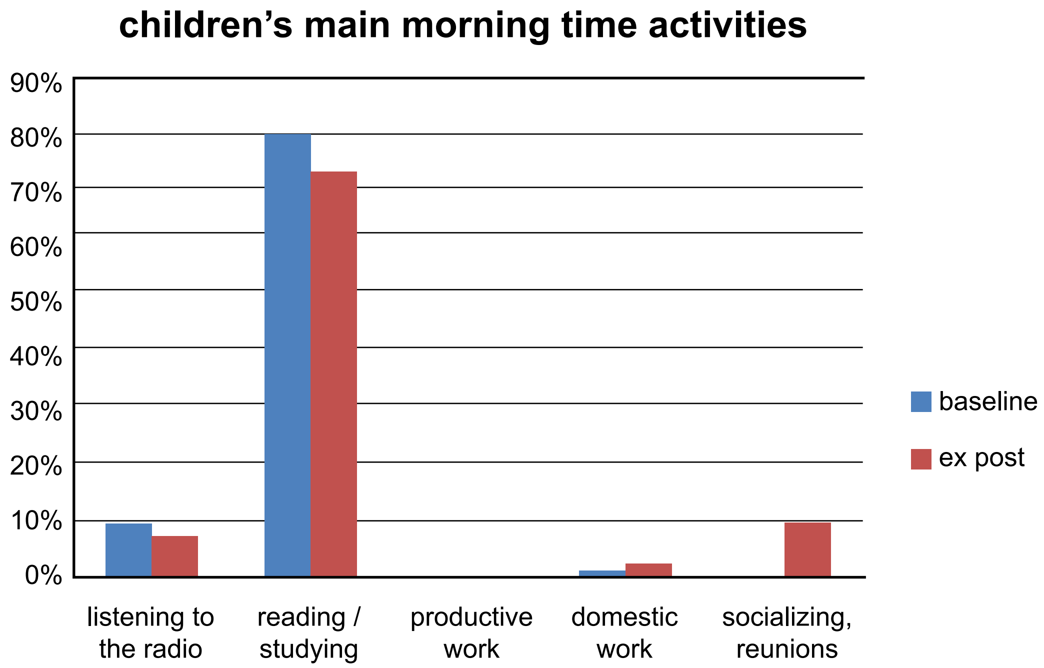


Figure 37: Women's morning and evening time activities before and after starting to use solar lamps.

For children, the most important observation is that the share of children using the evening hours for studying has increased by more than 25 percentage points in the Arua sample, and has reached 91 % now that households use solar lamps. In addition, there seems to be a shift of children's studying time from morning to evening. The field test results from Lira draw a similar picture: While children in only 35% of the control group households use the evening hours for reading or studying, their share in households that use a solar lamp is as high as 50%.



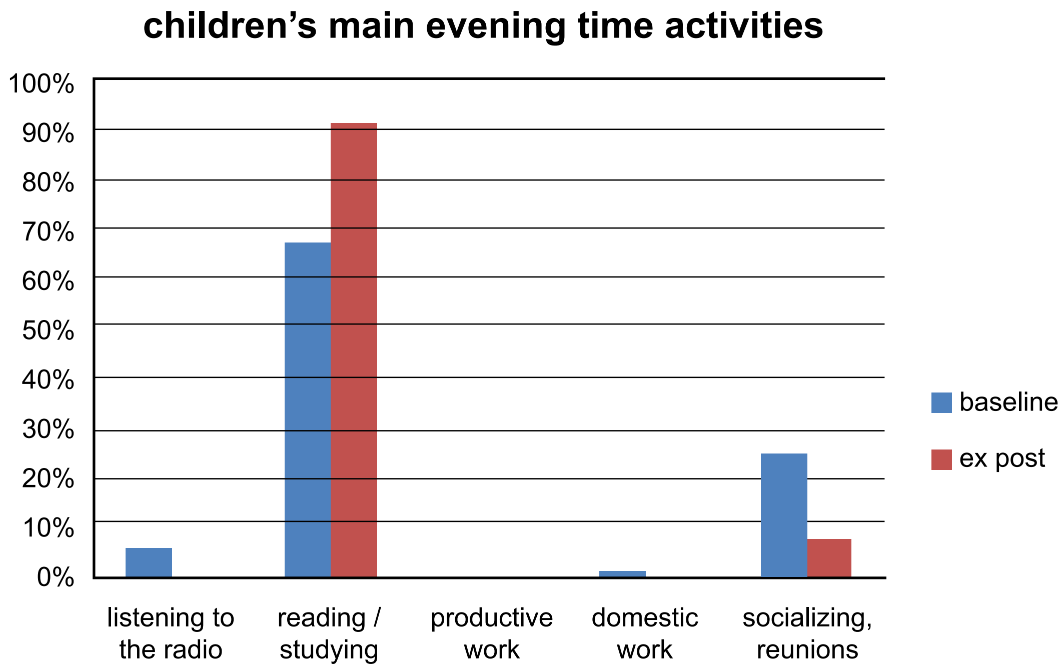


Figure 38: Children's morning and evening time activities before and after starting to use solar lamps.

In conclusion, children have benefitted from the introduction of solar lamps in their household in terms of improved studying conditions, and men have taken the opportunity to do more reading and productive work. As far as women are concerned, however, solar lamps do not seem to enable them to take up new activities; rather, improved lighting conditions through solar lamps seem to encourage women to defer domestic work from the morning to the evening hours, which may possibly inhibit them from pursuing social or recreational activities in the evening hours. In addition, recalling that at baseline some 5 % of women had hoped to take up new productive activities after dark when the light in their houses was to be improved, it is all the more disappointing that actually less women reported to pursue productive activities in the evening with a solar lamp than without.

