Impact evaluation of Netherlands supported programmes in the area of Energy and Development Cooperation in Burkina Faso

The provision of solar energy to rural households through a fee-for-service system

Public Private Partnership DGIS- NUON
Implemented by FRES and the local company Yeelen Ba

- Impact Report -

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This impact report is part of an evaluation commissioned by the Policy and Operations Evaluation Department (IOB) of the Netherlands Ministry of Foreign Affairs. It belongs to a series of impact evaluations of renewable energy and development programmes supported by the Netherlands, with a focus on the medium and long term effects of these programmes on end-users or final beneficiaries. A characteristic of these studies is the use of quantitative research techniques, in combination with qualitative techniques, to get insight in the magnitude of effects. The purpose of the impact evaluations is to account for assistance provided and to draw lessons from the findings for improvement of policy and policy implementation. The results of these impact evaluations will be input to a policy evaluation of the "Promoting Renewable Energy Programme" (PREP) to be concluded in 2014.

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Table of Contents

Tables

Figures

List of abbreviations

b/w	black and white television
CFA F	Communautés Françaises d'Afrique Francs, Burkinabè Francs
CFL	Compact Fluorescent Lamp
DVD	digital videodisc
FGD	Focus Group Discussion
Diff-in-Diff	Difference-in-Differences estimation
FRES	Foundation Rural Energy Services
hh	Household
IEG	Independent Evaluation Group of the World Bank
INSD	Institut National de la Statistique et de la Démographie, National Institute for Statistics and Demography
IOB	Policy and Operations Evaluation Department of the Netherlands Ministry of Foreign Affairs
IV	Instrumental Variable methodology
kWh	kilowatt-hours
LPG	Liquefied Petroleum Gas
MW	megawatt
LED	Light-Emitting Diode
lm	lumen
lmh	lumen hours
MDG	Millennium Development Goals
N	Number of observations
NGO	Non-Governmental Organisation
OLS	Ordinary Least Squares
PREP	Promoting Renewable Energy Programme
PS	Propensity Score
PSM	Propensity Score Matching
PV	photovoltaic
SHS	Solar Home System
SOFITEX	Société Burkinabè des Fibres Textiles
SONABEL	Société Nationale d'Electricité du Burkina (state-owned electricity utility)
TV	television
UN	United Nations
VAT	value-added tax
WTA	Willingness To Accept approach
WTP	Willingness To Pay approach
YB	Yeelen Ba

Exchange rates

EUR 1 = CFA F 655	(fixed official exchange rate)
EUR 1 = CFA F 184	(PPP 2011 for Burkina Faso and the Netherlands)

1. Introduction

This evaluation report presents the impact assessment of an intervention that provides Solar Home System (SHS) to rural households in Burkina Faso using a market-based approach. The project is supported by the Dutch Ministry of Foreign Affairs and implemented by the Dutch NGO 'Foundation Rural Energy Services' (FRES), which has set up a local company called Yeelen Ba. The national regulation authority has authorized Yeelen Ba to market SHS services on an exclusive basis within rural areas of Kénédougou province in Western Burkina Faso. The SHS can provide electric light and, depending on the service package chosen by the household, allow for the usage of small electric appliances including television. The present evaluation assesses potential benefits in living conditions, for example in terms of time savings, increased security, and educational attainment. The magnitude of these impacts is likely to vary across households and with the intensity and duration of exposure. Take-up may further differ strongly between segments of the population, since often only wealthier households can afford the relatively expensive SHS. The focus of this report is therefore not only on the ultimate impacts but also on the adoption of the new energy service by the rural households. A mixed-method approach is used, i.e. the assessment relies on qualitative interviews and field visits as well as on a longitudinal database constructed by conducting two waves of surveys, one in 2010 and one in 2012, using a structured questionnaire and interviewing over 1,150 households each time.

In remote, poor rural areas with a relatively low population density and low energy demand, decentralized solutions such as SHS are a promising alternative to the investment-intensive extension of the electricity grid fed by centralised electricity generation from fossil fuels. This is particularly true for Burkina Faso, which is facing six main challenges in the energy sector. The main challenge is to increase power generation complemented by a well thought demand side management strategy in order to meet energy demands growing by an average of 10 percent per year. Another related challenge is to reform the tariff and subsidy policy in order to achieve efficiency and equity in energy services. A third challenge is to bring down the considerable transmission losses in the electricity grid that is largely operated by the state owned Société Nationale d'Electricité du Burkina (SONABEL). Two further challenges are to increase the access to electricity in rural areas and to introduce alternatives to wood fuels. Finally, establishing a sustainable supply of low-cost electricity from neighbouring countries represents the last challenge in the Burkinabè energy sector (World Bank 2007, 2013). An important regulatory step in the solar photovoltaic (PV) sector is the exemption of all solar products (including solar batteries, inverters, direct current and heat appliances) from both import taxes and value added tax, which entered into force in January 2013 for at least 5 years.

There is a large body of literature on the importance of electrification as part of infrastructure on development (see Straub 2011 for an overview). Yet, only few studies disentangle the impacts of electrification projects at a micro level employing rigorous evaluation methodologies (Koehlin et al. 2011, Bernard 2012). Even though studies do find impacts on income (Khandker, Barnes and Samad 2013) or female employment (Dinkelman 2011), an overall positive impact of electrification cannot yet be concluded. This is especially true for rural areas and SHS, for which impacts are even less well documented. Although Koehlin et al. (2011) recognise a significant uptake in solar power for lighting and TV in China, South Asia, South Africa and Kenya, only one rigorous study examined those impacts in sub-Saharan Africa (Bensch, Peters and Sievert 2013). The study is based on a relatively small sample from rural Senegal. The authors apply a matching approach called Coarsened Exact Matching to account for potential biases stemming from self-selection. They find significant effects on lighting usage as far as the quality of lighting is concerned. Moreover, they detect higher study time by children living in electrified households as well as a higher perception of security during the night. Still, they do not use a panel dataset which could give insights on longer-term impacts and further reduce the risk of biased impact estimates. Generally, longitudinal impact research on renewable energy sources is exceptional as noted by IOB (2013).

This report is structured as follows. Section 2 is a detailed description of the intervention to be assessed including introductory background information on the status quo of energy provision in Burkina Faso. Section 3 lays out the mixed method evaluation approach that is used. Section 4 discusses the results; at the heart of this section is the impact assessment along the results chain of the development intervention. Section 5 briefly summarizes the main findings. Section 6 concludes.

2. The Intervention: Market-based distribution of solar home systems

Electric power is so far predominantly supplied by the national electricity company SONABEL. 28 thermal power plants represent 87 percent of the total installed capacity of 250 megawatt (MW). The remaining 13 percent accrue to four hydro-electric stations, whose effective energy production, however, is volatile due to erratic rainfall conditions. The country's hydroelectric potential is estimated at 100 MW in five identified sites. This is considerable for African standards, but the required investment is huge. Solar potentials only very recently started being tapped. In the second semester of 2013, the largest PV project in West Africa is going to be built. The first phase of a solar PV farm near the capital of Burkina Faso, Ouagadougou, is expected to be ready by 2015, to have a capacity of 22 MW and generate 32 GWh per year, providing around 6% of the country's current electricity production. Another recent milestone was the inauguration of a solar PV production line run by the Taiwanese company Speedtech in July 2013. Nevertheless, domestic power production is still low such that energy imports increased over the past years and represent between 10 and 20 percent of the country's gross imports. All this contributes to the fact that the electricity prices are among the highest in Sub-Saharan Africa with an average of 26 US cents per kWh (World Bank 2013). It is therefore not surprising that the electrification rate is halting at 14 percent for the total population, 40 percent in urban areas and mere 5 percent in rural areas. Per capita consumption is about 50 kilowatt-hours (kWh) in Burkina Faso compared to, for example, 100 kWh in Cameroon, 270 kWh in Ivory Coast and 6,700 kWh in the Netherlands. For cooking, even 90 percent of the population rely on traditional energy sources such as firewood and charcoal (World Bank 2013).

Against this background, the Dutch NGO 'Foundation Rural Energy Services' (FRES) has set up a company called Yeelen Ba in 2008 that aims to provide electricity produced by solar energy to private households and small businesses in rural Burkina Faso. 'Yeelen Ba', which means 'Big Light' in the local language, obtained in the same year the authorization from the national regulation authority to supply energy on an exclusive basis within rural areas in 10 of the 13 districts (*départments*) in Kénédougou province. Kénédougou is one of the three provinces in the Western region of Hauts-Bassins, which is – in terms of population – the second largest region out of 13 in Burkina Faso. About 318,000 people live in rural Kénédougou, representing 92 percent of the population in that province. For comparison, Burkina Faso has a population of 16.8 million, currently growing at a rate of 3.3 percent per year. FRES has a share of 20% in Yeelen Ba via its involvement in Yeelen Kura, which is a similar company in Mali. The remaining 80% are held by NUON, a large Dutch energy provider. Apart from Burkina Faso and Mali, FRES is currently active in South Africa, Uganda and Guinea Bissau. Another project is considered for Benin.

The solar home systems offered by Yeelen Ba are subsidised by EU and Dutch funds. In July 2009, the first customer had been connected. As of end 2012, Yeelen Ba counts over 1,000 customers in villages with up to 4,000 inhabitants, while most of them are in the range of a few hundred inhabitants. The way for Yeelen Ba was paved by Yeelen Kura's operations in Southern Mali next to the Kénédougou border, which started operations in 2001 and surpassed the number of 1,000 clients provided with solar-based electricity in 2011. The living conditions in Burkina Faso and Mali are similar and households in the target area in Burkina Faso expressed on several occasions their wish to have access to a similar energy service as their neighbours in Mali.

Yeelen Ba offers different types of solar home systems (SHS) on a fee-for-service basis. The fee-for-service system has been chosen to ensure sound maintenance of the solar panels by local businesses, which eventually should be self-sustaining in the long term without any donor involvement. In principle, a standard SHS comprises an accumulator, a charge regulator, and a solar panel. The number of light bulbs and sockets as well as the power that can be used is determined by the size of the SHS. Yeelen Ba offers three different packages at different fees shown in Table 1. All systems provide enough electricity to feed at least two light bulbs for around four to five hours. Alternatively, low consumption appliances like radios, fans, or mobile phone chargers can be used. Running a fridge, for instance, is not possible and requires taking several solar panels.

Table 1: Services packages and costs offered by Yeelen Ba (all amounts in CFA F)

	Package 1		**Package 2**		**Package 3**	
	2 bulbs and 1 socket (b/w) or 3 bulbs	2 bulbs or 1 socket	2 bulbs and 1 socket (b/w) or 4 bulbs	2 bulbs and 1 socket or 3 bulbs	3 bulbs and 1 socket	
	2010	2012	2010	2012	2010	2012
Connection costs	43,660	25,430	54,280	29,580	74,980	35,800
Annual fee (in case of advance payment)	77,880	42,065	103,840	64,940	178,750	99,150
Monthly costs	6,490	3,845	8,653	5,940	14,896	9,050
Rate per day	216	128	288	198	497	302

Notes: b/w refers to black and white television. The 2010 figures refer to the price structure before the first price reduction in November 2010.

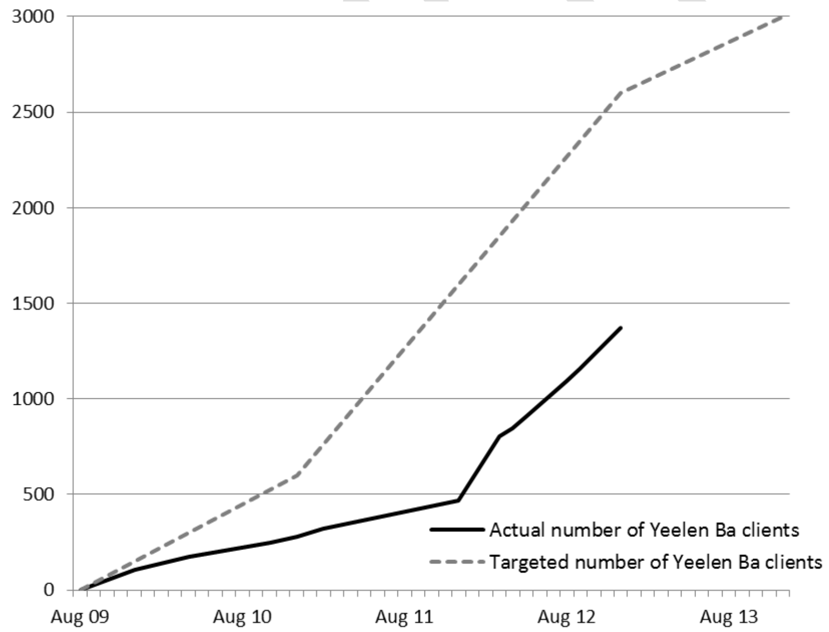
Source: Yeelen Ba August 2012.

According to the fee-for-service approach the customer rents the SHS from Yeelen Ba. Customers typically go to a sales shop in their area to subscribe to the service. They pay connection costs plus a monthly fee. If they pay for a year upfront, they get a month for free. Customers do not necessarily pay the connection costs through a single instalment since these costs can be stretched over three months – formerly even over the whole first year. The fees to be paid by customers were reduced first in November 2010 since Yeelen Ba obtained government exemption for VAT on electricity consumption and another time in January 2012 to adjust them to the prices charged by Yeelen Kura in Mali. The general rule for clients that do not pay the monthly fee is to disconnect the households after two months. However, exemptions are possible conditional on signing a letter of commitment. If households do not pay within six months, the panel will finally be removed. Since the start of Yeelen Ba, 91 systems have been removed of which 16 systems have been removed in 2012 – the latter mainly belonged to households who had accumulated debts before prices have been reduced. Moreover, several clients are suspended temporarily until they settle their current bills.

Yeelen Ba employees usually visit customers on a monthly basis to check the correct usage of the SHS and for billing purposes. Marketing activities typically include radio spots and village sensitization campaigns. Such campaigns usually include a gathering of villagers, a sensitisation regarding the Yeelen Ba products and finally a demonstration of the panels. In some villages, for example Guena and Sindo, this is complemented by door-to-door marketing, in other larger villages like Morolaba these campaigns are repeated annually. In the beginning of the project, additional small surveys assessed the market potential and the willingness to pay of households. Yeelen Ba's main selling arguments are that SHS are clean and are, in particular, more powerful and reliable than solar panels commercially available on local markets. Try-out periods are also possible for customers. A recurrent challenge for Yeelen Ba is to solve the customers' confusion about the SHS property status: People are not used to rent something, which they continuously use, without gaining ownership.

Out of Kénédougou's 151 villages, a total number of 120 villages have been targeted by Yeelen Ba's initial marketing activities. These villages accommodate about 28,000 households. In 2010 Yeelen Ba customers could be found in about 40 of them. By the time of the follow-up in 2012, the number of targeted villages had increased to 132 and the number of villages where Yeelen Ba customers can be found reached 95. The 19 villages in Kénédougou that are not served by Yeelen Ba are either already served by a different operator, for example the state-owned SONABEL, or will be assigned to a different operator in the near future. At the time of the baseline survey, Yeelen Ba had installed some 250 panels. Yeelen Ba's original objective was to reach 2,600 clients by the end of 2012 (which implied a penetration rate of about 10 percent) and 3,000 clients by the end of 2013 (see Figure 1). By serving 3,000 clients, the project is expected to reach the break-even point based on a calculation where the solar panels are replaced each 8 years and batteries reach a service life of 6 years.

Figure 1: Yeelen Ba's sales figures and objectives



Source:
Yeelen Ba and FRES December 2012.

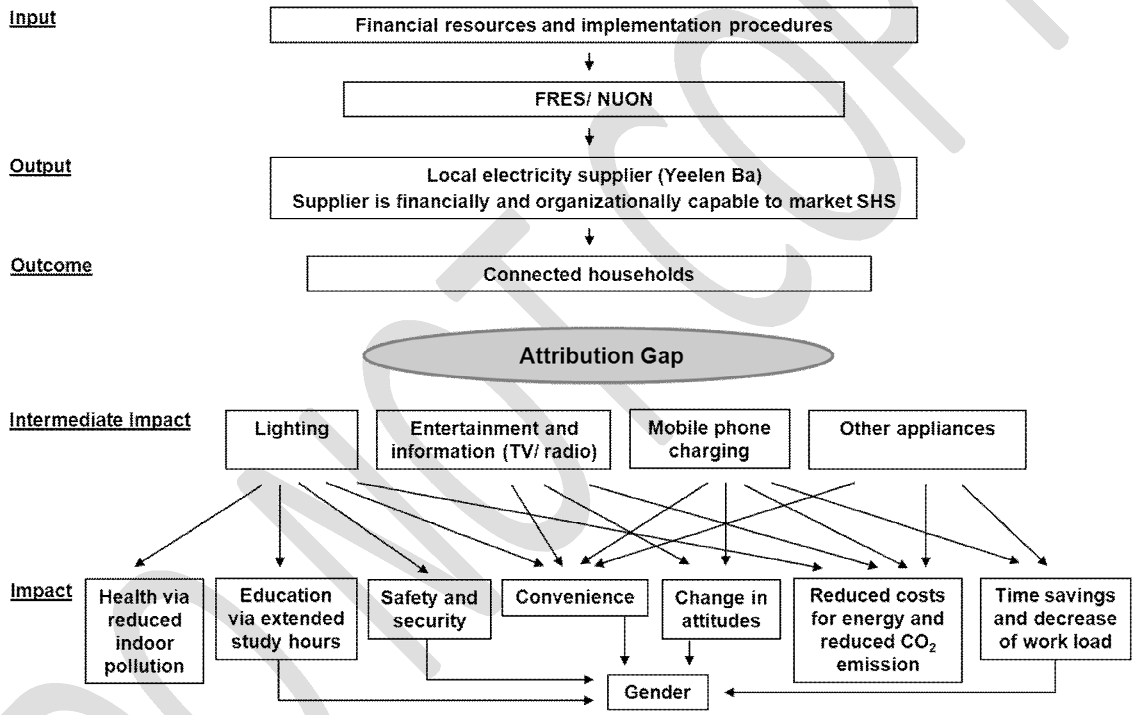
Yeelen Ba lags behind its customer targets particularly due to a difficult year 2010. First, the VAT exemption was obtained only very lately and, second, internal management problems came up, including a case of fraud caused by personnel. A new director has been appointed by FRES by the end of 2010 in order to restore order and regain confidence. Nevertheless, Yeelen Ba managed to acquire only 178 new clients in 2011. After the second price reduction in January 2012 and another change in the directorate, the customer base considerably increased such that, at the time of the follow-up in September 2012, Yeelen Ba had 1,160 clients served by 7 agencies.

3. Evaluation approach

3.1. Evaluation objective

The objective of this evaluation is to assess all positive and negative effects – intended or not – related to the market-based distribution of SHS via Yeelen Ba in the province of Kénédougou. The evaluation focuses on households. Along the results chain shown in Figure 2, the research questions listed in Table 2 on both outcome and impact level will be addressed.

Figure 2: Results chain



Source: Own representation.

We expect that for beneficiaries the major impact is on 'softer' levels such as increased convenience and comfort, i.e. using electric lighting and appliances such as radio, TV, or a mobile phone charger. Beyond the convenience and comfort level we examine impacts on household activities after nightfall. These might change in the wake of electrification due to increased usage of lighting and television, for example in terms of the time children dedicate to home studying. As the results chain shows, in principle also effects on health due to reduced indoor air pollution are possible. However, this impact can be expected to be rather small given that indoor air pollution is largely induced by traditional cooking, which is not affected by the SHS intervention. Electrification may also lead to fewer accidents with burning candles or with other lighting sources. Moreover, light may reduce the incidence of snake or scorpion bites. Since, we doubt that these aspects – while important for the perceived security – can be measured in a quantitative way, these issues have been raised in focus group discussions and are along with all other results presented in Chapter 4.