All in all, it is not clear whether the evidence can be interpreted as an overall benefit for women who have now more liberties in stretching their daily activities over extended days, or whether women tend to actually do more domestic work simply because the improved lighting situation gives them the possibility to do so. Further in-depth field research will be needed to come to valid conclusions on this question.

7.3e What benefits does the mobile phone charging function have?

As could be seen from the baseline data, the use of mobile phones plays an important role in the everyday life of households in the sample (chapter 6.9). Three of the lamp models that have been tested in the Arua field test had a mobile phone charging function: Mighty Light, Solux 100, and Solux 50. The phone charging pins had to be purchased separately and came at an additional cost of 10,000 USH. The Mighty Light charger is connected to the battery of the system, which makes the phone charging independent of insolation, while on the two Solux models phones are charged directly from the panel. Almost all users of lamps with phone chargers (those that did not encounter technical problems with the pins which was the case for a few Mighty Lights) made use of the additional function. On average, the systems were used for phone charging for 3 hours per day. Households have also made use of the function to generate additional income: 70 % of the users of solar phone chargers collected a fee for charging other people's phones. In most cases the fee was set at the general market price for phone charging, i.e. 500 USH (except for one household who offered a "special rate" of 300 USH). If a household charges 7 phones per week, which corresponds roughly to the average phone charging duration of 3 hours per day, an income generating (when charging other people's phones against a fee) or savings (when charging family members' phones and thus avoiding to pay a fee) potential of 3,500 USH per week can be established. Obviously, the use of the small solar systems for phone charging cuts down their light output, so that phone charging should be seen as an alternative rather than an additional service provided by these systems.

7.3f What benefits does the radio function have?

Almost all households who had an Aishwarya used the radio function of the lamp, except for 2 households where the lamp had battery problems. On average, these households reported that they used the radio for more than 3 hours per day. About half of them noted that this reduced the lighting duration, yet hardly any respondent was able to estimate by how many hours. The radio function is obviously tempting for lamp users: The majority of people that observed a degradation of the battery still used the radio. This suggests that there is little understanding of the fact that radio use puts further strain on the battery if the state of charge is already low. People were probably not aware that they could extend the life span of the battery by refraining from using the radio in addition to the lamp. Given the already poor solar fraction of the Aishwarya lamp, a strong recommendation that emerges from the field test is that in the Ugandan context, the Aishwarya model without radio function would be more appropriate and should therefore be prioritized by retailers for distribution.

Six users of Freilassing had bought a radio that can be connected to the lamp. They used the radio on average a bit longer than 2 hours per day. Three out of these 6 households noted that the use of the radio reduced the lighting duration of the lamp by 1–2 hours. In case of the Freilassing lamp, which has a very strong solar fraction, the use of the radio bears much less risk of damaging the battery through frequent overload than in the case of Aishwarya.

7.4. How much are customers willing to pay for a solar lamp?

Methodology

Various methods have been developed by marketing experts and economists to measure (potential) consumers' willingness to pay (WTP) for specific products or product types. However, WTP remains a highly elusive concept (and in this regard comparable to income, which is also difficult to assess from a development economics perspective). In the Uganda field test, different direct and indirect research techniques have been employed to measure the target consumers' willingness for solar lamps.

i) Dutch Auctions

Firstly, a number of different lamps were put up to auction. Auctions are a smart instrument to assess WTP without potentially manipulating statements; to this end, the auction design must give bidders an incentive to disclose their true WTP (from a game theory perspective). The "Dutch Auction" format was chosen for the GIZ solar lamps field test, whereby the price of the item for sale decreases incrementally from a pre-determined (high) starting price at regular intervals. A bidder may intervene at any point by announcing that he/she is willing to buy the item at the current price .
The auctions were held in April 2009 on the day after the focus groups were concluded, and participants were recruited from the focus groups. Bidders can thus be characterized as target consumers with no previous product knowledge, but which had ample opportunity to explore the lamps and make themselves familiar with their features. In total, 18 people (among them 3 women) turned up for the auction, with 11 of them from rural areas and 7 from Arua town.

ii) Van-Westendorp Price Sensitivity Measure

An alternative method for retrieving WTP indications from target consumers has been developed by Van Westendorp: he proposes a sophisticated set of questions, the answers to which can be used to compute a "Price Sensitivity Measure":

a. At what price would you consider this product so expensive that you would not consider buying it (too expensive)?

b. At what price would you consider the price of this product so low that you would question its quality (too cheap)?

c. At what price would you consider the product starting to get expensive – not out of the question, but you'd need to give some thought to buying it (expensive)?

d. At what price would you consider the product to be a bargain (inexpensive)?

The questions were (i) integrated into the ex-post test-user survey, and (ii) brought up by the moderator in the focus groups.

**Box 8: Observation on methodology:
Van Westendorp method appropriate for low-income rural research context.**

Observation on methodology: Van Westendorp method appropriate for assessing WTP of low-income rural research context
Observations during the data collection affirmed that the van Westendorp instrument is an appropriate method for assessing WTP in the given research context. Respondents in general had no difficulty in understanding the different nuances in the questions and were able to give straight answers.