Table 2: Research questions

On the outcome level:	(i)	To what extent has access to electricity changed?
	(ii)	How reliable is the electricity supply through SHS?
	(iii)	Which socio-economic groups (incl. income groups) have benefitted from increased access?
On the impact level:	(i)	For what purpose and by whom in the household is electricity used?
	(ii)	How have expenditures for energy changed?
	(iii)	To what extent has safety/protection changed?
	(iv)	To what extent has convenience changed? What monetary value do households attribute to this increased convenience? How does this assessment differ between men and women?
	(v)	To what extent do activities during evening hours change? Have study hours/reading time of children changed? Do women and children enjoy more or less rest for physical recreation?
	(vi)	To what extent has perceived indoor air pollution been reduced (according to the dwellers)?
	(vii)	How have, in response to the possibly increased media exposure, attitudes and behaviours, such as women's status, fertility, children's school enrolment changed?

In addition, the impact on behaviour and attitudes resulting from increased media exposure will be examined, such as on women's status, reproductive behaviour, and children's school enrolment. Some studies have demonstrated that the information from and exposure to television and radio influence, for example, the desired number of children (La Ferrara, Chong and Duryea 2012; Chong and La Ferrara 2009; Peters and Vance 2011) and the reported acceptability of domestic violence towards women (Jensen and Oster 2008). Jensen and Oster also find suggestive evidence that exposure to cable television increases school enrolment for younger children. As Figure 2 shows, gender is in general a cross cutting issue in this evaluation, as many of the shown transmission channels might in particular improve the situation of women because the productivity of many home activities may positively respond to access to electricity.

3.2. Evaluation design

It is the ambition of this study to assess impacts based on a counterfactual assessment, i.e. the situation in the target areas of the project needs to be compared to a "What would have happened without the project?" scenario. For this purpose not only households are included in the study that acquired an SHS from the project, but also households who do not. The major problem faced in this evaluation setup is that the take-up of Yeelen Ba's services is not random, and hence households that acquire an electricity connection might systematically differ from those that do not. The characteristics that differ may be time-constant or time-variant and specific to the household or the village the household resides in. Not taking into account these differences by simply comparing the two groups of households bears the risk of falsely attributing changes to the programme that are in fact triggered by those non programme-related differences. To give an example, the authors of the impact report on the FRES activities in Mali, South Africa and Uganda have been confronted with this problem (PriceWaterhouseCoopers 2013). When discussing educational attainment of respondents they highlight that "[…] higher education can be a result of access to electrification but also a driver for (being able to afford) electrification." In the same way, the educational attainment of the children is affected, as their parents might pay more attention to their children's education – just because they are more educated themselves. The authors are therefore not able to disentangle the impacts of the SHS intervention from socio-economic background characteristics. In order not to suffer from the same shortcomings, much effort has been put into a rigorous evaluation design for this study, which will be outlined in the following.

If running a randomized experiment is not an option,[2] the most reliable way of accounting for selection effects is to track households in the programme's catchment area starting already before service take-up, the so-called baseline. This is also the route we followed in this evaluation. Data has been collected at two points in time, the baseline survey was undertaken in November 2010 and the follow-up survey was undertaken in November 2012 using structured questionnaires. Interviewing households in the same month is important to avoid any bias due to seasonality. In addition an RWI/ISS research assistant accompanied the data collection in order to capture determinants in the decision to install an SHS that get unnoticed in a structured questionnaire, such as being particularly economical or open to new technologies.

Based on Yeelen Ba's roll-out plan a random sample has been drawn from the villages served by the programme. This procedure was deemed to provide a sufficient number of both prospective 'control' households that won't take up a Yeelen Ba panel between baseline and follow-up and 'treatment' households who will acquire a Yeelen Ba panel. However, due to the slow uptake of Yeelen Ba panels (see Section 2) and, hence, the low number of 'treated' observations, a panel analysis using the baseline and follow-up data it became clear after the baseline that a panel data analysis has a limited potential and cannot be the unique base for the evaluation. Hence, before conducting the second survey, it was decided to shift the methodological focus of this study to a cross-sectional comparison based on the follow-up dataset.

Yet, in order to make the most of the existing panel data structure, in particular to use it in a way that it increases the rigor of the cross-sectional analysis, the sampling of households in the follow-up stage was adapted. As the number of control households exceeded the originally expected number, part of them was not re-interviewed using the comprehensive household questionnaire, but just a short questionnaire. Eliciting only basic information ensured that weights can be computed, which ensure representativeness of the results. A few households were also excluded all together, since they lived in districts without any uptake of Yeelen Ba panels and thus did not qualify as control households. These villages have instead been visited by a team member in order to gather further qualitative evidence on Yeelen Ba uptake. This sampling approach, which is described in detail in Section 3.3, freed up resources to oversample Yeelen Ba users for an improved impact assessment while guaranteeing that the representativeness of the data was not put in jeopardy.

Another finding of the baseline study that had an impact on the identification strategy was the large number of households owning (usually lower-quality) SHS that they had acquired privately on the market. They will be called 'private panel' households in the following. As will be shown, these households differ substantially from the remaining control group households without a solar panel. In the subsequent analysis, they will both be separately compared with the treatment group of Yeelen Ba households in order to serve as a lower and upper bound of project impacts.

The cross-sectional analysis is implemented through the use of a propensity score matching procedure (PSM) that matches control and treatment households on characteristics that are likely to determine the uptake of an SHS. Given the absence of pre-programme baseline data for a large part of treatment households, we chose variables of which we can reasonably assume that they are unlikely to be affected by the intervention (e.g. educational attainment, ownership of certain assets,

[2] If feasible, experimental setups are widely seen as more reliable, since they do not suffer from self-selection into treatment in the way outlined here. For an experimentally evaluated energy intervention see Grimm, Peters and Sievert (2013), which was as well prepared in the framework of the PREP series of impact evaluation studies.

characteristics of the villages they live in). With PSM the treatment effect is calculated across users and matched control units within the common support, i.e. households that are similarly likely or – given observable characteristics – have the same propensity to acquire an SHS. A high degree of similarity may reduce the risk of potential selection bias attributable to differences in observable and as well unobservable characteristics. Furthermore, different algorithms can be applied (in our case kernel in combination with caliper[3]) to better match treatment and control units. Thus, it is assumed that a comparison of two groups of households who have a similar statistical probability to use a Yeelen Ba panel (or, alternatively, private panel), but of whom one indeed does, and the other not, allow to identify impacts (for PSM see also Annex 1). A drawback of matching is that one cannot trace the way the covariates control for the observable characteristics, hence wherever this can lead to further insights PSM is combined with multivariate regression techniques where the propensity scores serve as weights (see Bensch et al. 2013, where a similar approach has been used).

With the panel data a difference-in-differences (Diff-in-Diff) approach can be implemented, even if the robustness is limited given the small sample size. Diff-in-Diff allows controlling for all confounding factors that may have an impact on the outcomes of interest and that are constant over time. The key assumption behind an unbiased Diff-in-Diff estimator is that unobserved characteristics affecting programme participation do not vary over time with treatment status. To further reduce potential biases due to systematic differences between users and non-users, we apply baseline propensity score weights to the Diff-in-Diff estimation and account for as many as possible observable time-variant characteristics including period-specific district effects. This is for instance relevant if farm-gate prices for agricultural goods vary across locations in the project area. However, we do not expect major differences in this respect, given the geographically narrowly defined project area. Compared to PSM, the Diff-in-Diff estimator better manages to isolate the effect of electrification. In the present context, however, this improved performance comes at the cost of a smaller set of households used to identify this effect. While matching can rely on 270 Yeelen Ba users who have been additionally sampled in the follow-up wave, the Diff-in-Diff approach identifies the impact only based on 58 households among the baseline sample who have started to use Yeelen Ba between baseline and follow-up (those who switched from not treated to treated). Most attention will therefore be paid to the matching results, whereas Diff-in-Diff results shall only serve as a robustness check whose information value needs to be assessed case-specifically.

Instrumental variables (IVs) are another alternative to test the robustness of the obtained results. A good IV in our case determines take-up of a SHS but does not directly affect the outcomes of interest and hence allows circumventing endogeneity problems. Distance to the closest selling point could serve as such a variable. The closer a household lives to a selling point the more likely it might be to take up the technology, but distance should not be correlated with battery or kerosene consumption; hence this variable can be used as an IV to identify the effect of having a SHS on battery or kerosene consumption. Another potential IV is the distance to the Malian border, given that private panels as substitutes to Yeelen Ba panels are much cheaper in Mali than in Burkina Faso. Again, distance should not be correlated with battery or kerosene consumption. Both variables were assessed in the course of the analysis but eventually had to be discarded, since F-tests identified them as weak instruments, i.e. their impact on uptake is not strong enough.

[3] Caliper imposes a tolerance level on the maximum propensity score distance between treatment and control and kernel applies weights to control units according to their distance to the respective treatment unit.

3.3. Data collection and sample composition

This study primarily intends to reach findings about SHS impact on households as the primary beneficiaries of the intervention. For this purpose, a certain number of households have been selected (sampled) in a way that their results are representative for the whole population in the target area of the intervention. In this context, a household is – in line with the official definition by the national statistics office INSD – defined as a community of individuals who live in the same house. These individuals pool their resources to meet their basic food needs under the authority of a single person, called the 'head of household'. In Burkina Faso, it is quite common that several individual households share the same premises.

For the baseline survey in 2010, it was decided to interview a total of 1,200 households. This sample size was derived from statistical power calculations assuming that Yeelen Ba roughly meets its client target. Applying the most direct impact indicators such as lighting hours shows that even a smaller sample size would have been sufficient to detect the expected magnitude of the impact. However, for other relevant outcomes such as respiratory diseases the expected effect size is unknown, since we lack information from other studies. Yet, the size of these impacts can be assumed to be rather small, and hence do require a rather large sample size. Other intermediary impacts such as activities after nightfall (e.g. children studying at home) can be expected to lie somewhere in between in terms of the expected effect size. In order to capture as many effects as possible while remaining within the limits of the available budget, we opted for a sample size of 1,200 households to be equally distributed across 40 randomly drawn villages in the Yeelen Ba catchment area. The interviews took place from 1 November until 25 November 2010 and 15 October to 8 November 2012.

For the household surveys, structured questionnaires were administered to the household head and key female household member. Semi-structured interviews on the community level were conducted with community leaders, schools and health facilities (see Electronic Appendix for the original French versions of the questionnaires). In addition, focus group discussions (FGDs) with group of six to ten individuals have been used to check the completeness and appropriateness of the questionnaire, to investigate and complement the exact meaning of the structured survey results and to bring them in a broader context. For example, it was probed into the reasons why certain households do not intend to take up the SHS technology and to get insights into energy-related attitudes and knowledge. For a detailed account of the survey implementation including the survey tools, sampling methodology and a timeline the interested reader can refer to Annex 3.

Partly due to changes in the methodological approach outlined in Section 3.1, four types of baseline households summarized in Table 3 have been excluded from the sample to be used for the subsequent impact analysis: first, those 210 households that are located in the seven villages not revisited by the follow up survey team as there has not been any uptake of Yeelen Ba SHS in the respective district. Second, 106 households could not be retrieved for the follow-up as they had permanently not been available during the survey – most of them had moved (e.g. to neighbouring Ivory Coast) or had temporarily abandoned their home in order to settle close to their fields during the harvest period. Two households refused to be re-interviewed. The third group that does not enter the in-depth quantitative analysis is represented by the one-third of non-Yeelen-Ba households who were interviewed using the short questionnaire. This group amounts to 232 households. Finally, households who had already owned a Yeelen Ba panel in 2010 are the fourth group of baseline households excluded from further analysis. They had already been in the treatment group before the baseline was conducted and are not useful for the present impact analysis of the Yeelen Ba panels.

Table 3: Baseline households excluded from the impact analysis

Household in non-revisited villages	Households not retrieved	Non-Yeelen-Ba households with short questionnaire in follow-up	Yeelen Ba clients already at baseline	Total
210	106	232	26	574

The quantitative impact analysis, on the other hand, includes three groups of households. They have all been interviewed using the comprehensive household questionnaire and are located in 7 of the 13 districts in the province of Kénédougou (see map in Annex 4). The first group comprises the other two-thirds of retrieved non-Yeelen-Ba households (column (1) and (2) in Table 4). The second is made up of all baseline households that had acquired a Yeelen Ba SHS between baseline and follow-up (column (3)). Finally, the remaining Yeelen Ba users living in the 33 visited villages, who have not been interviewed in the baseline survey, are listed in column (4) as the third main group of households. Altogether, the sample used for the subsequent impact analysis comprises 896 households, among which 626 households carry both baseline and follow-up information. They are highlighted in the table by a dashed line and will be used in the following for the Diff-in-Diff estimations. As explained above, the focus will, however, lie on the follow-up data framed by a dotted line in the table, which will be assed by matching approaches in the subsequent impact analysis.

Table 4: Sample used for impact analysis

	CONTROL		TREATMENT		Total
	Non-Yeelen-Ba households with long questionnaire in follow-up		New Yeelen Ba clients		
	no solar panel (1)	private panels (2)	already interviewed in baseline (3)	additionally included in follow-up (4)	
Baseline	330	238	58	-	626
Follow-up	330	238	58	270	896

Note: The group of households without a solar panel includes 39 households with a car battery or a generator set at follow-up. The dashed line shows the two-wave dataset used for Diff-in-Diff and the dotted line exposes the cross-sectional follow-up dataset that is predominantly used in this study.

4. Results

Table 4 has summarized the empirical basis for this evaluation. The two types of Yeelen Ba clients (column (3) and (4) in the table) can be taken together to represent the census of Yeelen Ba households in the surveyed villages.[4] In consequence, there are three groups that will be compared in the following: Yeelen Ba users, private panel users and households without a solar panel.

[4] As the assignment to one of these two Yeelen Ba groups occurred by pure chance, there is no reason to suspect that this difference influences the results. However, descriptive statistics of main variables listed in Annex 5 seem to indicate that there is at least a slight difference between the two groups, which, of course, may also be driven by chance.

4.1. Background household characteristics

In this section basic descriptive statistics on the socio-economic structure of the households in the project area are presented. This information refers to the follow-up situation in 2012, because the subsequent impact assessment is mainly based on the follow-up data. Readers keen to get more information on the status quo at baseline are referred to the baseline report (Bensch et al. 2011).

In this sample, 62 percent of households live in such a community of households referred to as 'concession'. All but seven sampled households are headed by men. As can be taken from Table 5, the average household is inhabited by 8.5 members, which considerably exceeds the average household size in rural Burkina Faso of 6.3 (Ministère de l'Économie et des Finances 2009). This reflects the common phenomenon that households are larger in cotton regions, such as Kénédougou, as cotton farmers tend to be better-off and may have a higher labour demand.[5] At the same time, polygamy is widespread in the intervention area and typically richer men have more wives. This can be seen when disaggregating the household composition by expenditure quintiles and may well explain the significantly larger number of household members in Yeelen Ba households.[6]

Table 5: Household structure

	Yeelen Ba	Private Panel	No Solar Panel	Expenditure Quintile	
				1st	5th
Household size	9.6	8.4***	7.5***	6.2	10.5
Share children under 6 years, in %	22.5	22.2	21.9	24.6	21.3
Share of elderly (older than 64 years), in %	3.5	3.2	4.2	4.7	2.8
Age of household head	42.9	42.7	44.6*	42.5	44.5
Share of polygamous households, in %	66.5	62.6	48.5***	35.4	71.4
Ethnicity of household head					
Senoufo, in %	21.2	51.3***	41.4***	48.0	41.2
Toussian, in %	52.9	13.0***	19.4***	18.3	22.6
Bolon/ Dafing, in %	7.6	18.5***	12.7**	11.5	11.6
Number of observations	328	238	330	147	227

Note: The asterisks refer to the significance level detected by *t*- and *chi-squared* tests on differences in means between the group of Yeelen Ba households and either private or no solar panel households. *, ** and *** indicate significance levels of 10%, 5% and 1%, respectively.

Source: Solar Home System follow-up dataset 2012

The surveyed households mainly belong to eight different ethnicities with the largest three being displayed in Table 5. Ethnicity and household expenditure do not seem to be strongly correlated, whereas there are highly significant differences between the three compared groups in terms of ethnicity as such. The share of Toussians, for example, is around three to four times higher among Yeelen Ba households. This particularity will be further examined below.

[5] Cotton farmers are on average better-off than pure food crop farmers, first of all because they participate in the export market, but also because they have better access to fertilizer and pesticides (see Grimm and Günther 2007a, b) which helps them to achieve a higher productivity. However, they are on the other hand more exposed to variations in weather conditions and cotton prices on the commodity markets.

[6] Note that expenditures will be used throughout the analysis as a proxy for income of a household since in the given context it is easier to measure expenditures than income. Households earn income from many different and irregular sources so that it is difficult for them to provide precise information. Moreover they are typically more reluctant to report income than consumption. Expenditures refer to yearly household expenditures per capita and include expenditure for food (both consumed at home and in restaurants), clothing, health, energy, telecommunication, transportation, education, ceremonies and resources sent to other family's members, agricultural and livestock activities. Auto-consumption is not included in the expenditure aggregate.

Agriculture is the main income source in the project area. Among the sample population, 98 percent of all households report to own land and more than 90 percent of household heads are primarily occupied with agriculture (Table 6). Even though richer households work more often in farming, this is not the case for Yeelen Ba households. They are significantly more likely to be found among civil servants, who make up only a very small percentage of the sample. Lastly, small entrepreneurs like retailers, blacksmiths and mechanics account for 5 percent of household heads. Maize and cotton are the most important cash crops. The share of cotton farmers is, in general, high compared to other parts of Burkina Faso. Cotton is particularly relevant in the northern part of the province, where the two larger cotton factories of the state-controlled SOFITEX (Société Burkinabè des Fibres Textiles) are located, which process the cotton into fibre for export. Focus group discussions revealed that villagers in the south used to cultivate more cotton before as well, but given the recent price decline, they started to diversify their agricultural production to vegetables, fruits and other cash crops.

Table 6: Agriculture, livestock and land ownership

	Yeelen Ba	Private Panel	No Solar Panel	Expenditure Quintile	
				1st	5th
Sector of activity of household head					
farming, in %	88.7	92.4	92.7*	86.3	95.0
public service, in %	4.0	1.3**	0.6***	0.1	1.3
other, in %	5.8	4.6	3.3	6.7	2.8
Household cultivates land, in %	94.2	98.3***	98.8***	96.5	99.5
Size of land owned, in ha	17.2	13.4	11.6*	7.5	18.9
land used for food crops, in ha	10.9	8.9	8.1	5.7	12.5
land used for cash crops, in ha	6.3	4.5	3.5**	1.7	6.4
Cotton producers, in %	60.4	69.6**	53.6***	43.4	72.3
Livestock owners, in %	88.2	92.4*	88.7	80.9	98.5

Note: *, ** and *** indicate significance levels of tests on differences in means to the Yeelen Ba households of 10%, 5% and 1%, respectively.

Source: Solar Home System follow-up dataset 2012.