For the analysis of the survey results on WTP, responses were recorded in cumulative frequencies **(Figure 39)**; the emerging curves yielded different price points that can be interpreted as follows:

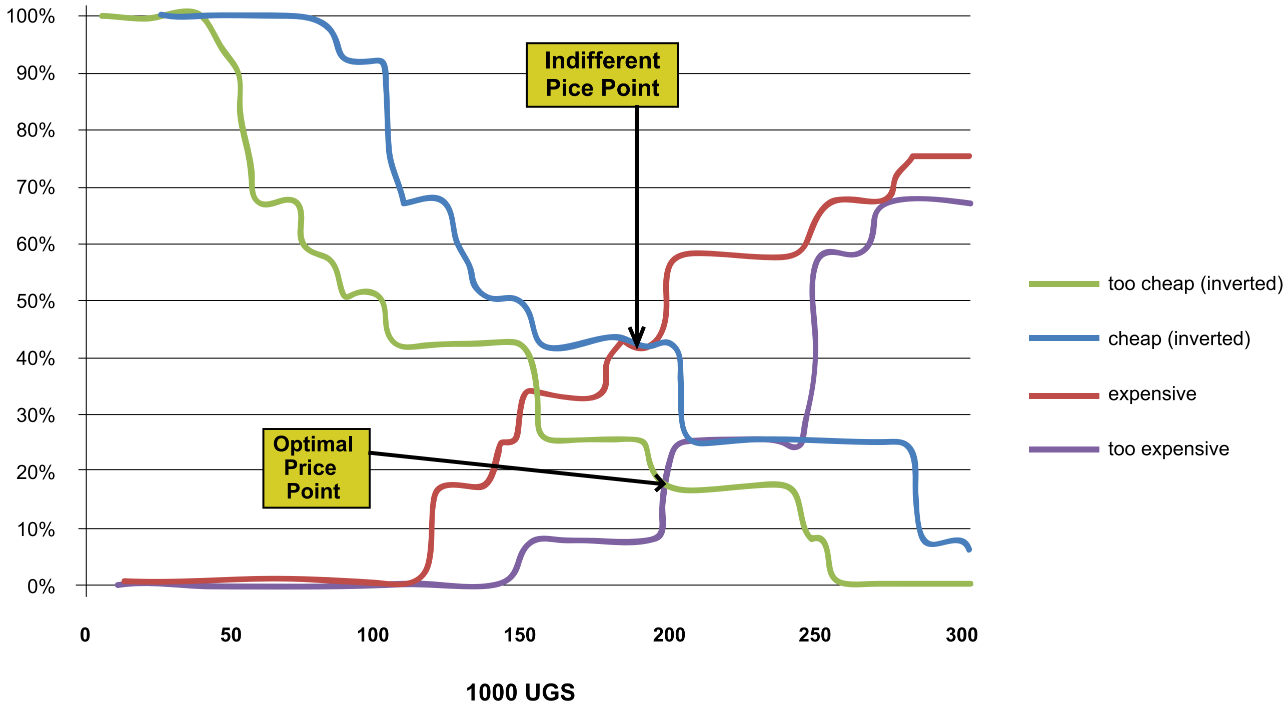
- The Optimal Price Point marks the price at which the share of respondents that find the product 'too cheap' equals those who find it 'too expensive'. Van Westendorp suggests that this point can be interpreted as the price with the maximum customer acceptance.

- The price at which the same share of respondents would consider the product as 'cheap' and 'expensive' is referred to as Indifferent Price Point (IPP), and is generally used as a proxy for the medium market price.

- At the Point of Marginal Cheapness (PMC) the number of respondents who consider the product as 'cheap' equals that who consider it 'too cheap'. A price below this threshold might spoil the market through gambling away clients' confidence.

- The analogous Point of Marginal Expensiveness (PME) marks the point where the same number of respondents finds the product 'expensive' and 'too expensive'. A price above this point is predicted not to be accepted.

The significance of the different price points as suggested by Van Westendorp is based primarily on a logic of "potential customers lost vs. potential customers gained", no sound micro-economic reasoning for interpreting the price points is offered. Nevertheless the methodology is considered as a suitable instrument for broadly establishing reasonable price ranges for different solar lamps.



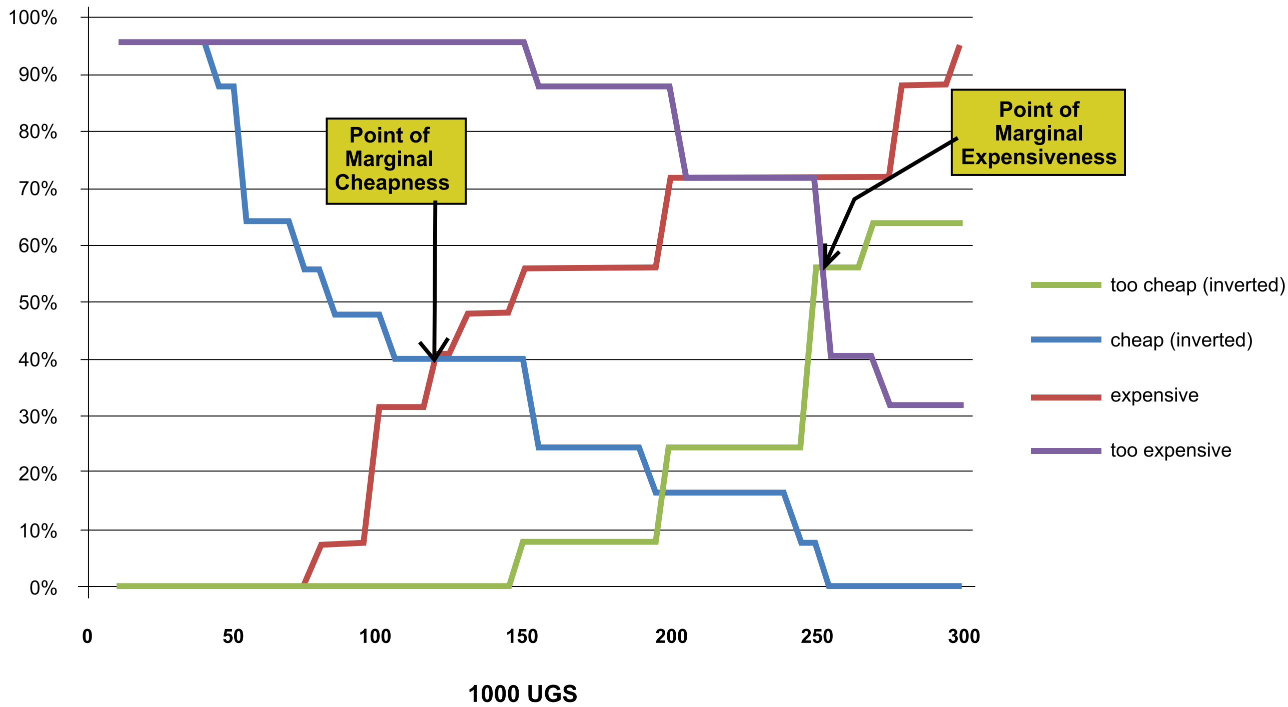


Figure 39: Example of analysis of Van Westendorp graphs; WTP indications by test-users of Solux 100.