72 percent of all household heads did not receive formal education (Table 7), part of whom went to Islamic alphabetisation courses (census data reports 64 percent; Ministère de l'Économie et des Finances, 2009). In general, the household members' educational attainment strongly relates to sex, income and age. For example, 84 percent of all household head's spouses do not have any formal education. This share is particularly high among the very poor households with 90 percent. Examining primary school enrolment rates for children between 7 and 12, it can be seen that the situation has significantly improved over the last decade, including gender differences. Today about 65 percent of all children are enrolled in school and there seems to be no significant difference between boys and girls at least regarding primary school enrolment. Differences, though, remain among children from different income groups and are particularly pronounced between the three groups compared (see also Table 7).

Table 7: School enrolment and educational attainment, in percent

	Yeelen Ba	Private Panel	No Solar Panel	Expenditure Quintile 1st	Expenditure Quintile 5th
Education of household head		**			
no formal education	72.8	68.2	73.9	72.2	61.5
primary education	18.4	26.6	20.6	21.4	32.8
secondary education and more	8.8	5.2	5.5	6.4	5.7
Education of household head's spouse			***		
no formal education	77.4	81.7	86.2	90.4	76.1
primary education	19.7	16.6	13.2	9.6	22.7
secondary education and more	2.9	1.7	0.6	0.0	1.2
Primary school enrolment among children aged 7-12					
all children	75.9	57.4***	64.2***	52.3	63.8
boys	73.1	64.6**	63.0***	53.1	71.2
girls	78.8	50.6***	65.5***	51.4	57.1
Secondary school enrolment among children aged 13-16	44.4	25.0***	30.2***	24.9	33.6

Notes: Official school entrance age is 6 (in practice often later) and lasts six years. The category "secondary education and more" includes persons who completed vocational training or went to university. *, ** and *** indicate significance levels of tests on differences in means to the Yeelen Ba households of 10%, 5% and 1%, respectively.

Source: Solar Home System follow-up dataset 2012.

Considering the households' six main expenditure categories, the highest share of total income is spent on food (17 percent of total expenditures). This share is relatively constant across expenditure quintiles while the budget share spent on transportation increases with total expenditures. In contrast, the expenditure shares on health and clothing decrease over the expenditure distribution (Table 8). Across the three compared groups, no clear pattern is observable. Only for schooling, it can be found that Yeelen Ba households spend the most money, which is in line with enrolment figures presented above.

Table 8: Share of total expenditure spent on various expenditure aggregates and per capita expenditure

	Yeelen Ba	Private Panel	No Solar Panel	Expenditure Quintile 1st	Expenditure Quintile 5th
Expenditure aggregate (in %)					
food (incl. restaurants and water)	17.1	14.8*	18.0	15.2	16.0
transportation	14.2	17.2**	10.9***	8.5	14.5
telecommunication	9.0	9.6	7.7*	9.8	8.1
schooling	8.1	4.4***	6.2**	5.3	6.8
health	7.8	6.9	8.4	11.8	5.3
clothing	7.1	6.8	7.8	12.9	4.4
Total yearly per capita household expenditure (in CFA F)	179,910	168,670	119,050***	44,830	295,030

Note: *, ** and *** indicate significance levels of tests on differences in means to the Yeelen Ba households of 10%, 5% and 1%, respectively.

Source: Solar Home System follow-up dataset 2012.

The households' subjective perception of their income situation is presented in Table 9, where it is contrasted with the so-called asset index as an objective wealth indicator reflecting the ownership of different household assets.[7] Half of the households consider their income as either appropriate or

[7] In accordance to Filmer and Pritchett (2001) and Sahn and Stifel (2003), the asset index is constructed as a single index calculated with principal component analysis using information about the ownership of bicycles, motorized vehicles, phones, radios, sheep, and cows, as well as the housing conditions (wall, floor and roofing material).

sufficient, while the other half believes their income not to be sufficient. Yeelen Ba households are more satisfied with their income situation than households without a solar panel. Yet, they are less satisfied than private panel households, where only 40 percent perceive their income as insufficient.

Table 9: Perception on household's income, in percent

	Yeelen Ba	Private Panel	No Solar Panel	Expenditure Quintile	
				1st	5th
Perception on household's income		**	***		
sufficient	12.2	19.4	12.2	9.3	18.9
appropriate	38.2	40.9	27.4	24.2	39.3
insufficient	49.5	39.7	60.4	66.5	41.8
Asset index	0.69	0.69	0.56***	0.48	0.73

Note: Since the asset index takes negative values, it is linearly transformed such that it ranges from 0 to 1. *, ** and *** indicate significance levels of tests on differences in means to the Yeelen Ba households of 10%, 5% and 1%, respectively.
Source: Solar Home System follow-up dataset 2012.

With respect to the accessibility of the villages and access to markets from these villages it can be noted that during the rainy season (June to August), districts in the South of the province are better accessible. Table 10 reports that 38 percent of them have a 'good' road connection (not necessarily paved) to the main road that connects Bobo-Dioulasso and Mali, while in the Northern part of the province only 10 percent of the interviewed villages report to have a good connection to the main road going to Orodara and Bobo-Dioulasso (see map in Annex 4). In the South, 62 percent of villages do not have a regularly organized market compared to 50 percent in the North. The average distance between those villages without an own market and the closest market (which can be in another village or nearby a road) is around 10 kilometres.

Table 10: Village accessibility and market access

Village location	Road accessibility during the rainy season (in %)				Share of villages without a market (in %)	Distance from closest market outside village (in km)
	good	possible with difficulties	possible in case of emergency	inaccessible		
North	10.0	20.0	50.0	20.0	50.0	9.9
South	38.4	30.8	30.8	0.0	61.5	9.2

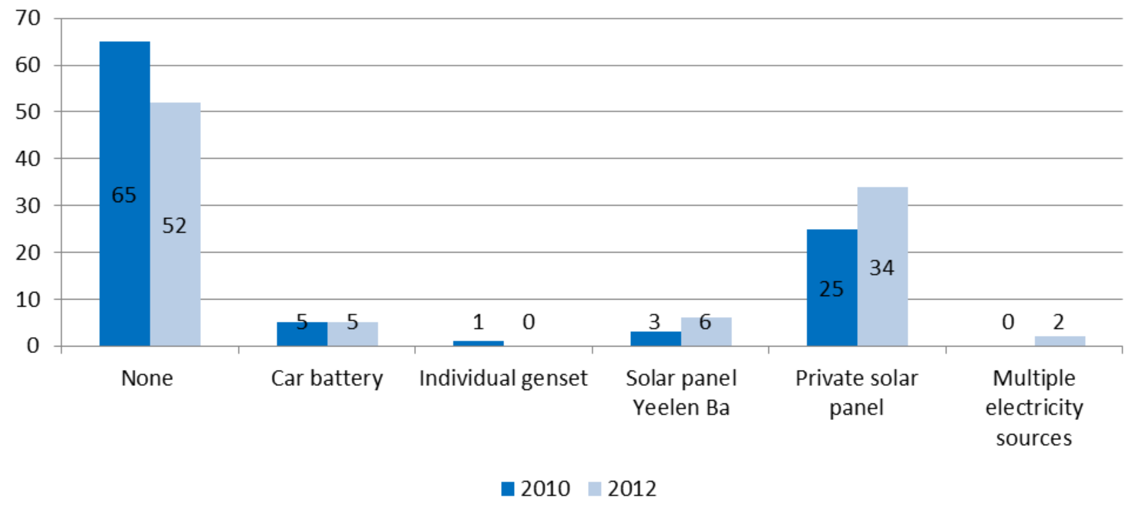
Note: As reported by village head or contact person. 'North' refers to the 20 villages in the four districts in the North of the province (Kayan, Morolaba, Samorogouan and Sindo) and 'South' to the 13 villages in three Southern districts of Djigouera, Koloko and Kourinion.
Source: Solar Home System baseline dataset 2010 and follow-up dataset 2012.

Among the background variables presented in this section, a set of essential household characteristics is distilled that are potential relevant drivers of both the decision to acquire a solar panel and of the related impacts. The following variables are used as variables in a model trying to explain the decision to acquire a certain electricity source (section 4.2): Household size, whether the household is polygamous, the age of the head of household, whether s/he has formal education and whether s/he is a subsistence farmer. Further selected variables related to the economic situation of the household are the asset index and the monthly household expenditures excluding energy. This joint set of variables turned out to have the highest explanatory power. These variables also enter the list of covariates included in all regression analyses in section 4.3 and are used for the construction of the propensity scores to be used for matching in the same section. As can be seen in Annex 6, the applied matching approach succeeds in producing three groups that are comparable along these observable key variables. Hence, the balancing condition is fulfilled.

4.2. Yeelen Ba panels and alternative electricity sources

This section briefly presents details on the uptake of Yeelen Ba SHS and alternative electricity providing devices. The high rate of electricity users is certainly one of the most surprising results of the survey. While the official electrification rate in rural Kénédougou was zero at the time of the last publicly available household living standard measurement survey in 2003, at the baseline stage already every fourth surveyed household had access to some form of electricity. Even if one excludes car battery users, at follow-up stage already more than 43 percent of the households can be considered electrified (mostly via SHS, see Figure 3).[8] As become already clear above, while Yeelen Ba has been active in the region for about three years, most of the electricity-using households have a private solar panel (36 percent), which they bought on markets, mostly in Bobo-Dioulasso and across the border in Mali. No other service provider or NGO distributes panels in the surveyed villages. The penetration rate of Yeelen Ba is six percent and further five percent possess a car battery to operate their electric appliances. Other sources like individual diesel generators or a connection via neighbours are rarely used and only two percent of the households have multiple electricity sources at their disposal. 53 village associations own generators, which are used in case of public celebrations but also rented out for individual celebrations, to neighbouring villages or for selective productive use activities. Individual diesel generators (gensets), instead, are virtually inexistent. Interestingly, a few households use the battery of their motor-bicycles as electricity source to charge their mobile phones. No household is connected to the national grid, which was the pre-condition for the government to give Yeelen Ba the licence for this area. It is planned to establish a connection from Orodara to Koloko, thus electrifying two of the surveyed villages: Koloko and Mahon. Nonetheless, for Mahon that would most probably mean that only the households situated directly along the road gain access to the grid.

Figure 3: Electricity sources, in percent



Source: Solar Home System baseline dataset 2010 and follow-up dataset 2012.

[8] The high penetration of private solar home systems was already stated in a short market analysis undertaken by Yeelen Ba. This study reports that 27 percent of all interviewed households in 47 villages of the project area owned a solar panel with battery. However, the report emphasizes that this high share is probably biased as a count across all households in the 47 villages visited would yield a penetration rate of 4.3 percent. It is not clear from the report how that count was obtained. The report further states that most of these solar panels are of weak quality and are mainly used for TV and less frequently for lighting (Yeelen Ba 2010).

Coherent with the findings in Section 4.1, when looking at the ownership of electricity sources across the five expenditure quintiles it can be seen that there is a strong correlation between income and the availability of electricity sources. While a high share of the first expenditure quintile has no electricity source, this share drops with increasing expenditures. Households using car batteries, clearly an inferior electricity source compared to solar panels, are slightly more represented in the third expenditure quintile. For all other electricity sources, it holds that the richer the household the more likely it is to own an electricity source. Thus, as we would expect, a high income seems to be a determinant of the usage of a solar panel – private or Yeelen Ba.

Table 11: Electricity source ownership, in percent

Electricity Source	**Average**	**Expenditure Quintile**				
		1st	**2nd**	**3rd**	**4th**	**5th**
None	50.2	78.2	60.1	49.9	34.5	27.8
Car battery	6.4	2.6	8.5	7.7	6.1	7.2
Individual genset	1.1	0	0.8	0.8	1.8	1.9
Yeelen Ba	6.7	3.3	5.4	6.3	6.5	12.2
Private panel	37.2	16.3	26.3	35.9	52.9	55.0

Source: Solar Home System follow-up dataset 2012.

For a closer look at the determinants of owning a Yeelen Ba or a private panel a multinomial logit model is applied with the ownership of a Yeelen Ba panel and of a private panel as the two dependent variables. The 330 households owning no solar panel (including 39 households with a car battery or individual diesel generator) serve as reference case. Such a model can work out the correlations between the ownership of one of the two devices and socio-economic characteristics in a multivariate setting. It thereby accounts for joint interactions among different variables and goes beyond the comparison variable by variable that has been conducted in Section 4.1. The final model is given in Table 12. It incorporates the control variables reported at the end of Section 4.1 as well as the distance to the next Yeelen Ba agency and district dummies. In an iterative process, various further variables that have been raised as potential influencing factors were tested for inclusion such as the share of children under 15, Toussian ethnicity, distance to the Malian border and association membership of the household head. The presented model proved to be the most coherent one. The variables included cover the household composition as well as financial aspects, basic socio-economic indicators and the distance to the next Yeelen Ba agency. District dummies account for potential regional differences.

When looking at the coefficients with Yeelen Ba as dependent variable, it does not come as a surprise that household expenditures and the asset endowment are of importance. In addition, households with more members are significantly more likely to own a Yeelen Ba panel. The age of the household head plays also a role. When accounting for both the linear and squared term in the estimation, the probability of a household having a Yeelen Ba panel decreases with the age of its head, until he or she reaches an age of roughly 65 years. Only for older household heads, the probability increases again. In general, the driving forces seem to be similar for Yeelen Ba and private panel households, even though they are more pronounced and significant among Yeelen Ba households. In line with expectations, selection into solar panel ownership seems to be stronger here. Nevertheless, the model underpins the impression that could already be gleaned in Section 4.1: that households without solar panels and private panel households represent two distinct groups. Understandably, the only coefficient where Yeelen Ba and private panels differ in terms of direction is the *distance to next Yeelen Ba agency*. The coefficient is positive for private panel households and negative for

Yeelen Ba household. This means that a household is more likely to have a Yeelen Ba panel the closer he lives to an agency and vice versa for the private panels.

Table 12: Multinomial logit estimates of using a Yeelen Ba panel or a private panel

Independent Variables	**Dependent Variable**	
	Yeelen Ba panel	Private panel
hh size, in logarithmic terms	0.562**	0.159
	[0.03]	[0.52]
Polygamous hh (=1)	0.179	0.026
	[0.48]	[0.91]
Age of head of hh, in years	-0.125**	-0.063
	[0.01]	[0.17]
Squared age of head of hh	0.001*	0.000
	[0.05]	[0.39]
Head of hh has formal education (=1)	-0.623	-0.413
	[0.16]	[0.33]
Head of hh is subsistence farmer (=1)	0.000	0.131
	[1.00]	[0.55]
Asset index	4.802***	5.535***
	[0.00]	[0.00]
Monthly hh expenditures excluding energy, in logarithmic terms	0.617***	0.368**
	[0.00]	[0.01]
Distance to next Yeelen Ba agency	-0.005	0.006
	[0.60]	[0.33]
District Dummies	yes	yes
Constant	-7.544***	-6.770***
	[0.00]	[0.00]
Observations	858	858

Note: *p*-Values in parentheses. Stars indicate significance level with * $p<0.1$; ** $p<0.05$; *** $p<0.01$. Observations are weighted and 44 observations are lost due to missing information. Household size and household expenditures are used in their logarithmic form in order to not put too much importance to extreme values.

Source: Solar Home System follow-up dataset 2012

Other more subtle reasons that govern the decision to acquire a Yeelen Ba panel have been tried to be elicited in interviews and FGDs. The FGDs in villages with both high and low take-up primarily delivered insights about the perception of Yeelen Ba. An important factor seems to be a kind of a "leadership effect", which is the importance of the experience of early adopters for the take-up of new technologies in a community. This aspect is discussed in detail in Section 4.4 together with findings on the perception towards Yeelen Ba in general. The interview with the local Yeelen Ba representative responsible for the two districts Koloko and Kangala where parts remain without any Yeelen a uptake led to the following insights. First, she highlighted the closeness to the Malian border. Many households cross the border to buy their solar panel in Mali, as panels are significantly cheaper there. According to her, the major obstacle to a user-fee based system is that most of the households are just not used to pay for something they do not own. Another reason she gave for the higher take-up observed in certain areas of the Kourinion and Djigouera district is the concentration of households of the Toussian ethnicity. Toussian women are known to have more influence on the decision making in their households. First, they may stress more the benefits of electricity for women and children and, second may persuade their husbands to r rather rent a long-lasting higher-quality panel than to buy a lower-quality private panel without any after-sales service.

Most households have already been using their electricity source for some years (see Table 13). In contrast, Yeelen Ba panels are on average in use for about a year, as Yeelen Ba has attracted most customers in 2012. Non-Yeelen Ba SHS are on average four years old. This information, though, does not necessarily refer to the year when households started to use electricity for the first time, but to the duration of the energy source by the time of the survey. Figure 4 traces the number of new Yeelen Ba customers. Two groups are distinguished, those who had a private panel before and those who did not. The figure indicates that a non-negligible share had already a private panel before. In total, 12 percent of Yeelen Ba households stated that they have used to own a private panel before, while 76 percent said that they had no source of electricity. It has to be noted, though, that these figures are likely to underestimate the proportion of households for whom Yeelen Ba does not represent first-time electricity access, as they are based on retrospective questions that might not have fully been understood. Among the 58 new Yeelen Ba customers who were interviewed in both survey waves, for example, as many as 23 (equal to 40 percent) already owned a private panel at baseline. In contrast, not a single user of a private panel owned a Yeelen Ba panel before; in fact 88 percent had no electricity source at all before according to their statements. Among the households without any source of electricity, only 12 percent have already possessed any source of electricity in the past.

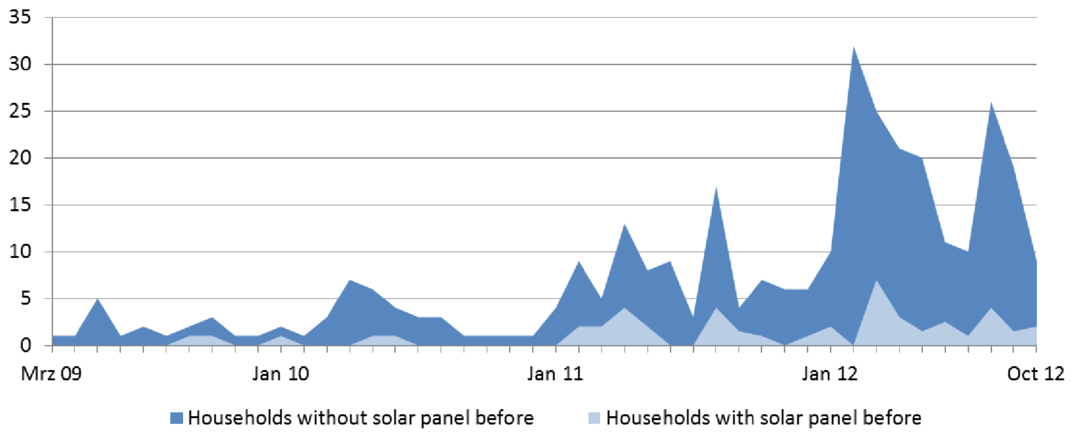
Table 13: Duration of energy use by source

Electricity Source	Car Battery	Individual Genset	Yeelen Ba Panel	Private Panel
Age, in years	2.4	6.6	1.0	4.0
Share of users without any electricity source before, in %	–	–	76	88
Number of observations	40	10	325	279

Note: For three Yeelen Ba households no acquisition data was available.

Source: Solar Home System follow-up dataset 2012.

Figure 4: Number of new Yeelen Ba clients, by month of panel acquisition



Source: Solar Home System follow-up dataset 2012.

Both households with Yeelen Ba and private SHS largely use just one panel. A few (around 3 percent of Yeelen Ba users and 5 percent of private panel users) installed two panels to increase the available power. Concerning the reliability of the new electricity access, eleven percent of Yeelen Ba users stated that there was a time in the last six months when their solar home system did not work. In almost half the cases, this was simply due to a broken lamp, which also has to be replaced by the company. Excluding these cases, Yeelen Ba customers had to wait for one month (35 days) until the problem has been fixed by a Yeelen Ba technician. The policy promising that every problem will be fixed within 48 hours after reporting, therefore does not seem to be fully effective yet. In comparison, the private panels do not seem to perform considerably worse: only about three percent of their users experienced a system failure in the six months preceding the interview, whereas 17 percent incurred reparation costs during the last 12 months, usually including replacement of lamps. On average these costs amounted to 20,619 CFA F, while Yeelen Ba clients had no such costs at all due to fee-for-service concept where the maintenance is included in the monthly fee.

4.3. Impact Assessment

The following impact assessment addresses the intermediate and ultimate impacts as outlined in Figure 2 in Section 3.1. As a starting point, the households' own appraisal of the main purposes the solar panels are used for is presented in Table 14. For private panel households even more pronounced than for Yeelen Ba households, lighting as such represents the primary purpose of electricity. These results are in line with a study of the Independent Evaluation Group (IEG) of the World Bank based on ten World Bank electrification projects, according to which lighting and television account for the lion's share (about 80 percent) of rural electrification consumption (World Bank IEG 2008).

Table 14: Purpose of electricity usage for Yeelen Ba and private panel households, in percentage

	Yeelen Ba			Private Panel		
	1. purpose	2. purpose	3. purpose	1. purpose	2. purpose	3. purpose
Lighting	78.3	13.4	1.9	88.7	6.7	0.4
Studying	15.8	40.1	6.2	5.5	26.1	5.9
TV	1.6	8.1	8.1	0.8	10.1	5.1
Security	0.9	6.2	5.0	0	3.8	0.8
Mobile phone battery recharge	0.3	6.2	5.3	0.4	13.9	9.3

Source: Solar Home System follow-up dataset 2012.

4.3.1. Usage of traditional energy sources

In terms of traditional energy sources, the data confirms what can be observed in many rural areas in Africa: the advance of dry-cell battery driven lamps imported from China, in French called 'lampes chinoises'. As a consequence, kerosene and candles are no longer the dominant fuels for lighting purposes. In 2003, kerosene still was the main source of energy used for light for 99.4 percent of rural households, whereas among the rural households sampled in 2012 clearly less than ten percent use kerosene at all (see figures in squared brackets in Table 15). Candles even vanished completely from the survey region. Now the most common energy sources beyond firewood for cooking are batteries. Most batteries (on average 77 percent) are used for lighting, with 21 percent of batteries used for radio and 2 percent for other purposes.

Table 15 lists the two traditional energy sources whose consumption is affected by the solar energy intervention, kerosene and batteries. To document impacts three sets of estimates are shown: a simple mean comparison based on the cross-section sample, a mean comparison based on the matched cross-section sample and a Diff-in-Diff comparison based on the panel data. To allow the reader to get an idea about the effect size, in each case the mean difference and the sub-group means are shown (in brackets). Differences between the groups as determined by matching represent the most reliable impact estimates in the present setup. Diff-in-Diff estimations serve as a robustness check.

Table 15: Impacts on energy source usage, in percent

		Control group	Difference between Yeelen Ba and control group				
			Non-adjusted means		Matching		Diff-in-Diff
Kerosene	Share of users, in %	no solar panel	-7.9***	[1.5 - 9.4]	-6.0***	[1.7 - 7.7]	-1.2
		private panel	-1.8	[1.5 - 3.3]	-2.0*	[1.6 - 3.6]	-2.0
	Consumption per month among users, in l	no solar panel	-0.4	[1.2 - 1.6]	-0.8*	[1.2 - 2.0]	-0.4
		private panel	0.0	[1.2 - 1.2]	-0.1	[1.2 - 1.3]	0.1
Batteries	Share of users, in %	no solar panel	-2.5**	[96.6 - 99.1]	-3.4***	[96.2 - 99.6]	-3.4*
		private panel	-1.2	[96.7 - 97.9]	-0.8	[96.4 - 97.2]	-0.6
	Consumption per month among users	no solar panel	-0.1	[10.8 - 10.9]	-3.7***	[10.4 - 14.1]	-5.0**
		private panel	0.7	[10.8 - 10.1]	0.3	[10.8 - 10.6]	1.7
Number of observations (treatment and control)		no solar panel	328 and 330		308 and 319		55 and 317
		private panel	328 and 238		308 and 231		55 and 228

Notes: Figures in squared brackets refer to the mean values of Yeelen Ba households and the control group, the difference of which yields the value of interest. Due to the applied matching algorithm including the common support condition, means in the Yeelen Ba group can differ across the two alternative comparison groups. *, ** and *** indicate significance levels of 10%, 5% and 1%, respectively.

Source: Solar Home System baseline dataset 2010 and follow-up dataset 2012.

For both energy sources, the table presents figures on the proportion of households using the source and the amount these using households consume. These two aspects can be expressed as the extensive margin (usage yes/no) and intensive margin (how much usage) of energy usage, respectively. The largest difference can be observed for kerosene between households with and without solar panels. The share of households without solar panel who use kerosene is almost three times the share of private panel households and six times the share of Yeelen Ba households (9.4 versus 3.4 versus 1.6 percent). This is not surprising since kerosene is mainly used for lighting and electrified households can substitute kerosene lamps with electric lamps. The average monthly consumption of kerosene-using households amounts to 1.5 litres where households with solar panels consume slightly less. However, overall the use of kerosene is relatively low. During focus group discussions villagers confirmed a substantial decrease in kerosene consumption in recent years, especially for lighting. This is mainly due to increasing kerosene prices and the availability of low-cost battery driven lighting devices. The impact on batteries is thence similar to that of kerosene, though less accentuated: The share of battery users goes down compared to both control groups (but remains high with around 96 percent) and consumption only becomes lower compared to households without solar panels.

Cooking is not affected by the intervention (see also the following section on appliances). Nevertheless, collecting firewood is an essential part of every-day life for virtually all households. Roughly 99 percent of households, regardless of their electricity status, stated that they regularly collect firewood. There are only 0.7 percent of these households that only buy firewood. Women are in most cases responsible for firewood collection (94 percent); children only in a few cases (5 percent). An average household takes five and a half hours to collect the 16 bundles used per week.

As confirmed in focus group discussions, liquefied petroleum gas (LPG) as a cleaner cooking fuel is predominantly used by the better-off civil servants, which is why one also observes a higher share of LPG users among Yeelen Ba households, which nevertheless does not exceed 5 percent.

4.3.2. Appliance ownership

The most frequently owned electronic appliances are mobile phones, followed by lamps and battery-powered radios (Table 16). Television and DVD recorders and, to a lesser degree, cassette recorders, line-powered radios and fans are also used in electrified households. Ownership basically means having a single appliance of the respective type. Multiple units per household can be found for lamps (see next section) and mobile phones. Among mobile phone-using Yeelen Ba households each household possesses on average 2.5 mobile phones, 38 percent even three or more. Electric devices like TV sets owned by households without solar panels have sometimes been received as a gift from relatives. They are only used by those few households owning car batteries or gensets.

Some of the households have already taken part in the baseline survey in 2010, where they have been asked about their desired electronic appliances. Interestingly, most household heads did not think of lighting as the most urgent appliance but rather preferred to own a television. However, they may not have fully accounted for the additional costs of buying a TV on top of the electricity source. Their wives rather preferred to obtain a refrigerator. This is especially true for the Yeelen Ba group. However, refrigerators cannot be run with a single Yeelen Ba package and also need more power than is typically provided by private panels. Hence it is no surprise that refrigerators are virtually inexistent in our sample of households.

Table 16: Appliance ownership in surveyed households, in percent

Appliances	**Yeelen Ba**			**Private Panel**			**No Solar Panel**		
	Owned (2012, N=328)	**Previously most desired** (2010, N=35)		**Owned** (2012, N=238)	**Previously most desired** (2010, N=113)		**Owned** (2012, N=330)	**Previously most desired** (2010, N=308)	
		male	female		male	female		male	female
Mobile phone	98.6	0	2.9	97.9	1.8	1.8	88.5	1.2	1.7
Lamps	100	8.6	0	92.8	20.4	15.9	9.7	14.3	13.0
TV	50.3	74.3	62.9	43.7	70.8	62.5	4.5	64.9	61.1
DVD	26.8	0	–	26.9	0	0.9	0.6	0.3	0.3
Radio									
Battery only	42.7	–	–	50.0	–	–	53.9	–	–
electric	19.5	0	0	28.2	0.8	0	3.9	1.3	1.0
Cassette recorder	19.2	11.4	0	25.2	2.7	0	6.7	7.1	2.3
Refrigerator	1.2	0	17.1	0.4	0.8	12.4	0	4.2	13.6
Fan	5.5	0	0	7.6	2.7	0.9	0	0.6	0.3
Charcoal iron	4.6	–	–	5.5	–	–	2.4	–	–
Fuel-run mill	5.8	5.7	11.4	9.7	0.8	4.5	4.5	3.2	4.6

Notes: Baseline and follow-up sub-sample figures differ because baseline data can be only be shown for those follow-up households who have been interviewed and belonged to the same group in the baseline. This is not the case for the newly included follow-up Yeelen Ba households and for those follow-up private panel and no solar panel households, who acquired a solar panel only after baseline or got disconnected in the meantime, respectively.

Source: Solar Home System baseline dataset 2010 and follow-up dataset 2012.

For the four main appliances – mobile phones, lamps, TV and radio – Table 18 delivers impact figures related to the change in ownership shares. Differences in mobile phone ownership turn out to vanish completely when applying matching. For lighting and television, considerable changes occurred, which are attenuated in the Diff-in-Diff perspective as this analysis better accounts for the fact that a good part of the new Yeelen Ba clients already owned other electricity sources (notably private panels) before, which have been used in particular to light electric lamps. In light of the supposed quality differences between Yeelen Ba and private panels, it is interesting to see that there are actually differences between the two groups in terms of ownership (usage intensity will be looked at later). While Yeelen Ba households use more lighting and TV, it seems that the limited number of options to connect appliances to the panels rather discourages them to run radios. The number of radios is significantly lower in Yeelen Ba households compared to private panel households.

Table 17: Impacts on appliance ownership, in percent

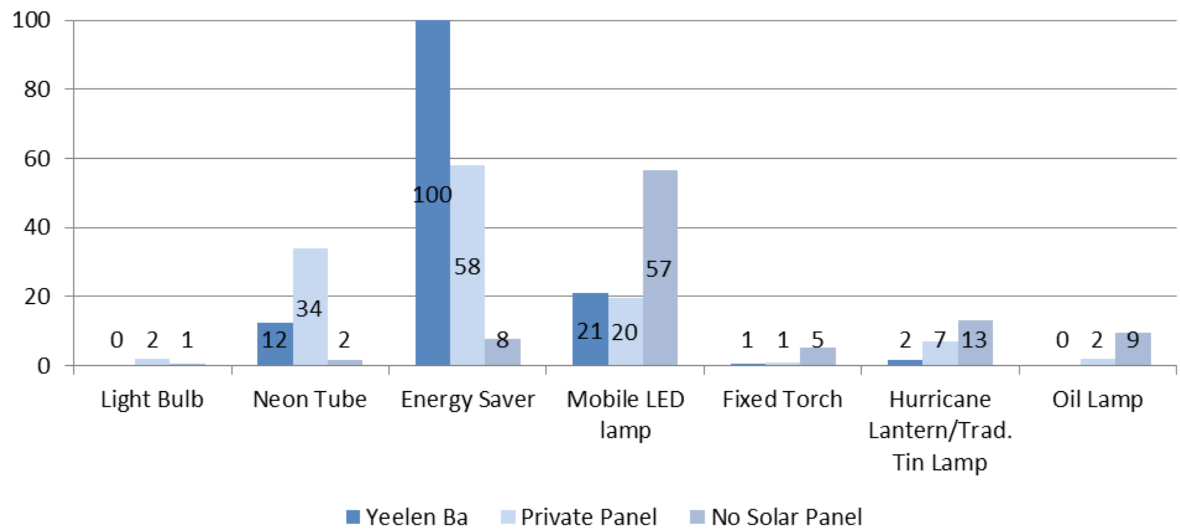
	Control group	**Difference between Yeelen Ba and control group**		
		Non-adjusted means	Matching	Diff-in-Diff
Mobile phone	no solar panel	10.0***	2.9	-8.1
	private panel	0.6	0.6	1.4
Electric lamps	no solar panel	89.1***	86.7***	44.7***
	private panel	5.9***	6.9***	10.3
TV	no solar panel	45.7***	42.9***	35.0***
	private panel	6.6	8.0**	19.6**
Radio	no solar panel	3.4	-8.6**	7.5
	private panel	-11.6***	-11.7***	-4.8

Source: Solar Home System baseline dataset 2010 and follow-up dataset 2012.

4.3.3. Lighting

Each of the three Yeelen Ba service levels actually include compact fluorescent lamps (CFL) as lighting devices (see Section 2). Non-Yeelen Ba households with an electricity source – be it a private panel, a generator or a car battery – use CFL as well as neon tubes. Light bulbs are only rarely used among these households (Figure 5). Interestingly, nearly every household owns a torch which is mostly used outside the house when household members go out after nightfall.

Figure 5: Ownership of different types of lighting devices, in percent



Note: Gas lamps and rechargeable lamps are not shown as they had a share of less than 1 percent in all three groups. Photographs of the various lighting devices are shown in Annex 7.

Source: Solar Home System follow-up dataset 2012.

Mobile LED lamps are far more common in households without electricity than in electrified households and have sizably crowded out traditional lighting sources such as gas and kerosene-based lamps like hurricane lanterns and traditional tin lamps. Candles are not used at all in the survey area. In focus group discussions, a household explained this by the fact that candles are simply too expensive compared to the newly introduced technologies. Mobile LED lamps as well as fixed torches permanently installed in the dwelling run with dry-cell batteries and are cheaper and "cleaner" since they do not produce smoke and do not cause fire accidents. From an environmental perspective the disadvantage of battery-driven lamps is the waste produced by empty batteries. Households usually burn the batteries together with their waste; neither a suitable infrastructure for appropriate disposal nor the consciousness for its necessity exists. In a similar vein, CFL or fluorescent tubes used in electrified households produce toxic waste as they contain mercury. While Yeelen Ba usually collects their users' broken CFL, most other households stated that they dump the broken bulbs straight into the natural environment.

Four indicators for lighting exposure are assessed: Lighting exposure in terms of space is proxied by the *number of rooms illuminated* and the *number of lamps used for exterior lighting*. *Total lighting hours per day*, which aggregate the lighting duration of all lighting devices in the household, capture lighting exposure in terms of time, whereas *total lumen hours per day* additionally account for the lighting quality given that lumen hours are calculated by multiplying lighting hours by the "amount" of light (lumen) emitted from the different sources. These are displayed in Table 18. The *number of rooms illuminated* is not significantly affected. According to matching all three groups illuminate around 1.8 to 1.9 rooms, of which Yeelen Ba households illuminate four in five by electric lamps. Here, slightly less than two-thirds of all electric lamps are used; the rest serves for exterior lighting. *Exterior lighting* as the second indicator is effectively impacted by the intervention, both as compared to households without any solar panel and to private panel households.

Considering the large household sizes, the total number of electric lighting devices is moderate: Only six percent of Yeelen Ba households use more than three electric lamps, whereas this share is twice as large among private panel users. The duration each lamp is lit – be it non-electric or electric (inside or outside the house) – is relatively high and amounts to an average of four to five hours per day. This information jointly determines the *total lighting hours per day*. The results clearly show that Yeelen Ba households benefit from more artificial lighting. They increase the time their dwelling is illuminated with artificial light by about four hours, increasing the total time of illumination to 14 hours. Compared to private panel households, they still consume one hour more of lighting.

This translates to lumen hours (lmh) in Yeelen Ba households that are six times higher than in non-electrified households. However, the calculated lumen consumption of private panel owners is higher compared to Yeelen Ba users, both in terms of non-adjusted means and when determined by matching. Lumen consumption impacts among Yeelen Ba users compared to private panel users only become positive (but insignificant) when applying Diff-in-Diff. Private panel users show higher lumen values mainly due to their stronger usage of neon tubes. The lumen values applied here are based laboratory tests, where neon tubes emit more lumen compared to energy saver bulbs (O'Sullivan and D. Barnes 2006). This may, however, not always be the case in practice. As from the experience made in the field, it seemed that private panels performed rather weakly such that lighting devices powered with these panels were dimmer than the light bulbs used with Yeelen Ba panels. A plausible explanation is that the Yeelen Ba batteries are of a better quality than the private panel ones.

Table 18: Impact on lighting hours

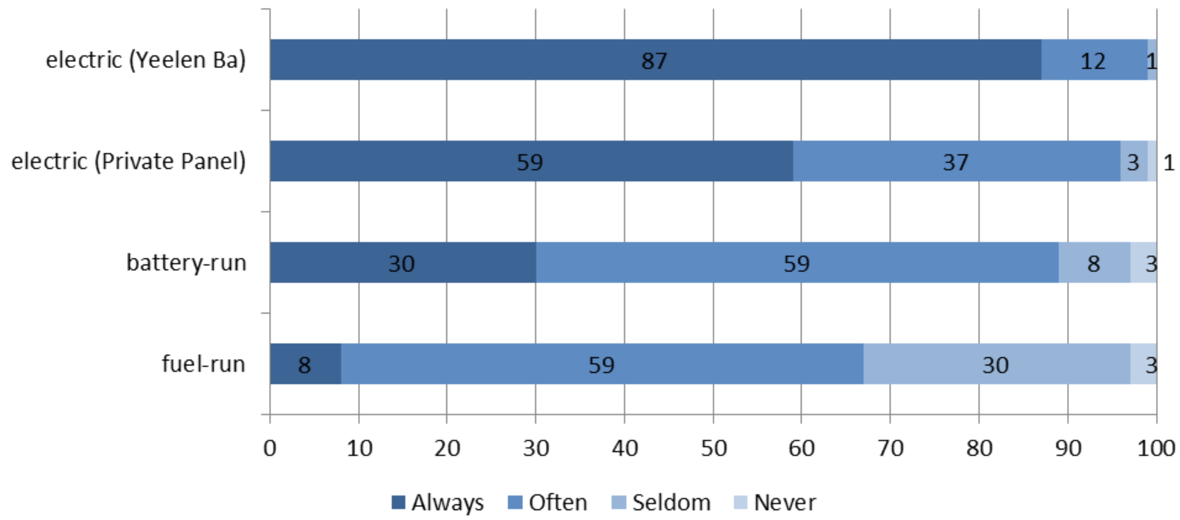
	Control group	Difference between Yeelen Ba and control group				
		Non-adjusted means		Matching		Diff-in-Diff
Number of rooms illuminated	no solar panel	0.32***	[1.91 - 1.59]	0.02	[1.85 - 1.83]	0.52
	private panel	-0.03	[1.91 - 1.94]	-0.05	[1.91 - 1.96]	0.30
Number of lamps used for exterior lighting	no solar panel	1.06***	[1.12 - 0.06]	1.04***	[1.12 - 0.08]	0.63***
	private panel	0.31***	[1.12 - 0.81]	0.30***	[1.12 - 0.82]	0.23*
Total lighting hours per day, in h	no solar panel	6.3***	[14.3 - 8.0]	3.8***	[14.0 - 10.2]	7.7**
	private panel	1.1***	[14.3 - 13.2]	1.2	[14.4 - 13.2]	3.8
Total lumen hours per day, in lmh	no solar panel	6260***	[7350 - 1090]	5775***	[7195 - 1420]	4550***
	private panel	-1460**	[7350 - 8810]	-1240**	[7380 - 8620]	1850

Note: *, ** and *** indicate differences on significant levels of 10 %, 5 % and 1 %, respectively.