Results on willingness to pay

Like in the section on consumer preferences, we will distinguish here between the WTP measured among consumers that have limited experience with the use of solar lamps (auction results) and experienced consumers, i.e. those who attribute a certain value to a lamp on the basis of 3 months test use in their homes.

Four out of six lamps that were put up to auction were actually bought at a price that was at least half of the pre-determined high starting price. Bidders were ready to pay 100,000 USH (48 US$) for an Aishwarya lamp with integrated radio, but only 65,000 USH (28 US$) for an Aishwarya without radio. One Solux 100 was auctioned at a price of 145,000 USH (63 US$) and one Freilassing at a price of 170,000 USH (74 US$). No bid above 50,000 USH (the pre-determined minimum sale price) was placed for Solux 50, and no bid above 22,500 USH for Solata, respectively **(Figure 40)**.

The Price Sensitivity Measure computed from the ex-post test user survey deviates from these results, as one would expect given consumers' different information basis (NB: only those cases were included in the WTP analysis where lamps had no technical problems).

First of all, it should be noted that the WTP indications (Optimal Price Points according to Westendorp) were more or less in the range of GIZ subsidized prices or local market prices (where applicable), but remained below these retail price proxies for all of the lamp models.

Differences between WTP and realistic retail prices were most pronounced for the two top-end products Solux 100 and Freilassing, for which test users indicated that they were ready to pay only around 200,000 USH, whereas the realistic retail price would be more in the range of 300,000 USH.

As this stands in contrast to the overall high user satisfaction with these two lamps, it may be concluded that 200,000 USH (87 US$) marks a threshold of WTP for a solar lamp among the target consumer group in the survey area. PicoPV Products beyond this threshold will most probably be difficult to sell at large scale in Northern Uganda, especially since prices for small SHSs (e.g. a one light system with a 10 Wp panel) sold in different shops in Arua town start at 180,000 USH. Several experts with whom qualitative interviews were taken confirmed that the price range above 200,000 USH would not be feasible for solar lamps, as people would opt for a solar system. The qualitative findings suggest that advantages seen in a one-light SHS as opposed to solar lamp are that in people's perceptions, SHSs offer more flexibility, as in principle they can be upgraded (even though it is in reality often difficult to maintain appropriate sizing), that people feel more confident to do small repairs themselves, and that spare parts are easily available.

Figure 38 at the end of this chapter summarizes the detailed results of the Price Sensitivity Measure, indicating the possible price ranges (between the Point of Marginal Cheapness and the Point of Marginal Expensiveness) for each lamp, as well as the realistic price ranges, i.e. the price range between the Optimal Price Point and the Indifferent Price Point.

When comparing WTP indications from "inexperienced" bidders and "experienced" survey respondents, some interesting observations occur **(Figure 40)**:

WTP for the top-end products was significantly higher after households had tested these lamps, while it was actually lower for Aishwarya, as compared to the auction price.

Recalling also the very slow sales progress for the expensive products in the first phase of the field test, these results point to a low level of trust in solar lamps.

However, excellent light output (as provided by Aishwarya) is more "seductive" than durability and robustness (which can be claimed to justify the price of Solux 100 and Freilassing).

Obviously, durability and robustness are product characteristics where an information asymmetry between consumers and manufacturers (or dealers) comes in and interferes with WTP formation: as consumer warranties and quality labelling of products are highly underdeveloped in rural areas in Uganda, people are very hesitant to invest major sums in costly high quality electric equipment (certainly also because limited household budgets do not allow for such risks).

The focus groups yielded another interesting observation with regard to WTP and gender: The discussions, along with several qualitative interviews held in the margins of the consumer survey, revealed that provision of lighting fuels is traditionally a women's responsibility in the survey area. Several women reported that they were sometimes scolded by their husbands when they had not procured kerosene or candles. Some women even reported of domestic violence occurring in relation to lack of lighting fuels in the house. They reported: "When men come home and find the house dark, they say it is the woman's fault". Accordingly, women have a pronounced consciousness about the costs of kerosene-based lighting and the burden of responsibility for purchasing kerosene. Notably, the WTP, retrieved from each group through the Price Sensitivity Instrument, was higher in the women group than in the groups of technicians, business people, teachers and (male) teachers, across all lamp models.