Source: Solar Home System baseline dataset 2010 and follow-up dataset 2012.

This observation is also in line with a second lighting quality measure, the general perception of households regarding the quality of their lighting. Yeelen Ba users are in general more satisfied with their lighting on average assigning a value of 1.15 on a scale from 1 to 4 ranging from “always satisfied” to “never satisfied”, whereas private panel owners only averaged at 1.39. Figure 6 disaggregates this measure and furthermore contrasts the values of electric lighting powered by solar panels with traditional fuel-run and battery-run lamps used by non-electrified households.

Figure 6: Satisfaction with lighting quality of different lighting devices, in percent



Note: The observations numbers for the different categories are N=322 (Yeelen Ba), N=218 (Private Panel), N=66 (fuel-run lamps), N=205 (battery-run lamps). *Always satisfied* was assigned the value 1, *often* the value 2, *seldom* the value 3 and *never* the value 4.

Source: Solar Home System follow-up dataset 2012.

4.3.4. Energy expenditures

Energy spending is expected to increase less than proportionally with income growth (Albouy and Nadufu 1999). This relationship can be confirmed by the survey data: across all three groups, richer households spend a lower share of their total household expenditures on energy than poorer households. This suggests that there is a basic energy need that all households need – or at least want – to satisfy and that energy in general is not a luxury good.

Recurring energy expenditures account for 12, 3 and 6 percent of the total household expenditures of Yeelen Ba, private panel and no solar panel households respectively. Thereby, Yeelen Ba users spend more than three times more on energy compared to owners of private solar panels who have similar expenditures as the third group of households without solar panels. This is first of all due to the fact that recurring expenditures include the monthly electricity fees paid by Yeelen Ba users but not the one-time investment of private panel users (or the monthly depreciation). Total monthly energy expenditures incorporating these investment costs are therefore as well calculated. For this purpose, the actual costs incurred by private panel users are stretched over a conservatively assumed service life of these generally lower-quality panels of three years. This yields additional monthly average expenditures of 2520 CFA F.

In order to disentangle the income effect from the differences induced by the different energy technologies available to the households, again matching and Diff-in-Diff are applied. Now, energy expenditures also factor in the investment costs of private panels. According to a comparison of Yeelen Ba households with similar households out of the no solar panel control group, Yeelen Ba clients pay on average a monthly extra of 4500 to 4850 CFA F for energy, depending on the estimation approach, and thereby almost three times more. Private panel households as well spend less than Yeelen Ba households – on average 3250 to 4550 CFA F per month even accounting for the acquisition costs of the private panel. These findings underscore that the increased convenience and scope of energy services through the usage of new electric devices comes with higher aggregate energy expenditures. At the same time, the unit costs of these energy services tend to decrease. To give an example, regularly running a TV set –say, five hours per week –can be expected to be cheaper with a Yeelen Ba panel than with a genset instead.

Table 19: Impact on average monthly energy expenditures

	Control group	**Difference between Yeelen Ba and control group**				
		Non-adjusted means		Matching		Diff-in-Diff
Household expenditures, in CFA F	no solar panel	5630***	[7740 - 2110]	4840***	[7530 - 2690]	4530***
	private panel	3300***	[7740 - 4440]	3250***	[7690 - 4440]	4530***

Note: *, ** and *** indicate differences on significant levels of 10 %, 5 % and 1 %, respectively.

Source: Solar Home System baseline dataset 2010 and follow-up dataset 2012.

For household expenditures, one may be particularly interested in the individual influence of the different matching and Diff-in-Diff control variables. In Section 3.2, it was **Error! Reference source not found.**proposed to implement a propensity score weighted regression approach in this case. The results of such an Ordinary least squares (OLS) regression using propensity scores as weights are shown in Table 20, both with and without the inclusion of control variables. The effect of interest is the *Yeelen Ba panel* effect. It can be seen that the coefficients for the Yeelen Ba panel variable are lower than the matching estimates. Formal education and subsistence farming, which both had no significant influence on solar panel ownership according to the multinomial logit model presented in Section 4.2, are now both highly significant when it comes to energy expenditures, though with opposite signs. Polygamy and asset ownership, which both are major wealth indicators, do not significantly affect energy expenditures.

Table 20: Impact on energy expenditures, determined by propensity score weighted OLS

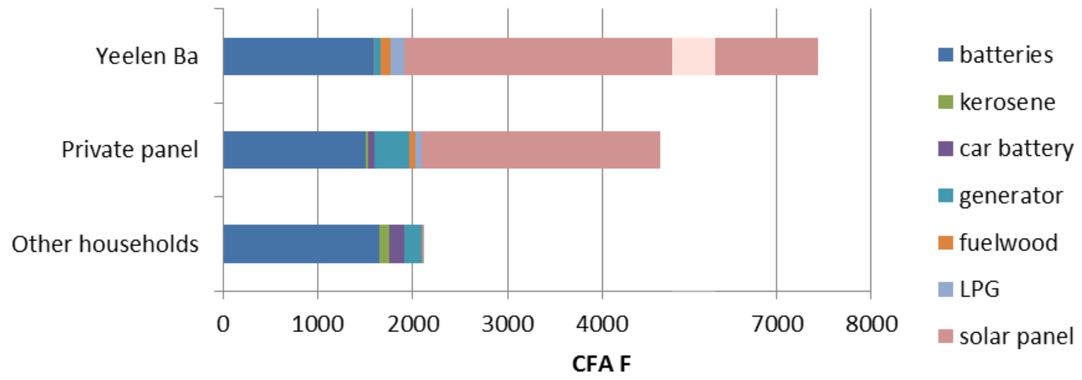
Variable	Energy expenditures in CFA F	
	(1)	(2)
No solar panel	Ref.	Ref.
Private panel	2 697***	1 987***
	[0.00]	[0.00]
Yeelen Ba panel	5 145***	4 353***
	[0.00]	[0.00]
hh size, in logarithmic terms		1 439***
		[0.00]
Polygamous hh (=1)		111
		[0.79]
Age of head of hh, in years		18
		[0.76]
Squared age of head of hh, in years		-0.15
		[0.78]
Head of hh is subsistence farmer (=1)		-2 138***
		[0.00]
Head of hh has formal education (=1)		1 290***
		[0.00]
Asset index		1 569
		[0.30]
Monthly hh expenditures excluding energy, in logarithmic terms		953***
		[0.00]
District Dummies	no	yes
Constant	2 528***	-10 506***
	[0.00]	[0.00]
Observations	858	858
R-squared	0.144	0.237

Note: p-values in squared brackets. *, ** and *** indicate differences on significant levels of 10 %, 5 % and 1 %, respectively.

Source: Solar Home System follow-up dataset 2012.

If the total energy expenditures are split up into their energy source components, it can be seen that in line with the observations made in the previous sub-sections, expenditures on batteries are highest among traditional sources as indicated in Figure 7. Battery expenses are slightly higher for households in the control group, i.e. non-electrified households, compared to the other two groups. In a similar vein, kerosene expenses are highest among non-electrified households, though on a clearly lower level as kerosene has been substituted by batteries as energy source for lighting. Expenditures on car battery recharging and generator fuel are as well higher among non-Yeelen Ba households. LPG and bought fuelwood are generally uncommon and therefore make up only a minor share of overall energy expenditures.

Figure 7: Average monthly expenditures, disaggregated by energy source (in CFA F)



Note: Candles and charcoal are virtually never bought and therefore not included.
Source: Solar Home System follow-up dataset 2012.

4.3.5. Access to information

New information is provided through television and better access to broadcasting and telecommunication via radios and mobile phones. Access to more and new information may imply the transmission of knowledge and the promotion of new norms and values, such as gender equality. Evidence has been provided by various studies, some of which were mentioned in Section 3.1. Table 21 reproduces statistics determined by matching on the main sources of information on political events for men and women. Neighbours or friends are the sole primary source of information for households without a solar panel, whereas radios play a similarly important role for households electrified by Yeelen Ba or private solar panels. Television and mobile phones have as well become more important information sources for electrified households. Women report to get more news from their partners and less from radio and TV than men.

Table 21: Source of information on political events, in percent

	Head of the household			Female household member		
	Yeelen Ba	Private Panel	No Solar Panel	Yeelen Ba	Private Panel	No Solar Panel
Radio	59.4	67.1*	55.8	42.3	43.6	35.7*
TV	35.0	31.3	12.6***	26.5	20.0**	4.9***
Neighbour/Friends	61.1	67.6**	71.0***	65.9	71.6*	75.2***
Town Crier	7.8	10.5	16.9***	7.2	11.0*	11.6*
Partner	0	0.1	0	5.4	12.4**	9.0*
Mobile Phone	12.5	11.7	7.4**	-	-	-

Note: Multiple answers possible. All figures refer to matching results, where Yeelen Ba values are those determined in the matching with no solar panel households. *, ** and *** indicate differences in means between Yeelen Ba households and the respective control group with significant levels of 10 %, 5 % and 1 %, respectively.
Source: Solar Home System follow-up dataset 2012.

When comparing baseline and follow-up data, it can be noted that the importance of radio decreased by 6 to 25 percent points for the head of household and 11 to 34 percent points for the female household member while the importance of TV increased (by 4 to 24 and 1 to 13 percent points, respectively) with both developments being particularly pronounced for Yeelen Ba users.

Considering this data, it seems that TV watching has substituted radio listening in terms of access to information about political events. For political events mobile phones play a minor role, but in general they have become an indispensable communication device and possibly also an important source of information and, hence, represent another important impact pathway of electrification. A closer look is therefore taken on the use of these three appliances: mobile phones, radios and TVs.

Mobile Phone

Mobile phones significantly reduce communication costs and are of increasing importance in developing countries (Aker and Mbiti 2010). They can for instance be used to stay in touch with migrated family members, to get the latest information on agricultural prices on the various markets in the region, to handle banking issues or simply to use the mobile phone as a radio and listen to music. As a reaction to high demand even in remote areas, mobile phone network coverage has greatly improved in recent years and in about half of the surveyed villages it is considered as good by local representatives, whereas in the other half the signal is either of only moderate or even bad quality.

Basically every head of household in a Yeelen Ba household uses his mobile phone to stay in touch with people who live either out of the village (99 percent) or even out of the province (98 percent). This is true for the heads of households of all three groups. Information on prices concerning agricultural products is retrieved by around 60 to 70 percent of the household heads. Finally, it is not surprising that the two electrified groups of households are more accustomed to use their mobile phone for credit transfers. According to matching, they are almost twice as likely to do so as households without a solar panel (8.6 to 9.6 compared to 4.9 percent).

Radio

Radio signal is available in good quality in about 70 percent of the villages. Impact indicators deemed to analyse radio usage assess whether heads of households listen to the radio on a regular basis. For this purpose, one first has to account for radio usage out of home, which is slightly higher than radio ownership in the households – by about 2 to 7 percentage points. The results on radio use are shown in Table 22. In line with the results on radio ownership found in Section 4.3.2, it can be observed that heads of private panel households are the most frequent listeners. Compared to households without an electricity source, Yeelen Ba customers do not listen more to the radio. This conclusion can as well be drawn from looking at the second indicator in the table, the time spent on listening to the radio among regular listeners. This turns out to be quite similar among the three groups with about 70 percent of regular radio users (household heads listening at least one hour per day to the radio).

Table 22: Impact on radio usage

	Control group	**Difference between Yeelen Ba and control group**				
		Non-adjusted means		Matching		Diff-in-Diff
Regular radio listening by head of household, in %	no solar panel	9.9***	[67.2 - 57.3]	0.8	[66.8 - 66.0]	n/a
	private panel	-10.3***	[67.2 - 77.5]	-9.9***	[67.5 - 77.5]	n/a
Head of household listens at least one hour per day to the radio (if regular listener)	no solar panel	-0.5	[68.7 - 69.2]	-4.2	[68.3 - 72.5]	n/a
	private panel	-1.9	[68.7 - 70.6]	-2.2	[69.0 - 71.2]	n/a

Note: The questions on radio use have not been asked in the baseline so that no Diff-in-Diff estimates can be calculated. *, ** and *** indicate differences in means between Yeelen Ba households and the respective control group with significant levels of 10 %, 5 % and 1 %, respectively.

Source: Solar Home System follow-up dataset 2012.

With 94 and 64 percent, respectively, heads of households mainly prefer to listen to news and music, whereas only a minority of 8 percent prefer sport programmes. For other household members, it can be seen that after nightfall between 9 to 12 percent of the female members listen to the radio, while this is only very rarely the case for children.

Television

In order to assess the viewing behaviour of households, like for radio usage, it needs to be taken into account that non TV-owning households may be able to get access to TV at someone else's place. Of course, this is most relevant for households without solar panels. Here, the total proportion of household heads who regularly watch TV amounts to 11 percent. They even watch similarly long as Yeelen Ba households; only regular TV users among private panel households watch more. With 2 hours and 40 minutes, they watch 15 minutes longer than the other two groups (regular TV users among their spouses watch 1 hour and 50 minutes on average). The impacts on TV usage averaging across all households are depicted in Table 23. The average duration of TV watching per day in Yeelen Ba households is 65 minutes for heads of households and 40 minutes for their spouses compared to 17 and 7 minutes in households without solar panels. While there are less heads of solar panels households than heads of Yeelen Ba households who regularly watch TV at all (as there are also less TV sets in their households), these heads of solar panels households watch longer time. This leads to an equalized average value for TV usage of these two groups.

Table 23: Impact on TV usage

	Control group	Difference between Yeelen Ba and control group				
		Non-adjusted means		Matching		Diff-in-Diff
Time household head watches TV per day, in min	no solar panel	49.4***	[65 - 16]	46.9***	[64 - 17]	28.2**
	private panel	-2.2	[65 - 67]	-1.9	[66 - 67]	1.1
Time household head head's spouse watches TV per day, in min	no solar panel	32.1***	[40 - 8]	33.2***	[41 - 7]	38.2***
	private panel	9.4*	[42 - 31]	11.7**	[42 - 31]	27.7**

Note: *, ** and *** indicate significant levels of 10 %, 5 % and 1 %, respectively.

Source: Solar Home System baseline dataset 2010 and follow-up dataset 2012.

Table 24 gives an idea of which types of TV programmes are watched in these time periods. Due to a weak Burkinabè television signal, some villages in the North of Kénédougou use the Malian signal. Malian and Burkinabè television broadcast similar programmes, though, different news. The table presents the results for Yeelen Ba households; the viewing preferences in the two additionally analysed groups is basically the same bearing in mind that only few households from the group of households without solar panel watch TV at all. The majority of the heads of households watches news, followed by African movies, and – to a lesser degree – sports and soap operas. The preferred TV programmes of female adults are African movies with 81 percent, followed by all other types of movies, news and soap operas. Not surprisingly, children from the age of 6 to 11 watch mainly the same programme as their mothers with the difference that cartoons are watched more often and news less often. The number of viewers among older boys and girls drops drastically. Possible explanations are that they are not interested in the programme watched by the elders or prefer going out and meeting friends rather than staying at home and watching television. The remaining boys and girls prefer mostly movies, particularly African-made.

Table 24: Type of television programme watched in Yeelen Ba households, by household member type in percent of those watching

	N	Cartoons	Soap Operas	African Movies	Other than African Movies	News	Sports
Male	302	3.7	14.3	46.6	2.5	70.1	14.3
Female	212	0.8	28.2	75.4	35.9	35.9	2.6
Boys (12-17)	92	14.0	22.0	76.0	46.0	14.0	2.0
Girls (12-17)	68	17.1	31.7	75.6	43.9	14.6	2.4
Children (6-11)	144	33.3	14.7	67.6	33.3	5.3	4.0

Source: Solar Home System follow-up dataset 2012.

4.3.6. Time use

In the present setup, TV watching is probably the most palpable impact on people's time use. At the same time, non-adjusted differences between the compared groups are again likely to be biased by self-selection into panel ownership. It is, for example, imaginable that people who need more sleep and hence go to bed early, may not take a panel in the first place, since they won't watch television. In contrast, someone who sleeps late and is bored in the evening, may strongly desire a TV set.

The impact assessment therefore once more involves matching (Table 25). Considering these values, the daily routine of households without a solar panel and Yeelen Ba users do not notably differ at all. Private panel households rather seem to have reduced their sleeping hours. Their household heads are on average awake for 17 hours and around 20 minutes longer than other household heads. Nevertheless, the effect of the solar panels on time use can be considered as rather subtle (except for TV usage) such that the different measurement approaches deliver results that do not substantiate any statistically or economically significant impact on time use of the household head. Typical Yeelen Ba heads of households get up at around 5.30 am in the morning, work eight and a half hours (beyond helping with household chores for about 40 minutes) and then go to bed at 10 pm.

Table 25: Impact on time use of household head, in minutes

	Control group	**Difference between Yeelen Ba and control group**				
		Non-adjusted means		Matching		Diff-in-Diff
Time when household head gets up	no solar panel	1.5	[5h28 - 5h26]	7.7**	[5h30 - 5h23]	0.0
	private panel	9.8***	[5h28 - 5h18]	11.5***	[5h29 - 5h17]	11.1
Time household head is working per day	no solar panel	15.5	[8h29 - 8h14]	- 0.1	[8h29 - 8h29]	-26.9
	private panel	-16.3	[8h29 - 8h46]	-14.9	[8h36 - 8h51]	-28.1
Time when household head goes to bed	no solar panel	13.4*	[22h04 - 21h51]	2.3	[22h03 - 22h00]	19.5
	private panel	-12.5*	[22h04 - 22h17]	-12.0*	[22h05 - 22h17]	11.1

Note: A negative value for the time at which the household head gets up or goes to bed indicates that the Yeelen Ba households does so earlier than the control group; accordingly, a positive value means 'later'. *, ** and *** indicate differences on significant levels of 10 %, 5 % and 1 %, respectively.

Source: Solar Home System baseline dataset 2010 and follow-up dataset 2012.

Women usually get up a bit earlier than their husbands, at around five in the morning and wake the children at six. The total daily women's workload of over 11 hours is more than two and a half hours longer than for their husbands. Since cooking is not affected by the solar electrification intervention, the main impact on time use can be expected to occur via lighting and TV watching. Lighting allows women to redistribute their household duties across the day according to their preferences such that, for example, nuts can be dehulled after nightfall. As been shown in the previous section, not surprisingly, there are far more women living in households with solar panels that use to watch television. Beyond improved lighting, this may explain the fact that women in the non-electrified group go earlier to bed than women living in Yeelen Ba households (21.30 pm compared to 21.50 pm). Moreover, there are coherent indications that the time dedicated to domestic work has decreased considerably (Table 26). It is, however, unclear how these changes have been triggered. The most likely explanations do not seem to apply: households do not use efficiency-enhancing domestic work appliances and spouses in Yeelen Ba households even finish their household duties earlier; they hence do not allocate significant parts of their duties to the night-time, which may have created efficiency gains as well. Differences in the proportion of spouses living in a polygamous relationship, where household duties may be shared, also do not seem to drive the results.

Table 26: Impact on time use of household head's spouse, in minutes

	Control group	**Difference between Yeelen Ba and control group**				
		Non-adjusted means		Matching		Diff-in-Diff
Time when household head's spouse gets up	no solar panel	5.3*	[5h10 - 5h05]	11.9***	[5h12 - 5h00]	13.2*
	private panel	8.0***	[5h10 - 5h02]	7.9***	[5h11 - 5h03]	16.8**
Time household head head's spouse is working per day	no solar panel	1.0	[6h24 - 6h23]	6.5	[6h22 - 6h16]	- 7.0
	private panel	- 0.7	[6h24 - 6h25]	3.4	[6h24 - 6h20]	-21.8
Time household head head's spouse spends on domestic work per day	no solar panel	-18.2*	[4h47 - 5h05]	-24.4**	[4h45 - 5h09]	-39.3
	private panel	-41.2***	[4h47 - 5h28]	-46.1***	[4h46 - 5h32]	-39.1
Time when household head head's spouse goes to bed	no solar panel	26.4***	[21h48 - 21h21]	19.6***	[21h47 - 21h28]	17.8
	private panel	8.4**	[21h48 - 21h39]	8.6**	[21h48 - 21h40]	9.8

Note: *, ** and *** indicate differences on significant levels of 10 %, 5 % and 1 %, respectively.

Source: Solar Home System baseline dataset 2010 and follow-up dataset 2012.

One potentially important impact of electrification is the improvement of studying conditions of school-age children. Studying hours at home on average actually tend to be higher for Yeelen Ba households. This, however, has to do with the fact that they send their children more often to school (see Table 7 in Section 4.1), which is unlikely to be a cause of the electricity access. When restricting the analysis only to those households where children go to school (either children of primary school age or boys or girls of secondary school age) virtually no differences can be observed. Studying outside home after school is very rare and can be observed for only around 5 percent of households in the sample, among them slightly more non-electrified households. It has to be noted, though, that the analysed sample in each case becomes very small. In the surveyed area, school children, furthermore, generally tend to study after nightfall. Even primary school children in households without solar panels study three-fourth of their time after 18 o'clock in the evening (this proportion is slightly higher for Yeelen Ba households with 80 percent). Hence, the main impact in this context is the improved quality of lighting in Yeelen Ba households instead of a change in the quantity of studying.

4.3.7. *Productive electricity use*

Electricity is also seen by many as an important milestone in fostering business development. Electricity supply may free up time that can be dedicated to productive purpose, it may allow reducing production costs, improve services or open up opportunities for new services. In the case of SHS, however, all these factors are less pronounced, since cooking as the most time-consuming household chore is not affected and the power of the system is too low to run appliances such as refrigerators or mills that are typically used in home businesses.

Radios and mobile phones provide auxiliary services for some businesses, e.g. the entertainment of customers or access to information on agricultural prices. Electric lighting facilitates working at night and, hence, extending working or opening hours. In 23 sampled households (equivalent to 2.6 percent) further appliances are used for productive purposes, mainly non-electrical devices like fuel-run mills, charcoal irons or mechanical sewing machines. Among them there is only one electricity-using household who uses an electric sewing machine. In addition, one Yeelen Ba household interviewed in the baseline uses his two Yeelen Ba solar home systems to run a video-TV-system. He has a subscription for a television package that allows him to show international football games. He usually takes 100 CFA F per game from the villagers. In busy months, he could pay the solar panels and subscription just by the entrance fees.

4.3.8. *Security and safety*

In different ways, electric lighting may have a preventive character for the sake of security and safety. First, the replacement of traditional lighting may reduce the *incidence of lighting-induced fire* in the household. In fact, there have been a couple of fires induced by kerosene lamps in non-electrified households. At baseline stage, households still reported 7 of them, in the follow-up, only one non-electrified household suffered from a fire, where luckily nobody has been injured.

Second, traditional lighting emits smoke that may have adverse effects on people's health. 22 percent of non-electrified households indeed still use smoke-emitting lighting devices including gas, oil and traditional tin lamps or hurricane lanterns compared to 2 percent of Yeelen Ba households. In these households, traditional smoke-emitting lighting makes up 77 percent of all lighting time consumed. Women have been asked about their *perception of indoor air quality* in the dwellings. Since cooking with woodfuels is the main indoor air pollutant and, hence, a potential confounder in this context, only households cooking in closed rooms have been asked this question, which is the case for more than 80 percent of households. This indicator is assessed together with two security-related indicators in Table 28. They represent the third and fourth potential impact assessed here: Third, the *incidence of animal attacks within the last year* and, fourth the *incidence of thefts within last six months*, as both wild animals such as snakes and scorpions and thieves may be kept away through electric lighting. While interior lighting may already serve this purpose, exterior lighting does so even more clearly. It is used by as many as 97 percent of Yeelen Ba households and 69 percent of private panel households.

The indicators are all constructed in a way that negative signs represent an improvement for Yeelen Ba households and correspondingly positive signs a deterioration. For indoor air pollution, the coefficients are very small and highly insignificant. Two qualifications have to be made. On the one hand, virtually all households with unsatisfactory indoor air hold cooking with woodfuels responsible for that. On the other hand, one can observe a difference when restricting the non-electrified group to those 22 percent who use smoke-emitting lamps. 29 percent of them do not perceive their indoor air as sufficiently good or even as bad compared to 15 to 18 percent found for the three aggregate groups in Table 27. It goes without saying that the other two indicators shown in the table are rare events for which it is particularly true that they may be triggered by a host of other aspects not related to electricity access. One should therefore not overinterpret the similarly mixed and non-substantial impacts observed considering the given sample setup. In any case, the individual perception of safety has increased as expressed in FGDs, which is also substantiated by the fact that 97 percent of interviewees consider darkness as dangerous.

Table 27: Impact on security and safety

	Control group	Difference between Yeelen Ba and control group				
		Non-adjusted means		Matching		Diff-in-Diff
Indoor air not considered as sufficiently good, in %	no solar panel	-1.9	[16.7 - 18.6]	1.4	[17.5 - 16.1]	n/a
	private panel	1.4	[16.7 - 15.3]	1.5	[16.5 - 15.0]	n/a
Animal attacks within last year, in %	no solar panel	-2.9	[15.3 - 18.2]	-7.1**	[13.9 - 21.0]	7.3
	private panel	1.0	[15.3 - 14.3]	0.3	[15.1 - 14.8]	6.2
Any theft within last six months, in %	no solar panel	-0.5	[6.8 - 7.3]	-2.1	[5.3 - 7.4]	-9.1
	private panel	-2.1	[6.8 - 8.9]	-2.0	[6.6 - 8.6]	-8.8

4.3.9. Gender

Gender is a cross-cutting issue as depicted in Figure 2 in Section 3.1. This also became evident in the analysis of indirect channels such as a lower workload conducted in the previous sections. Gender, or more precisely gender empowerment understood as a development towards a more equal and self-determined position of women in the household, may as well directly be influenced by an electrification intervention. TV programmes may, for example, exemplify a modern lifestyle of gender-empowered women. Two indicators are applied to assess such direct impacts on gender, or gender empowerment: first, the ability of the household head's (main) spouse to influence the intra-household decision making on six expenditure categories including food, the children's education, health and clothing. Following an approach proposed by the Asian Development Bank (ADB 2010), the proportion of expenditure categories for which the wife is at least partly responsible is used as a measure of this gender empowerment index.

The second indicator is related to violence against women, an issue that is recognized by the United Nations (UN) to undermine all MDGs and which is also seen as a crucial gender empowerment dimension in the related literature. Following the work by Jensen and Oster (2008), it measures the spouse's acceptance of beating, assuming that one step in contesting household violence is the spouse's non-acceptance of it. The spouse was asked whether she thinks it is justified that her husband beats her when she leaves the house without telling him, when she neglects the children, when she argues with him or when she burns the food. In a similar vein as for the decision making indicator above, the answers to these four categories are used to create an index ranging from 0 to 1. In this case, 1 denotes no acceptance of beating at all whereas 0 denotes full acceptance of beating. These indicators, of course, reflect aspects of the households' life that are rather deeply rooted in the local customs and therefore probably take time to get affected by an external intervention. Recognizing that most households only recently acquired a Yeelen Ba SHS (see Figure 4 in Section 4.2) implies that even if media exposure has an impact on gender empowerment it may take longer time and hence may not yet be visible in the given survey data. To account at least to some extent for such a lag, the analysis follows Jensen and Oster (2008) by only including households who use the panel for at least three months. Furthermore, for both indicators only those households are considered in the analysis who answered more than half of the questions. In addition, two related fertility preference indicators are assessed: first, the proportion of fertile women who use modern contraceptives and, second, the number of children desired by the spouse in the household. All indicators are presented in Table 28.

Beyond the set of household control variables used in the matching and Diff-in-Diff estimations of the previous sections, we now add another set of variables related to characteristics of the household's spouse. The selection of these characteristics is inspired by the literature (e.g. Trommlerová et al. 2013): the age and squared age of the head of household's spouse and her education level as well as a binary variable indicating whether she is member of an association. These covariates shall guarantee that we compare households that are similar not only in terms of socio-economic background characteristics but also in terms of the general position of the woman in the household.

The table shows that the participation of women in intra-household decision making is rather limited. Given the index means of around 0.3 to 0.4, around a third of decisions can be said to be taken with the involvement of the woman in the household. Beating seems to be unacceptable in around two-thirds of cases. The coefficients of these two indicators rather hint to positive contributions of panel ownership, even though, for example, the beating acceptance index shows a negative, borderline significant difference to the group of households without solar panels, which turn into the opposite when looking at Diff-in-Diff estimates.

Opposite signs for the matching and Diff-in-Diff estimates are even more pronounced for the two fertility preference indicators. It has to be noted that beyond the shortcomings of the cross-sectional matching approach, the parallel trend assumption underlying the Diff-in-Diff estimator may be violated here. No solar panel and private panel users as less well-off households may, for example, have caught up on gender empowerment in the last years irrespective of their access to electricity situation. The worse performance of Yeelen Ba households then only reflects a stronger relative improvement in the general development towards gender equality among the control groups.

Table 28: Impacts on gender empowerment

	Control group	**Difference between Yeelen Ba and control group**				
		Non-adjusted means		Matching		Diff-in-Diff
Decision-making index	no solar panel	0.084**	[0.42 - 0.33]	0.109***	[0.43 - 0.32]	0.049
	private panel	0.079**	[0.42 - 0.34]	0.075**	[0.42 - 0.34]	0.144
Beating acceptance index	no solar panel	-0.021	[0.72 - 0.74]	-0.043	[0.71 - 0.75]	0.11
	private panel	0.037	[0.72 - 0.68]	0.047	[0.71 - 0.66]	0.24***
Use of modern contraceptives, in %	no solar panel	8.5**	[28.6 - 20.1]	4.0	[26.8 - 22.8]	-14.0
	private panel	0.8	[28.6 - 27.8]	3.7	[29.2 - 25.5]	-18.7**
Number of desired children	no solar panel	- 0.51***	[5.3 - 5.8]	- 0.39**	[5.3 - 5.7]	0.03
	private panel	- 0.50***	[5.3 - 5.8]	- 0.38**	[5.4 - 5.8]	0.13

Note: *, ** and *** indicate differences on significant levels of 10 %, 5 % and 1 %, respectively.

Source: Solar Home System baseline dataset 2010 and follow-up dataset 2012.

Table 29: Impact on gender empowerment, determined by propensity score weighted OLS

Variable	Decision-making index		Beating acceptance index	
	PS-w OLS	PS-w OLS	PS-w OLS	PS-w OLS
	(1)	(2)	(3)	(4)
No solar panel	Ref.	Ref.	Ref.	Ref.
Private panel	0.03	0.04	-0.07**	-0.09***
	[0.38]	[0.31]	[0.02]	[0.01]
Yeelen Ba panel	0.10**	0.06	-0.04	-0.07*
	[0.01]	[0.17]	[0.21]	[0.08]
hh size, in logarithmic terms		0.05		-0.08**
		[0.23]		[0.03]
Polygamous hh (=1)		-0.11***		-0.02
		[0.00]		[0.62]
Age of head of hh, in years		-0.02***		0.01
		[0.00]		[0.51]
Squared age of head of hh, in years		0.00***		-0.00
		[0.00]		[0.38]
Head of hh is subsistence farmer (=1)		0.02		-0.01
		[0.64]		[0.90]
Head of hh has formal education (=1)		0.03		0.04
		[0.44]		[0.20]
Asset index		-0.28**		0.12
		[0.04]		[0.31]
Monthly hh expenditures excluding energy,		0.07***		0.02
in logarithmic terms		[0.00]		[0.21]
Age of head of hh's spouse, in years		0.04***		0.01
		[0.00]		[0.56]
Squared age of head of hh's spouse, in		-0.00***		-0.00
years		[0.00]		[0.69]
Head of the hh's spouse has formal		0.07*		0.00
education (=1)		[0.07]		[0.95]
Head of hh's spouse is member of an		-0.00		0.04
association (=1)		[0.98]		[0.14]
Female Enumerator (=1)		0.04		-0.03
		[0.33]		[0.32]
District Dummies	no	yes	no	yes
Constant	0.32***	-0.48**	0.75***	0.35
	[0.00]	[0.04]	[0.00]	[0.13]
Observations	757	757	661	661
Adjusted R-squared	0.006	0.048	0.005	0.038

Note: p-values in squared brackets. *, ** and *** indicate differences on significant levels of 10 %, 5 % and 1 %, respectively. As an additional control variable, the gender of the enumerator is accounted for. The questions used to construct the dependent variable are to some extent gender-sensitive and wives might tend to give different answers to male or female enumerators. They could, for example, hesitate to tell a male enumerator that they make the decisions in the household since this could be regarded as publicly devaluating their husbands. On the other hand, they might feel ashamed telling the typically urban and well educated female enumerators that they still accept their husbands beating. Measurement errors could occur when not accounting for this but these errors do not bias the result as long as they are not correlated with the treatment. Eventually, the coefficients turn out to be insignificant and of opposite sign. The gender of the enumerator, hence, does not seem to play a decisive role.

Source: Solar Home System follow-up dataset 2012.

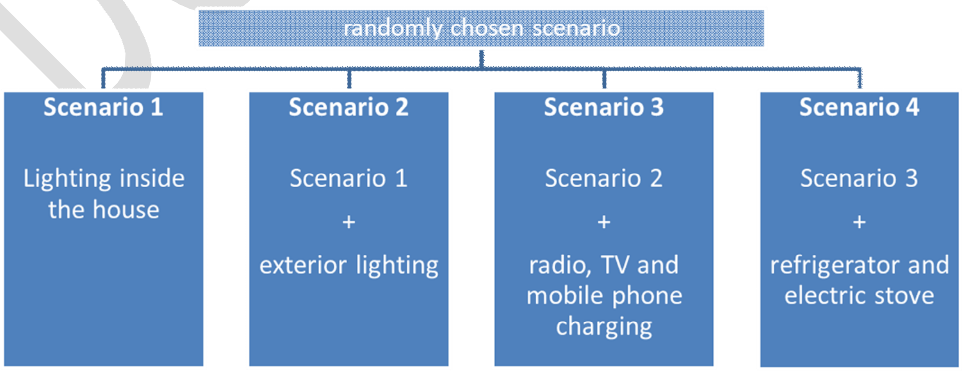
In order to examine the influence of the different control variables, again a propensity score weighted OLS (PS-w OLS) is performed. Table 29 shows the results for the two gender empowerment indicators. The Yeelen Ba coefficients go in the same direction as the matching coefficients, even though with opposite significance levels. In the estimations with control variables (columns 1 and 3), decision making is not significantly affected but beating acceptance. Interestingly, at the same time there is only one significant control variable for beating acceptance but eight significant control variable coefficients for decision making; apart from the negative asset index coefficient all of them are in line with expectations. Observable household characteristics are hence more likely to determine the intra-household decision making than the acceptance of intra-household beating. Still, it needs to be noted that for both estimations, the R-squared as an (imperfect) measure of the explanatory power of an estimation is rather low. To conclude, given the relatively short period of exposure to the modern energy services provided by the solar panels, there is no robust evidence yet on gender-related impacts of the SHS intervention.

4.3.10. Willingness To Pay and Willingness To Accept

The Willingness To Pay (WTP) can be used to analyse the aggregate value a household assigns to a good and is thus willing to pay. In the case of electricity this value includes not only economic benefits in a narrow sense such as kerosene savings or income generation potentials, but also convenience or subjective security perception. Likewise, the household faces costs related to electricity usage, again not only direct costs like monthly fees but also non-monetary costs such as the adverse effects of children watching too much television. Hence, when asked for its WTP, a household can be expected to implicitly sum up the benefits and to contrast them with the sum of costs, which is then aggregated in its WTP (for a more detailed discussion of this approach see Annex 2).

In the survey, the WTP approach was implemented by confronting the heads of non-electrified households with one of the four scenarios depicted in Figure 8, which was randomly selected by the enumerator before the interview. In the first scenario the interviewee was asked to estimate his willingness to pay in case the household was only served with indoor electric lighting. In the second scenario, electric lighting was available inside the house and outdoors, the third scenario additionally allowed for a radio, TV and a telephone charger. Finally, the fourth scenario included the same devices and services as the third scenario complemented by a refrigerator and an electric stove. The head of household was then asked how much he would be willing to pay per month for the service drawn. All households started from 6000 CFA F which corresponds to the monthly costs for the service level 2 package offered by Yeelen Ba.[9] This real-world service package comes closest to scenario 3 and includes two bulbs and a socket or 3 bulbs (see Table 1 in Section 2).

Figure 8: Scenarios randomly allocated to non-electrified households



Source: own illustration.

[9] In the baseline interviews, the initial price proposed to the household has been randomly chosen among a set of different prices. This procedure, however, has been abandoned in the follow-up.

Table 26 presents baseline data on WTP. At this stage, there were also a couple of Yeelen Ba and private panel households without any electricity source. It becomes clear that those households who acquired a Yeelen Ba during the ensuing period actually expressed a clearly higher WTP than those households who did not, including the households who resorted to private panels instead. The WTP levels are moreover similar to those reported in a small market analysis undertaken by Yeelen Ba. Yeelen Ba (2010) reports that the interviewed households declared to be willing to spend on average CFA F 3460 per month for a solar kit.