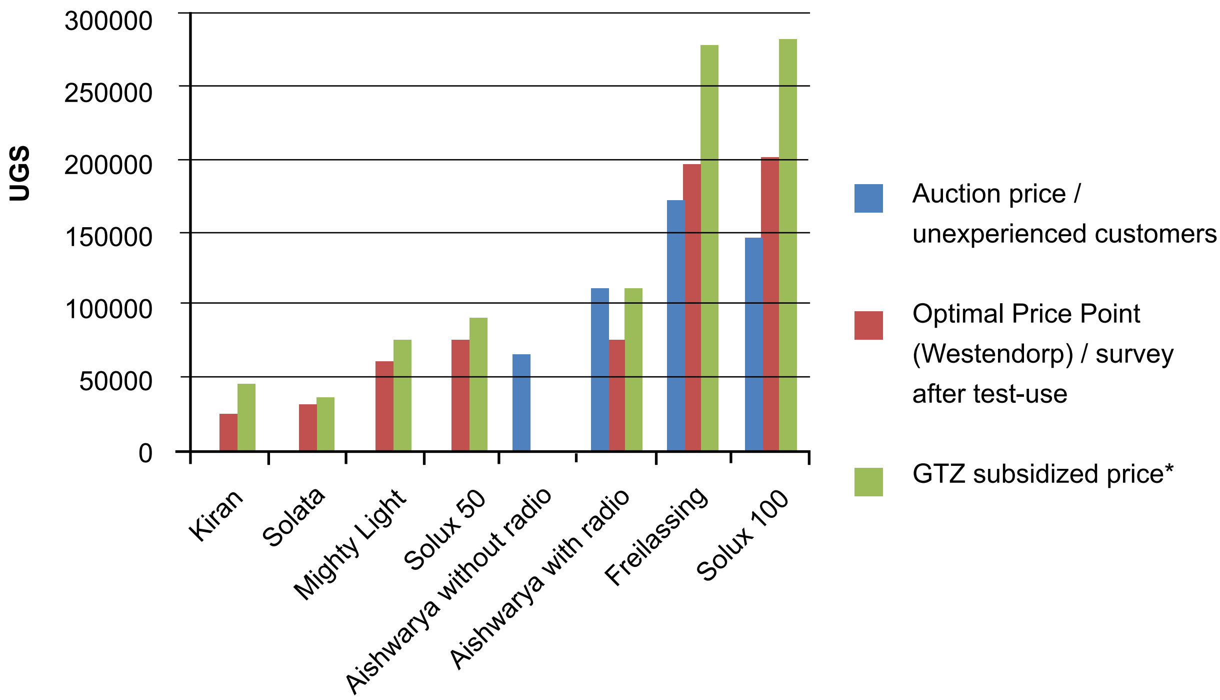


Figure 40: Auction results vs. WTP of test users vs. GIZ subsidized prices .

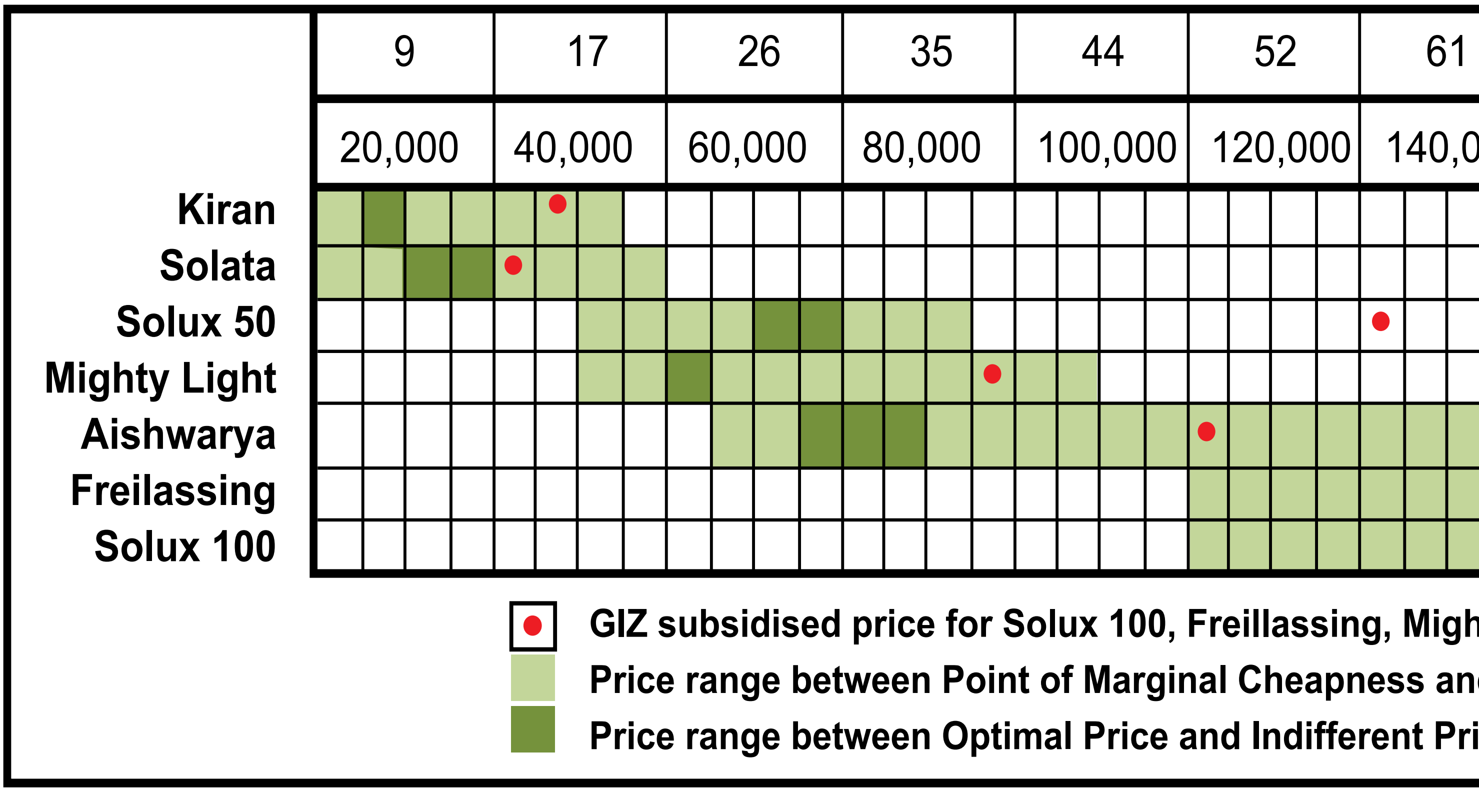
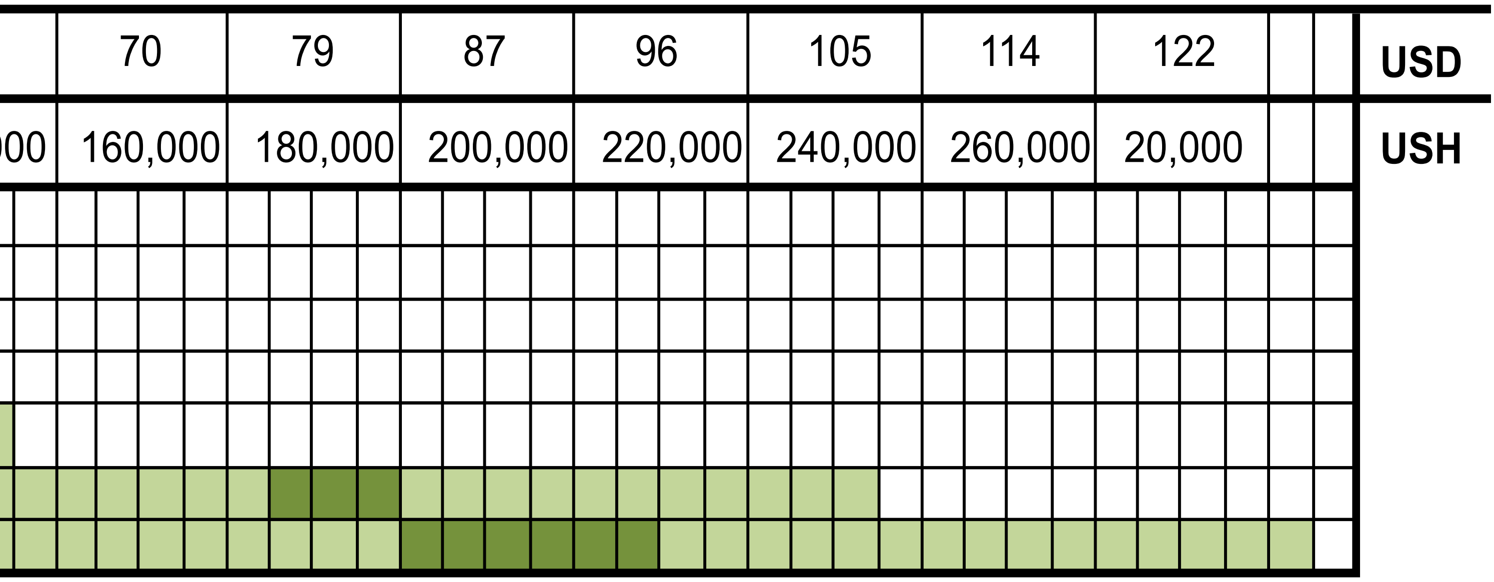