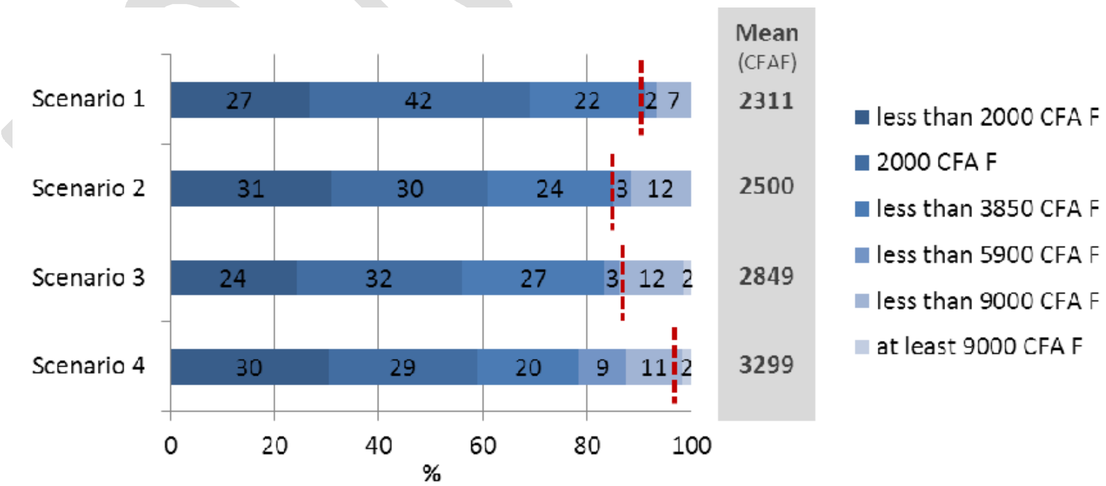
Table 30: Willingness to pay for electricity services at baseline

	Yeelen Ba	Private Panel	No Solar Panel	All
Willingness to pay at baseline across all four service levels*, in CFA F	6531	3098	2904	3240
Share of households with WTP higher than price of lowest Yeelen Ba service level, in %	46.9	14.4	17.6	19.2
Number of observations	32	90	274	396

Note: The four scenarios have been drawn similarly often in the three groups. The frequency by which the different scenarios have been drawn therefore did not drive these results.
Source: Solar Home System baseline dataset 2010.

Hence, between baseline and follow-up a good part of the households with a high WTP for electricity services acquired a Yeelen Ba panel, in technical terms they "revealed" their WTP. Accordingly, the WTP among non-electrified households at follow-up is lower on average. Figure 9 shows the follow-up WTP results differentiated by service levels. It can be seen that all households are willing to pay more if the service level increases. This is of course what one would expect as long as we are below a certain saturation threshold. Scenario 1 and Scenario 2 come closest to the smallest Yeelen Ba service package (S1), which costs 3845 CFA F per month. Yet, even for the second scenario the average WTP lies only by about 2500 CFA F per month. As indicated by the red dotted line in the graph, there are only 9 percent (taking the first scenario) and 15 percent of households (according to the second scenario) willing to pay the price Yeelen Ba charges for their first service package.

Figure 9: Willingness to pay for the four hypothetical scenarios



Note: The red dotted lines refer to the thresholds at which the WTP exceeds the price charged for the Yeelen Ba packages S1 (scenario 1 and 2), S2 (scenario 3) and S3 (scenario 4). The types of service offered in the different packages are depicted in Figure 8.

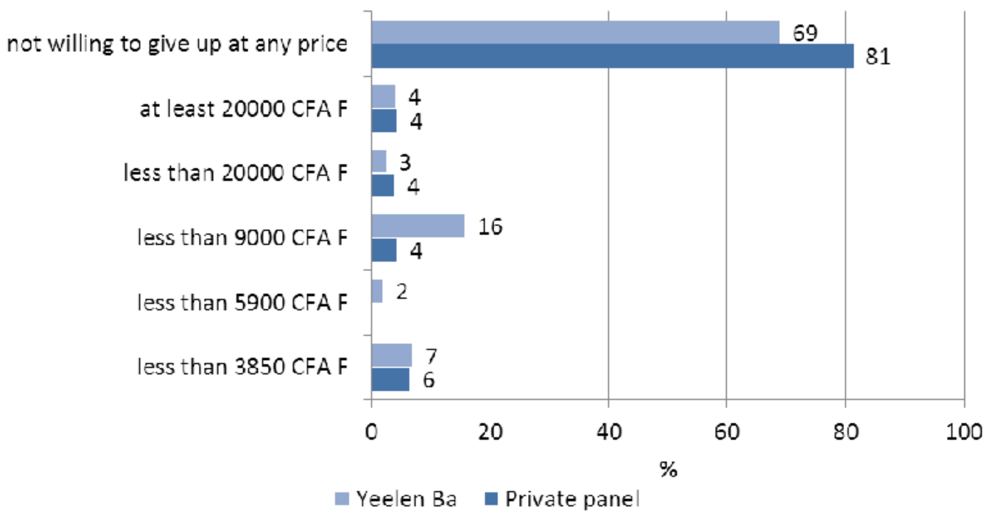
Source: Solar Home System follow-up dataset 2012.

For the third scenario, which reflects the Yeelen Ba service level S2, again, only a small share of 14 percent of yet non-electrified households is willing to pay the respective price of 5940 CFA F. Reducing the fee does not seem to trigger sizable effects. Even a price of 3500 CFA F would only lead to an additional 3 percent of households all households willing to pay that price. Finally, the fourth scenario resembles the third Yeelen Ba service level most, for which Yeelen Ba charges 9050 CFA F. The WTP of 2 percent of households confronted with the fourth scenario exceeded this value.

In contrast to the hypothetical question about the willingness to pay, the households with electricity were asked the contrary question: How much compensation per month do you claim for giving up electricity? This is called the Willingness To Accept (WTA) approach. Clearly, the idea is in principle the same: to define an estimate of the value a household assigns to an electricity service. However, households who own already a panel cannot be asked what they would pay to have it, but better how much they wanted in compensation if the panel is taken away. Yet, it is well known that the framing of the question matters. People find it in general harder to give something away than not to get something they value. Hence, strictly speaking it is unlikely to get the same result for both questions.

As before, Figure 10 distinguishes electricity users between households owning a private panel and households that use a Yeelen Ba panel. It turns out that the vast majority denies giving up electricity at any price. Only a fourth of current Yeelen Ba users would accept to get disconnected under the condition of receiving a compensation equal to or less the price of the S3 package, the most expensive Yeelen Ba service level. Hence, SHS-using households seem to value their panels even more than expressed in their monthly payment. The WTA of private panel users is even higher than that of Yeelen Ba users. This may simply be due to the fact that private panel households own their SHS, which is not the case for Yeelen Ba households.

Figure 10: Willingness to accept compensation for giving up electricity



Source: Solar Home System follow-up dataset 2012.

4.4. Appreciation of the Yeelen Ba services

Against the background of the objective and subjective costs and benefits of the Yeelen Ba panels, households and village representatives have been asked about their appreciation of the services offered by Yeelen Ba. Almost all village representatives considered the Yeelen Ba technology as appropriate for their village. It was often highlighted that solar panels are the obvious second-best choice, since grid electricity is unlikely to arrive soon in this remote area. When looking at service satisfaction, a strong difference between the northern and southern villages can be observed. In the North only five percent of the consulted village representatives think that Yeelen Ba offers a good service compared to 75 percent who believe the contrary. These numbers are significantly better in the South, where however still the majority does not consider Yeelen Ba as a good service provider. The people do not appreciate the fee-for-service concept and perceive the price for the offered services as far too high.

Table 31: Yeelen Ba perception by village representatives, in percent

Village location	YB's service is good (%)		YB's technology is appropriate for the village (%)		Distance to nearest agency	Share of villages (%) visited by a Yeelen Ba technician in the last …		
	yes	no	yes	no	average (km)	3 month	6 month	2 years
North	5	75	65	10	20.3	55	20	5
South	46	54	85	8	10.7	92	-	8

Note: In case the values do not add up to 100 % part of the interviewees could not or did not want to specify an answer. 'North' refers to the 20 villages in the four districts in the North of the province (Kayan, Morolaba, Samorogouan and Sindo) and 'South' to the 13 villages in the three Southern districts of Djigouera, Koloko and Kourinion.

Source: Solar Home System follow-up dataset 2012

How can the large differences in perceptions between the North and the South be explained? Two interrelated aspects are highlighted in Table 31: the distance to the nearest agency and the date of the last visit of a Yeelen Ba technician to the village. In order to reach the nearest Yeelen Ba agency, clients in northern villages have to travel twice the distance compared to clients in the South. In addition, more than 90 percent of the southern villages had been visited by a Yeelen Ba technician in the three months preceding the survey. In the Northern part of Kénédougou this was only the case for every second village. This is not surprising as the agencies are further away in the North. Moreover Yeelen Ba's headquarter is in the South. In any case, it seems that having a technician who regularly visits the villages or an agency close by so that clients can, for example, make inquiries and pay their bills, may also change the perception of the role of the fee-for-service system and more generally the appreciation of the price relative to the services offered.

Concerning the opinion of non-Yeelen Ba users, it has to be noted that the company is well known at the time of follow-up: 90 percent know Yeelen Ba and its services. On the other hand, about 40 percent of the households owning a private panel did not know Yeelen Ba at the time they bought their panel. The main information channels are friends, neighbours and the family. 75 percent of those non-Yeelen Ba households who know the company do so via these channels. The promotion activities carried out by Yeelen Ba are also effective. This channel was mentioned by 52 percent of these households, whereas 23 percent stated to know Yeelen Ba from the radio. However, only 29 percent also know the prices Yeelen Ba is offering.

While the company is still relatively young there are several households who mentioned to have made either bad experiences with a Yeelen Ba panel (1.5 percent) or have heard about bad experiences of someone else who owned a Yeelen Ba panel (11 percent). However, the main reason (around two thirds of the cases) brought forward why households do not have a Yeelen Ba panel is that the services offered are too expensive for them. Furthermore, one third of private panel households mentioned that they want to own their panel, suggesting that this was an important aspect when deciding what kind of panel to acquire. This is in line with impressions gleaned from the conducted FGDs. Participants in the FGDs frequently complained about the business model, i.e. that

Yeelen Ba users will never own the panel although they pay a fee each month. They simply did not understand why they have to rent the Yeelen Ba panel instead of buying it. This unease can partly be explained by the lack of knowledge of the fee-for-service system, but also by the price difference to privately acquired panels. Even for the smallest Yeelen Ba package the fees accumulated after one and a half years exceed the median price paid for private panels (65,000 CFA F).

The FGD with Yeelen Ba users in Sidi village, where a high number of Yeelen Ba clients can be encountered, and the FGD in Mahon village (Kangala district), which is a village without any SHS take-up, furthermore suggested the existence of a "leadership effect". All FGD participants with a Yeelen Ba panel in Sidi reported that a strong factor for obtaining their panel has been the experience made by the first Yeelen Ba client in the village. First of all they noticed that the lighting quality was much better than with private panels. Interestingly, most of the early adopters already owned a private panel. For the non-Yeelen Ba FGD participants in Mahon, the inverse proved true. In this case, one of the villagers had obtained a Yeelen Ba panel in order to recharge his laptop. However, according to the villagers the power of the panel was not strong enough to recharge the laptop. He cancelled his subscription to the services of Yeelen Ba[10] and no other villager has ever adopted a Yeelen Ba panel afterwards. Instead everyone shares the hope that the electricity company SONABEL connects the village to the national grid. In conclusion, both cases provide evidence that some kind of leadership effect exists meaning that one or a few pioneering households in the community start using the panel and others only follow if the product is perceived as being of high quality.

When asking the Yeelen Ba users if they would like to change any aspect of their electricity supply a vast majority of 85 percent answered with yes. To a similar degree, they either wish a power increase or price reductions. Table 32 contrasts these responses with those of private panel users. Among them, a majority rather wants a power increase. This does not come as a surprise since Yeelen Ba panels are of higher quality and power compared to the private panels. The monthly payment interval is one aspect that has been complained about in the FGD with Yeelen Ba users assembled in Sidi village, as they would prefer to pay annually. This made clear that many Yeelen Ba users do not know that annual payments are actually possible and even considerably cheaper. Finally, those who knew about this payment scheme complained that they have to pay before and not after usage.

Table 32: Desired change in electricity supply, in percent of interviewees

	Yeelen Ba	Private Panel
power increase	12.2	39.4
fee/ price reduction	18.0	16.5
both power increase and fee/ price reduction	54.4	28.0
other	0	1.3
none	15.3	14.8

Source: Solar Home System follow-up dataset 2012.

4.5. Energy usage in social infrastructures

Beyond access to electricity on the household level, households may derive benefits from electrified health stations and schools. These are the most relevant and widespread social infrastructure

[10] Note that Yeelen Ba explains this case differently: According to them he could not pay the fees and the panel had to be removed.

institutions in the surveyed villages. None of the encountered health stations and schools is equipped with a Yeelen Ba panel – a situation that might change in the future. There has been one secondary school in Sérékéni that was in the wake of connecting its administrative office at the time of the follow-up survey. At the level of the whole province, there were 18 community services in the Yeelen Ba client database in September 2012 including municipal buildings, mosques and police stations.

Table 33: Availability and electrification status of social infrastructure

Schools		Health Stations		Municipal Buildings	
total	with electricity	total	with electricity	total	with electricity
68	7	18	9	11	4

Note: Schools types included are primary and secondary schools and others such as franco-arabe schools. Municipal buildings comprise community centers, prefectures and mayor's offices.

Source: Solar Home System follow-up dataset 2012

Most schools in Kénédougou do not dispose of any electricity source. Only 7 out of 68 schools in the surveyed villages use electricity generated by a solar panel. One secondary school claims having observed a decline of graduating students after the theft of the solar panel. A reason might be that pupils no longer benefit from the lighting to study together after classes in the evening. The school director in Pindie-Badera believes to see a difference in the learning outcomes between the pupils in Sidi (a village about 15 km away) and his own pupils, like "day and night". He attributes this to the fact that many households in Sidi own a Solar Panel, thus the children can profit from the lighting for learning, while this is not the case for Pindie-Badera. As another school director puts it: "The lamp enlightens the head." Thus, nearly all of the interviewed directors attribute a great value to electricity access – at least at household level.

According to the interviewed teachers, the most important problems for schools are the lack of class rooms, of tap water and of houses to lodge the teachers, but also the lack of electricity. Respondents emphasized that electric lighting at schools would permit the pupils to study together at night after classes and teachers could prepare the classes for the next day. They continued stating that this would also be preferable to the situation where the pupils have electricity at home but can't concentrate on studying due to family work that has to be done or the noise around them. It would also pave the way for offering evening classes, which might be a solution to the problem of over-crowded class rooms. In their opinion, apart from lighting, electricity could be used to run computers. The main current energy source used at schools is fuelwood for cooking. Usually, the pupils bring one bundle of firewood per week for the preparation of meals. At primary schools meals are free of charge, at secondary schools pupils have to pay 75 CFA F per meal.

Most of the health stations in the survey region have originally been equipped with a solar panel, but today only half of them (9 of 18) still have panels that are operational. The panels are mainly used for lighting, especially in the maternity sections, since most of the births occur at night. Although the health stations are often fully equipped with electric appliances like fans and fluorescent tubes, the power of the panel usually does not allow more than the illumination of a few rooms. All of the eight health stations, from which detailed information on energy usage was obtained, use gas-run fridges to store vaccinations and drugs. Health stations without solar panels use torches to work at night, which basically implies writing reports and making consultations.

Respondents were as well asked to comment on the health stations' main problems. Although the electrification background of the survey was revealed to the respondent, most health stations named the bad condition of the buildings and the poor equipment as the major problem. Electricity is the second most pressing problem, especially for lighting. This would facilitate consultations and writing reports at night and improve the nurses' living conditions as their lodging next to the health station is typically not equipped with electric lighting devices. Refrigeration, which is typically expected to be an important usage of electricity in health stations, has not been mentioned.

5. Summary: Answers to the evaluation questions

In this section we summarize the findings of the impact evaluation by providing point by point answers to each evaluation question on the level of outcomes and impacts as they are formulated in the Terms of Reference underlying this study. For details we refer in every case to the corresponding section in the report.

5.1. Outcome

To what extent has the access to electricity changed?

At the time of the survey end of 2012, Yeelen Ba panels could be found in 6.7 percent of the households (Section 4.2). The penetration rate thereby more than doubled within the last two years. Simultaneously privately acquired SHS (`private panels') massively entered the market too. In 2012, every third household owned such a solar panel. Alternative electricity sources are virtually inexistent. Considering the general presence of private panels, not all households who became Yeelen Ba clients can be counted as newly provided with electricity services. Among the Yeelen Ba users interviewed in 2012, 24 percent stated to have owned another electricity source before. Among the households that were visited both in the baseline and follow-up this share even amounts to 40 percent. There are at the same time indications that the quality of electricity access has improved. The Yeelen Ba solar kits include high-quality equipment, which makes less people complain about the power of the SHS than among private panel users. Furthermore, the Yeelen Ba panels allow more households using electric lighting and television (Sections 4.3.2, 4.3.3 and 4.3.5).

How reliable is the electricity supply?

In particular the higher quality of the batteries used by Yeelen Ba guarantee that households benefit from a reliable electricity supply even after hours of electricity use. System failures are rare – both among Yeelen Ba households and private panel users (Section 4.2). Since the fee for service system also includes lighting devices, Yeelen Ba households experience more often longer periods with part of their electric lighting being non-functional. Households stated that it usually took Yeelen Ba around a month to fix such problems. Yeelen Ba's promise that every problem will be fixed within 48 hours after reporting, does not seem to be effective yet.

Which socio-economic groups (incl. poor/non-poor, m/f) benefit from increased access?

Determinants of Yeelen Ba take-up have been assessed both quantitatively and qualitatively. Purchasing power is a critical aspect of uptake. Whereas in the lowest quintile of the income distribution only 3.3 percent of households have a Yeelen Ba panel, this proportion is 12.2 percent in the highest quintile (Section 4.2). Education in turn does not play a role in panel acquisition. Concerning the sector of activity, it needs to be taken into account that almost all households (more than 90 percent) are primarily occupied in agriculture. Still Yeelen Ba households are significantly more likely to be found among civil servants. Female-headed households virtually do not exist in Kénédougou (Section 4.14.2).

5.2. Impacts

In the following, the evaluation questions specific to the present assignment will be answered based on the rigorous impact analyses that have been conducted.

For what purpose and by whom in the household is electricity used?

Even the most powerful SHS kit of Yeelen Ba only provides three light bulbs and one socket, which in most cases is used for television (Section 4.3.2). More than half the households count at least four buildings and as many as 97 percent of Yeelen Ba households use at least one lamp for exterior lighting. Hence, not all buildings can be illuminated. Priority is given to the head of households dwelling. Importance is also put to using the electric light for studies at night of school children and the improved security situation of the whole family generated by electric lighting (Section 4.3). Concerning television, heads of households watch most and about 50 percent more than their spouses (65 compared to 40 minutes per day, see Section 4.3.5). Small children often watch with their parents (complemented by watching cartoons), whereas adolescents tend to watch least.

Furthermore, more than two-thirds of Yeelen Ba households have at least two mobile phones at their disposal. Virtually all recharge their mobile phone battery at home. Finally, some households (less than 20 percent) additionally use the SHS electricity to run a line-powered radio.

How have expenditures for energy changed?

According to a comparison of Yeelen Ba households with similar households out of the no solar panel control group conducted in Section 4.3.4, Yeelen Ba clients pay on average a monthly extra of 4500 to 4850 CFA F for energy, depending on the estimation approach, and thereby almost three times more. Private panel households as well spend less than Yeelen Ba households – on average 3250 to 4550 CFA F per month even accounting for the acquisition costs of the private panel. These findings underscore that the increased convenience and scope of energy services through the usage of new electric devices leads to higher aggregate energy expenditures. At the same time, the unit costs of these energy services tend to decrease.

To what extent has safety/protection changed?

Of course, objective and even subjective safety is difficult to assess. This study therefore relies on a range of proxy indicators and findings from FGDs (Section 4.3.8). Substantive evidence could not be gathered. However, the individual perception of safety has increased as expressed in FGDs, which is also substantiated by the fact that 97 percent of interviewees consider darkness as dangerous.

To what extent has comfort/convenience changed, disaggregated by gender? What monetary value do households attribute to this increased convenience?