Figure 41: Price Sensitivity Measure computed from ex-post test user surveys for different lamp models.



ty Light, Aishwarya; retail price in Uganda for Kiran Solata and Solux 50
d Point of marginal Expensiveness; range of possible prices
ce Point; reasonable price range

8. OVERALL FIELD TEST RESULTS

The Uganda field test results point to a great market potential for PicoPV in general and solar lamps in particular in rural areas in Northern Uganda.

Improved lighting ranks high on the list of priority needs expressed by interviewed households. People feel constrained in their night-time activities. They report that there is a lack of security, and that accidents associated with the use of lighting devices happen frequently in their houses .

The solar lamps that were tested in the region attracted great interest among the target consumers. Particularly women, who are traditionally in charge of provision of light, were enthusiastic about the new kind of products. They recognized their potential to greatly improve the lighting and living conditions in their houses while coming at prices that are not completely out of reach for the lower income strata.

However, the Uganda field test highlights that there is still a long way to go to ensure that the technical design and quality standards of products match average user habits and levels of product know-how.

In brief, (i) PicoPV products exhibit technical weaknesses that lead to inacceptable failure rates and risk severe market spoilage; and (ii) users are too inexperienced and unfamiliar with solar products at this point in time to handle the systems appropriately.

The Uganda field test has produced the following key findings with regard to the four guiding research questions:

8.1 Which lamp model do users prefer?

Distinct preferences were expressed by (i) users who had no previous experience with the use of solar lamps, as opposed to (ii) those users who had actually tested a solar lamp in their everyday life.

Clients with no previous solar lamps experience and product know-how tend to be impressed by high luminance levels ('Lamp brightness') and lamp designs that resembles the traditional hurricane lamps, with a handle at the top of the lamp and a 360° horizontal light cone, which makes people recognize the products as multi-purpose lamps that best suit their everyday lighting needs. To detect good quality, which also matters but does not drive purchasing decisions as much as light output, inexperienced lamp clients refer to the place of manufacturing (in absence of established quality labels), with products "made in Germany" high in demand and marked wariness of Chinese products.

High quality products with good light output but unimposing or unfamiliar designs gain acceptance once people have tested the lamps for several weeks in their homes (e.g. Solux 100, Freilassing, and Solux 50). In the long run, sustainable light output, i.e. consistent lighting duration at sufficient illuminance levels, and robustness of all components are the key factors for user satisfaction and willingness to pay once they know the product.

After using the lamps, people also figured out that lamps should have indications whether the switch is in on or off position; that a LED charge indicator is helpful to manage charging; that different luminance levels are a useful feature; that cables should have a sufficient length to allow for keeping the lamp safely in the house while the panel is out for charging; and that for phone chargers, the pins for different mobile phone brands should be assembled to one single piece rather than come individually as loose pins.

8.2 How did lamps perform under real-life conditions?

Overall, the field test has underpinned that in order to come to valid conclusions regarding product quality, it is imperative to complement lab tests with long-term tests under real-life conditions, especially at this early stage of the market in which lab testing methods are still in draft stage and remain in flux.

Hardly any of the lamp models in the field test met the expectations in terms of quality and durability as suggested by the lab test results.

Several lamps turned out to be equipped with inapt charge controllers for everyday use by households with no previous experience and limited understanding of solar systems. Frequent deep-discharge of batteries, low battery life-spans and overall unsatisfactory lighting service were frequently observed.

Apart from that, the components that most often caused lamps to fail were cables, plugs, input jacks and switches.
These parts are obviously under extreme stress when lamps are in everyday use by extended families with several children, and when modules are put down for charging on the ground in the courtyard (while lamps are kept inside to protect them against thieves).

8.3 Which economic and social impacts have households experienced due to the use of solar lamps?

The field test results highlight that only solar lamps with high luminance levels actually meet the lighting needs of rural households. Solux 100, which has proven to largely fulfil households' lighting needs in the field test, has a luminous flux of 80-100 lm according to the producer's specification; the GIZ / ISE lab test has established a mean luminous flux of around 50 lm over a burn time of 210 minutes for this lamp.

Almost all households continued to use some of their formerly used conventional lights in parallel with the solar lamps.
The lamp models with luminance levels that lie distinctly below that of e.g. Solux 100 had little potential to replace the kerosene-run hurricane lamps.

Nevertheless, the data show that the solar lamps have helped households save considerable expenses for kerosene and dry cell batteries. Those households that encountered no technical problems with their solar lamp spent on average 1,300 USH (0.60 US$) less on kerosene and 450 USH (0.20 US$) less on dry-cell batteries.

Also, the actual savings in running costs for lighting vary strongly between the different lamp models.
The analysis underscores that on principle, investing in a high quality lamp pays off: The savings potential of different lamps diverges enormously (up to 400 %) between high and low luminance lamp models, but also between lamps with excellent and poor technical performance.

The projected saving potential of 2,000 USH (0.90 US$) per week (assuming that one solar lamp would completely replace one hurricane lamp) established on the basis of baseline data, was reached by only one top-end product (Solux 100).
It has to be noted, however, that PicoPV kits with more than one lamp per system may allow for higher savings (none of these relatively new PicoPV products was included in the test) because they allow to illuminate more than one room at once.

The phone charging function on some of the lamp models has also proven to offer an additional source of income:
A striking 70 % of the users of solar phone chargers collected a fee for charging other people's mobiles! On average, a weekly income generating or savings potential of 3,500 USH through the phone charging function was computed.

In terms of social impacts, children have benefitted from the introduction of solar lamps in their household due to greatly improved studying conditions; men have taken the opportunity to do more reading and productive work.
A different picture emerges for women: The data point to a deferral of domestic work from the morning to the evening hours. At the same time, domestic work seems to have cut down women's time for reading, socializing and productive work in the evening hours. It is not clear whether the evidence can be interpreted as an overall benefit for women who have now more liberties in stretching their daily activities over extended days, or whether women tend to actually do more domestic work simply because the improved lighting situation gives them the possibility to do so. Further in-depth field research will be needed to come to valid conclusions regarding impacts of improved lighting on women's workload and daytime schedules, and on time remaining for social, recreational and productive activities in the evening hours.

8.4 How much are customers willing to pay for a solar lamp?

The survey indicates that the willingness to pay (WTP) for solar lamps among the targeted bottom of the pyramid consumers in Northern Uganda remains below 2010 retail price levels for the tested lamps.

However, it is significantly higher than estimated by previous publications on PicoPV in SSA (e.g. a 2010 Lighting Africa Study finds that users were willing to pay only between 6 and 11 US$ for an ambient light before they used it).

This is in particular the case for the top-end products in the sample: 200,000 USH or 87 US$ seems to mark a threshold of WTP for a solar lamp among rural households in the survey area. PicoPV Products beyond this threshold will most probably be difficult to sell at large scale in Northern Uganda. However, a niche market for the high quality products can be found among the higher income strata in the area, including electrified households that are interested to buy the lamps as back-up lighting devices for the frequent power outages.

Further, the field test observations confirm that information asymmetries between consumers and manufacturers (or dealers) with regard to product durability and robustness strongly distort WTP formation!

As consumer warranties and quality labelling of products are highly underdeveloped in rural areas in Uganda, people are very hesitant to invest major sums in costly high quality electric equipment (certainly also because limited household budgets do not allow for such risks).

9. POLICY CONCLUSIONS

To date, the considerable market potential for low-cost solar products in rural areas in Northern Uganda remains largely untapped.

With a baseline situation marked by high household expenditures for very poor lighting services and considerable sums of money spent even by poor people for charging mobile phones, PicoPV products have much to offer to the rural consumer base. They can help relieve household budgets, reduce health hazards by preventing accidents and indoor air pollution from fuel-based lighting devices, contribute to better educational outcomes, and offer new liberties on how the different household members can organize their days, thereby creating new scope for recreational, social, educational and productive activities.

Why is the market for affordable solar products not flourishing in Northern Uganda, as one might expect in view of this setting?

The principal conclusion from the Uganda field test is that the solar lamps market is inhibited by a great lack of awareness, product know-how and confidence on the side of the low-income consumer base in rural areas.

First of all, many rural consumers still do not know that the new kind of small low cost solar products exist, in spite of considerable marketing efforts by some pioneers. It is clear that reaching out to the masses of households in remote rural areas is a challenge.

Second, once people have come to learn about the new potential solution to their lighting needs, they are not in a position to make an informed purchasing decision. They would not know which criteria to watch out for to ensure that their basic lighting and phone charging needs are best served.

Thirdly, and most importantly, consumers are wary of unknown sales agents and low quality products that may not be suited for everyday use in rural households and that often do not have a reasonable lifespan. People consider the prices of PicoPV products high, often prohibitively high; this is not because they do not see the savings potential and improved lighting service offered, but because they have no guarantee that their investment will be sustainable nd tight household budgets do simply not allow for bad investments.

At the current state of PicoPV market development in Uganda, consumers cannot build trust on manufacturer promises as supply chain architectures rarely allow for enforcing warranties; consumers can also not resort to proven quality labels or established brands.

Thus, they (rightly) shy away from making a wrong investment decision which would cost many of them 1-4 times their monthly income (often due in a one-time payment in the absence of consumer credit options; this front loaded nature of payment for renewable energy services stands in contrast to payment for traditional lighting options which require lower initial investments but incur monthly fuel costs).

An equally striking conclusion from the Uganda field test is that sadly, consumer wariness of PicoPV products is well justified: failure rates among the tested products were unacceptably high, including among those products that had been the best performers in the most sophisticated lab test currently available (and in use by ISE, GIZ and the World Bank's Lighting Africa Initiative).

In spite of this pre-selection, we have found striking shares of inapt charge controllers, batteries not suited for long storage or frequent deep discharge, and poor quality cables, plugs, input jacks and switches.

Poor system design is ever more fatal in a context of unexposed users who have no previous experience with solar PV technologies and no knowledge of appropriate handling. More importantly, rural users are left widely unattended in exploring the functioning of their acquired PicoPV systems. Organising brief but effective user trainings, producers' commitment to orient their clients when they buy a PicoPV system, or-possibly less effective-printed user instructions that are tailored to rural users' backgrounds could all induce more appropriate handling of the systems, thereby increasing chances that systems better fulfil expectations.
It has to be noted that the clear discrepancy between products' lab and field performance does not come as a surprise to the

lab test developer – Fraunhofer ISE. In fact, the field tests have been agreed in advance between GIZ and ISE to be an integral element of the overall attempt to come up with a sound lab test methodology that can eventually be applied in an international quality assurance framework. It is clear that the draft lab test methods cannot be ready for the market yet, because PicoPV products require completely new combinations of battery types, charge controllers and LEDs and have to be tested together as a system. In addition, behavior of systems in storage and transportation, including both international shipping and in-country transfer to rural markets, need to be factored in.

However, the original plan to complement the 2008-2009 GIZ-ISE lab test with several 2009-2010 field tests (of which the Uganda field test was the first) and then improve the test methods based on the field results was neglected by a surprising number of NGOs, donors and governments. Instead, the draft lab test and the new PicoPV technology (with its admittedly intriguing promise to reach the famous 2 billion people without basic access to modern energy services) have been taken as a basis for massive diffusion projects in over 20 countries (in several cases with hefty subsidies for single products), at a point where methods for checking product quality are not fully mature and still need to be developed one step further.

We recommend to not implement massive diffusion programmes for PicoPV products until appropriate field testing and lab test methods have been approved, as long as sufficient quality of the lantern cannot be assured and/or a reliable warranty system for lanterns has not been established. Only sufficiently mature lab test methods, applied by sufficiently trained labs, will assure well-informed policy decisions, product certification and adequate customer information.

Overall, in view of the ultimate objective to help the market for PicoPV products pick up pace in rural areas in developing countries, the findings of the Uganda field test point to a number of possible levers to reduce bottlenecks both on the demand side and the supply side. The results make a strong case for governments and donors to take an active role in supporting quality assurance and consumer information efforts as well as further field tests which can feed back into improved lab test methods. Findings from lab test and field tests should provide the basis for manufacturers of PicoPV products to improve product design and set the right priorities for quality improvements.

The following concrete recommendations for interventions have emerged from the field research:

Active information and marketing efforts are needed to create awareness and build basic knowledge about the new kind of products among the target customer base.

Extending supply chains to reach out to rural customers is a challenge; the key success factors are good customer relations in rural areas on the one hand and sound competence for sales and after-sale service on the other hand, a combination that few individuals or institutions unite. Various supply chain models exist, and there is certainly no general "best practice" approach that suits all contexts. The experience in Northern Uganda has shown that working through locally grounded sales agents, who operate as independent micro-dealers or micro-franchisees of larger dealers, can be a successful approach. However, this model also implies challenges in terms of lack of product know-how, working capital and formal business structures.

User instructions are an essential component without which no solar lamp should be delivered; they must be easily understandable and tailored to the targeted consumers. Face-to-face user training by well-trained technicians and/or sales people could be even more effective to induce appropriate handling of the systems by the users, thus increasing product life spans and customer satisfaction.

Technical product know-how should be communicated more effectively to all agents in the supply chain. An effective tool could be e.g. technical product know-how sheets, i.e. generic fact sheets about properties of certain PicoPV product components.

A quality label needs to be established to build consumer trust; the challenge will be to communicate the label in an effective way to rural consumers. Recommendations for essential quality criteria are:

When assessing battery and module capacities, only systems that have a minimum daily burn time of 5-6 hours should be marked satisfactory. Lamps with a daily burn time below this threshold need to be equipped with an appropriate deep discharge protection to pass the lab test.

Tolerance of batteries for long storage should gain attention in the lab test reports. Batteries are needed that can be stored without need for regular charging, as it can take long for lamps to reach the country of destination, up-country retailers, and eventually customers in remote rural areas, where sales are often slower than in urban centres. Everyday use in rural households in Africa demands particular robustness of cables, plugs, input jacks and switches.

Lab test methodologies must be further developed in general, and to detect poor workmanship on these parts in specific.

In sum, various information gaps along the supply chain and on the side of end users, in combination with a lack of methodologies to underpin quality assurance systems, are preventing the high potential market for PicoPV products to unfold. However, with the clear entry points for policy interventions emerging from this report, dealing with these market barriers is possible and entirely depends on due political commitment.

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