Comfort has increased due to all the purposes for which electricity is used as mentioned above. All households can switch on electric lighting and charge their mobile phones at home, many can are additionally able to watch TV without having to go to someone else’s place. Particularly women can more easily reallocate their activities throughout the day.

In order to determine the monetary value that households attribute to the increased convenience and in general the value they assign to their electricity service, a Willingness To Accept (WTA) approach has been applied (Section 4.3.10). It turns out that only a fourth of current Yeelen Ba users would accept to get disconnected under the condition of receiving a compensation that amounts to the price of the most expensive Yeelen Ba service level. Hence, SHS-using households seem to value their panels even more than expressed in their monthly payment. So far relatively low disconnection rates – which were moreover mostly due to debts that had accumulated before the price reduction in the beginning of 2012 – support the observation that clients value the Yeelen Ba services.

To what extent do activities during evening hours change? Have study hours/reading time of children changed? Do women (and children) enjoy more or less rest for physical recuperation?

Improved lighting and television seem to explain the fact that women in Yeelen Ba households stay awake longer time than women from the non-electrified group (21.50 pm compared to 21.30 pm). At the same time they go out less often and do relatively more of their household duties at night, whereas there are coherent indications that the time dedicated to domestic work throughout the whole day has decreased considerably, which supports reallocation hypothesis as a way to improve gender empowerment by increasing women's 'agency freedom' (Sen 1985). Such changes cannot be observed for household heads (Section 4.3.5 and 4.3.6).

Watching television as a new activity made possible by the electricity access is actually mostly undertaken during evening hours. Besides working and going out, other main activities followed by household members at home are radio listening, chatting and praying. Households do not abandon these activities after electrification but substitute them to a certain degree by watching television.

Studying hours at home are on average higher for Yeelen Ba households. This, however, has to do with the fact that they send their children more often to school, which is unlikely to be a cause of the electricity access. When restricting the analysis only to those households where children go to school virtually no differences can be observed. In the surveyed area, school children, furthermore, generally tend to study after nightfall. Even primary school children in households without solar panels study three-fourth of their time after 18 o'clock in the evening. Hence, the main impact in this context is the improved quality of lighting in Yeelen Ba households instead of a change in the quantity of studying.

To what extent has indoor air pollution been reduced (according to the perception of dwellers)?

Indoor air pollution is an issue in light of the fact that more than 80 percent of households cook in closed spaces and that 22 percent of non-electrified households still use smoke-emitting lighting devices such as kerosene lanterns (Section 4.3.8). In fact, virtually all households attribute bad indoor air to cooking with woodfuels, but no household uses electric cooking stoves. At the same time, the improved lighting situation seems to make a small difference: 29 percent households who use smoke-emitting lamps do not perceive their indoor air as sufficiently good or even as bad compared to 15 to 18 percent among the other households.

What (if any) are the un-intended or negative impacts?

The set of potential energy services provided by the SHS is relatively restricted. It therefore does not come as a surprise that – at least for the time being – no particular unintended or negative impacts can be pointed out. When asked for their own perception, 12 percent of households without electricity see negative impacts induced by electricity. Their examples given are electrocutions, fire or damages to devices. Interestingly, the same question asked to electrified households yields an almost identical share of 11 percent, who mention the same issues only complemented by short-circuits that negatively affect electric devices. However, none of these households has actually undergone any of the cited negative impacts.

How have, in response to the possibly increased media exposure, attitudes and behaviours, such as women's status, fertility, children's school enrolment changed?

Differences between the compared groups in terms of children's school enrolment are still substantial. These differences, however, cannot be attributed to the SHS intervention. Women's status and fertility are as well aspects of the socio-cultural life of households, where impacts unfold only in a longer time frame, whereas Yeelen Ba households owned their panels for on average only 12 months at the time of the follow-up. Accordingly, the impact assessment only weakly hints to positive contributions of panel ownership and does not yet provide robust evidence on gender-related impacts (Section 4.3.8).

6. Concluding remarks

Yeelen Ba has introduced an innovative concept in its intervention area in rural Western Burkina Faso: to offer Solar Home Systems (SHS) to the local population via a fee-for-service system that allows to continuously benefit from electricity access without having to cover the high one-time investment costs of these electricity sources.

After first SHS have been marketed in mid-2009, Yeelen Ba experienced a rather slow and low uptake of their panels. Apart from the innovativeness of the marketing approach and management problems in the beginning (which have been promptly overcome) there are two main factors responsible for this. First, there has been a simultaneous boom in relatively cheap solar panels privately acquired on local markets. This makes the Yeelen Ba panels appear expensive to the population. While Yeelen Ba users appreciate the higher quality of their panels, this seems not to fully compensate for the higher prices. At least, many households do not see themselves as capable to afford the Yeelen Ba services. In line with this observation, Yeelen Ba is primarily adopted by the better-off households in the rural communities. The second factor relates to the business model of renting without the option to purchase, which is not appreciated by many. Some simply do not understand that they have to pay a fee each month for something of which they will never acquire ownership. Yet, even those who understand this novel concept would often prefer to buy their panel. In some cases, the opinion of leaders and learning from others proved to be relevant for the adoption of the Yeelen Ba panels as well. This is a common phenomenon, particularly for new technologies, as evidenced in the agricultural literature.

Objectively it is not clear whether a privately owned panel or a Yeelen Ba rented panel is more economic. At least in monetary terms, a private panel is cheaper at the end – even accounting for maintenance and bulbs. Possible quality differences are, of course, difficult to value in this context. At least in comparison to the situation without any electricity access, solar power seems to be a win-win: under the expectation of a reliable SHS recycling system established by the project, there is both a private return for the households and an environmental return for society through reductions in the use of kerosene, candles and batteries. The private return particularly originates from improved lighting and the new opportunity to privately watch TV, which are both highly appreciated by the users. In addition, there are minor impacts on time use of household members, e.g. on study time of children.

From a policy perspective the question is whether SHS should be promoted by direct or indirect subsidies. For most of the population in regions like the one in which Yeelen Ba is active, subsidies do not seem to be justified. The returns are mainly private and not external effects. Furthermore, large parts of these returns are monetary (most notably savings in energy expenditures) and, not least, people seem to be able to undertake the required investment. In contrast, subsidies might be required if more disadvantages groups in the population or more remote regions are as well targeted as it is the case for the United Nations initiative *Sustainable Energy for All* (SE4All). Se4All envisages providing access to modern energy to all households worldwide by 2030, i.e. including the disadvantaged groups. The poorer strata in the regions surveyed for this study but also in those of the other evaluation studies will hardly be able to bring up the investment costs required for an SHS – be it a higher quality or a lower quality one.

To achieve this purpose, direct or indirect subsidies targeted towards disadvantages groups are probably necessary. Direct subsidizes should in particular be considered in case of permanent liquidity constraints. In case of temporal liquidity constraints financing mechanisms might also be an option. This could also include fee-for-services approaches like the one applied by Yeelen Ba. This might in particular be promising if the scope of offered services is broadened towards smaller SHS kits (e.g. Pico-PV).

If donor agencies and governments decide to promote solar products, the question of which quality level to support emerges. Lower quality products – solar or battery-driven – are available everywhere in rural Africa without any public sector support and the price differences to higher quality products are huge. If the focus is to be put on the promotion of higher quality products as they are mostly favoured by donor agencies, a clear demarcation to lower quality products needs to be established in order to improve the level of information available to consumers. A straightforward approach would be to include larger SHS as they are marketed by Yeelen Ba in the quality assurance system developed by the World Bank programme Lighting Africa, which has so far concentrated on Pico-PV systems. It is nonetheless questionable if a quality certification of SHS kits would follow the same rationale that underlies the labelling of improved stoves, for example in the GIZ programme FAFASO in Burkina Faso. While the improved stove market broke down in the past because of a quality wise race to the bottom of locally produced stoves, this market failure is so far not perceivable for solar products.

Two further aspects might suggest complementary public intervention. First, in order to avoid reverse local environmental effects, a system of recycling or at least safe disposal of discarded SHS could be considered. Likewise, African governments should establish a disposal system for dry-cell batteries that are increasingly used by non-electrified households due to the price decrease in LEDlamps. Hitherto, these batteries are simply dumped into natural toilets or together with non-problematic garbage into the environment.

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Annex 1: Propensity Score Matching

When treatment participation is not by random assignment but depends on a set of observable characteristics, *X*, the concept of propensity scores is useful. In the present case the subscription to a Yeelen Ba solar home system (SHS) on a user fee basis clearly falls into this category of treatment. Users are probably not just a random group of households in the project area, but rather households that are for example a bit richer and better educated than the average household. Put differently, households are likely to select themselves, according to some observable characteristics, *X*, into the group of users.

The idea of Propensity Score Matching (PSM) is then to compare the actual users with a group of non-users that are based on the observable characteristics, *X*, equally likely to be a user than the actual users. Hence, the comparison is limited to a very homogenous group of households. The implicit assumption is that the users that are observed would behave - in case they would not use a SHS – in the same way as the non-owners – the matches - to which we compare them.

Key to the application of this approach is the co-called common support condition, i.e. there should be enough non-users of SHS that share the same characteristics than the users. This ensures that we have untreated matches for the treated observations for every *X*. The propensity scores can be obtained by estimating econometrically the latent probability of being a user of a SHS on a set of observed variables, *X*. Given that the latent probability is unobserved the binary information of use/non-use is used as dependant variable. Such a model can be estimated using for instance a probit or logit model and the estimated regressions coefficients can then be used to predict conditional on *X* the hypothetical probability of using a SHS. This is then called 'propensity score'.

Propensity score matching does not work if the characteristics that explain selection into treatment are unobserved. If for instance astuteness of the household head is a key determinant in the decision to use a SHS and if astuteness cannot be observed, PSM is not a solution. However, if astuteness is only one of the many characteristics explaining the selection process and if astuteness is strongly correlated with other observable characteristics such as education and income the PSM approach would indirectly also reduce a potential bias through unobservable characteristics and can be seen as a valid approach to increase the efficiency of the impact assessment.

For a more detailed presentation and the underlying mathematics of this approach see for instance Caliendo and Kopeinig (2008) or Cameron and Trivedi (2009). Note also that the literature proposes a number of other matching estimators.

Annex 2: Willingness to pay

There are some important aspects that need to be addressed when carrying out a willingness to pay (WTP) analysis. If sufficient variation in the price of the good is observable in a market, the WTP can be obtained from the revealed preferences of households in this market. If, for example, the price of fruits varies over time and across regions, the response in demand to price changes of fruits can be used to derive the WTP for fruits of different household groups. However, people might also assign a value to goods for which no market exists, for example clean water in rivers. In order to elicit this value, so called stated preferences techniques have been developed. These techniques can as well be applied to goods for which – in principle – a market exists, but no sufficient variation in market prices can be observed. Although SHS can be purchased on markets in rural Burkina Faso, the market is too small and prices do hardly vary. In addition, the particular fee-for-service product offered by Yeelen Ba is new and no market exists so far for this service. Therefore, stated preferences techniques can be used to scrutinize the value people assign to electricity from SHS in general and provided by Yeelen Ba in particular.

In principle, such stated preferences techniques simply ask respondents for their WTP. The most straightforward approach is the dichotomous choice method, for which the respondent is asked if s/he is willing to pay a certain price. For the double bounded dichotomous choice method, respondents are confronted with a follow-up question after the first response (e.g. if they are willing to pay 50% more/less depending on the first answer). If open-ended questions are applied, respondents are asked to state their WTP without any concrete offer. Devicienti et al. (2004), Abdullah and Jeanty (2009) and FAO (2000) are sample studies where the WTP approach has been applied to assess benefits from access to energy.

Note that for various reasons the stated WTP values may deviate from the revealed WTP, which can be observed only if the product is in fact available. The stated willingness might be biased because the respondents simply do not really grasp the idea of the question or because respondents answer strategically because they expect that their response influences the real product price later. This, in turn, can induce an upward or a downward bias (cf. Devicienti et al. 2004).

Annex 3: Survey implementation

Survey Tools

The principal tool used in this study is the structured questionnaire. Given that the aims of the survey included a number of questions in particular related to intra-household decision making and women's particular preferences and attitudes, we designed two questionnaires: (i) a household questionnaire to be answered preferably by the household head and (ii) a women's questionnaire to be answered by one female spouse (see Appendix 1 and Appendix 2 (files) for the original French versions of the questionnaires).

The questionnaire for the head of the household covers all key socio-economic aspects that characterise the household's living conditions such as the financial, security, health and demographic situation. A particular focus is put on the use of energy sources and appliances and related expenditures. Furthermore, the questionnaire includes a willingness-to-pay section (WTP), i.e. households have been asked how much they would be willing to pay to get a well-defined package of electricity services (for details on WTP see Annex 2). Beyond the comprehensive household questionnaire, a second short one-page household questionnaire has been prepared for part of the control households in the follow-up survey (see 3.2). The collected information is cut down to data on the existence of electricity sources, purposes the electricity is used for and the perception of Yeelen Ba.

The complementary women's questionnaire seeks information on women's perception and usage of electricity, on women's role in the household, on contraceptive usage, and women's attitude towards domestic violence. These questions help to analyse whether electricity in general and TV or radio usage in particular trigger new views and norms in terms of family planning and women's empowerment. As outlined in Section 3.1, this might be a more indirect but in the long-term extremely important transmission channel of how electrification translates into poverty alleviation in a broader sense.

Obviously, some of the issues raised in the women's questionnaire, such as domestic violence, are sensitive topics. The concrete wording of the questions has therefore been the same as the one used in the Burkinabè Demographic and Health Survey Questionnaire 2003. Hence, these questions have already been officially approved and asked in surveys in Burkina Faso. Like for all other parts of the questionnaire, answering these questions was voluntary. Since the Burkinabè partner organisation responsible for the implementation of the survey considered these questions as not particularly sensitive, these interviews were conducted by both male and female enumerators. Whenever possible, the women have been interviewed separately, thus ensuring that they could answer the questions without feeling observed by their husband or another male villager. In most cases, interviewees were immediately willing to answer these questions. Only in some cases enumerators had to explain the intention behind the inclusion of certain questions (e.g. those on contraception) in a survey about energy use. Eventually, more than 99 percent of the interviewed women answered all questions.

The community questionnaire (see Appendix 3 (file)) serves to collect information about regional characteristics and was, whenever possible, addressed to the local representative of the surveyed village. It includes questions on infrastructure access and quality, local economic conditions such as cash crop and employment opportunities, energy prices and general energy usage patterns in the village. In the follow-up survey questions on Yeelen Ba have been added in order to gain insights on its activities and villagers' perceptions. These questions encompass for example the distance to the next agency, the satisfaction with the Yeelen Ba service or the last time a Yeelen Ba technician visited the village. As such, the gathered village data can be linked to the household data from the household questionnaires.

In addition to these structured questionnaires, semi-structured interviews were conducted at schools and health centres to obtain information regarding their energy needs and energy consumption. These social infrastructures represent the most important public service providers at local level and are potential future clients for Yeelen Ba.

FGDs have been used to learn more about the reason why certain households do not intend to take up the technology and to get insights into energy-related attitudes and knowledge. A focus group in this context consists of a group of individuals (usually six to ten persons) selected and assembled by researchers to discuss and comment on, from personal experience, the topic that is the subject of the research (Powell 1996). Facilitators take care that each person participates actively in the discussion FGDs can play an important role to investigate and complement the exact meaning of the structured survey results and to bring them in a broader context (Schutt 2004).

In order to check the completeness and appropriateness of the questionnaire and to account for potentially unintended impacts, one FGD was done in the pre-test phase. During survey implementation another three FGDs were held in 2010 and 2012 respectively. In 2010, the FGDs addressed women associations and men cooperatives, each in a village of a different district. All discussions were guided by the same list of open questions including the use of electricity for private consumption and for productive use in the group (see Appendix 4 (file)). For example, it was asked which electricity sources are prioritized and how electricity can improve their daily work. The FGDs during the time of the follow-up in 2012 focused more explicitly on the usage of Yeelen Ba and were carried out with women associations, Yeelen Ba users and Yeelen Ba non-users separately. As well, the discussions were guided using the same list of open questions but in this case with a particular focus on why some do use the Yeelen Ba service while others do not.

Sampling

A two-stage random sampling was applied with the first stage being on the village level and the second on household level. At the outset, all 120 villages targeted by Yeelen Ba in Kénédougou Province were eligible as they could be considered as 'treated' in a sense that Yeelen Ba information campaigns have taken place and households can subscribe to the service. Among them, 40 were randomly drawn according to proportional-to-size probability sampling: the likelihood of each village to be in the sample was proportional to the number of households living in that village. The villages accommodate between 59 and 1,018 households and have an average population size of 1,940.

Logistically, the implementation of the village sampling faced some problems due to the inaccessibility of certain villages. The rainy season had uncommonly continued until October and in one case the bridges to access the village were not passable. As a result, seven villages from the original list of randomly selected villages had to be replaced. Based on general village information about schools, health stations, churches, and market places that was obtained from local authorities, it could be verified that the replaced villages do not differ structurally from the sampled replacement villages, except that they are not (easily) accessible by a vehicle during some periods of the year.

The sampling at the second stage, i.e. at the household level, was done on site by the survey team. In each village 30 households were selected randomly. For that purpose each of the five enumerators per team was assigned to a section of the village with the help of a map. In each section every n^{th} household was interviewed with the *n* depending on the number of households that lived in the respective part of the village. In virtually all cases we found the relevant household members to conduct the interviews. If the household head and his wife could not be found, other household members were asked to fix an appointment for the same day with the household head. In the rare case that no member at all could be found, the household next door was interviewed. None of the households refused to answer the questionnaire.

As indicated in the Terms of Reference of this study, the option of undertaking additional baseline interviews with every new client of Yeelen Ba for a period of about three months after the survey was scrutinized. This procedure would have ensured that we end up with a higher share of users in the follow-up survey. Yet, this approach would have been out of proportion, since the number of new clients per month was 20 in a total area of the province of around 8000 km^2. As an alternative, we discussed with Yeelen Ba whether their technicians could do the interviews. But this proved to be not feasible since Yeelen Ba was entering a period of organizational restructuring right after the survey, and hence the technicians unfortunately had not the time to administer the questionnaires on top of their actual tasks.

The follow-up survey was carried out exactly two years after the baseline survey. Among the 40 villages visited in 2010, 7 villages with 210 baseline household interviews have not been revisited, as there has not been any take-up of Yeelen Ba panels in the respective district. Instead, these villages have been visited by a member of the evaluation team to qualitatively assess the reasons for this lack in take-up. In the remaining 33 villages, several strategies were applied in order to retrieve as many baseline households as possible: Whenever possible, members of the baseline group were called by mobile phone two days before they were supposed to be interviewed. In addition, village or even district representatives were contacted in advance to pass the information. Eventually, 106 baseline households could not be retrieved, which implies an attrition rate of 10.7 percent. Most of these households had moved or had permanently not been available during the survey, e.g. they abandoned their home in order to settle close to their fields during the harvest period. Two households refused to be re-interviewed.

Different from the baseline, every third household encountered not owning a Yeelen Ba panel was interviewed using the short one-page questionnaire only. Another difference to the baseline sampling was that in the 33 surveyed villages, all households using Yeelen Ba panels at the time of the follow-up have been interviewed. To identify these households we used the Yeelen Ba clients list and were, if needed, supported by the local Yeelen Ba technician. In some cases, we encountered households that had been using a Yeelen Ba Panel for some time but were not on the list. After cross-checking their Yeelen Ba code and the installation date, they were then as well interviewed.

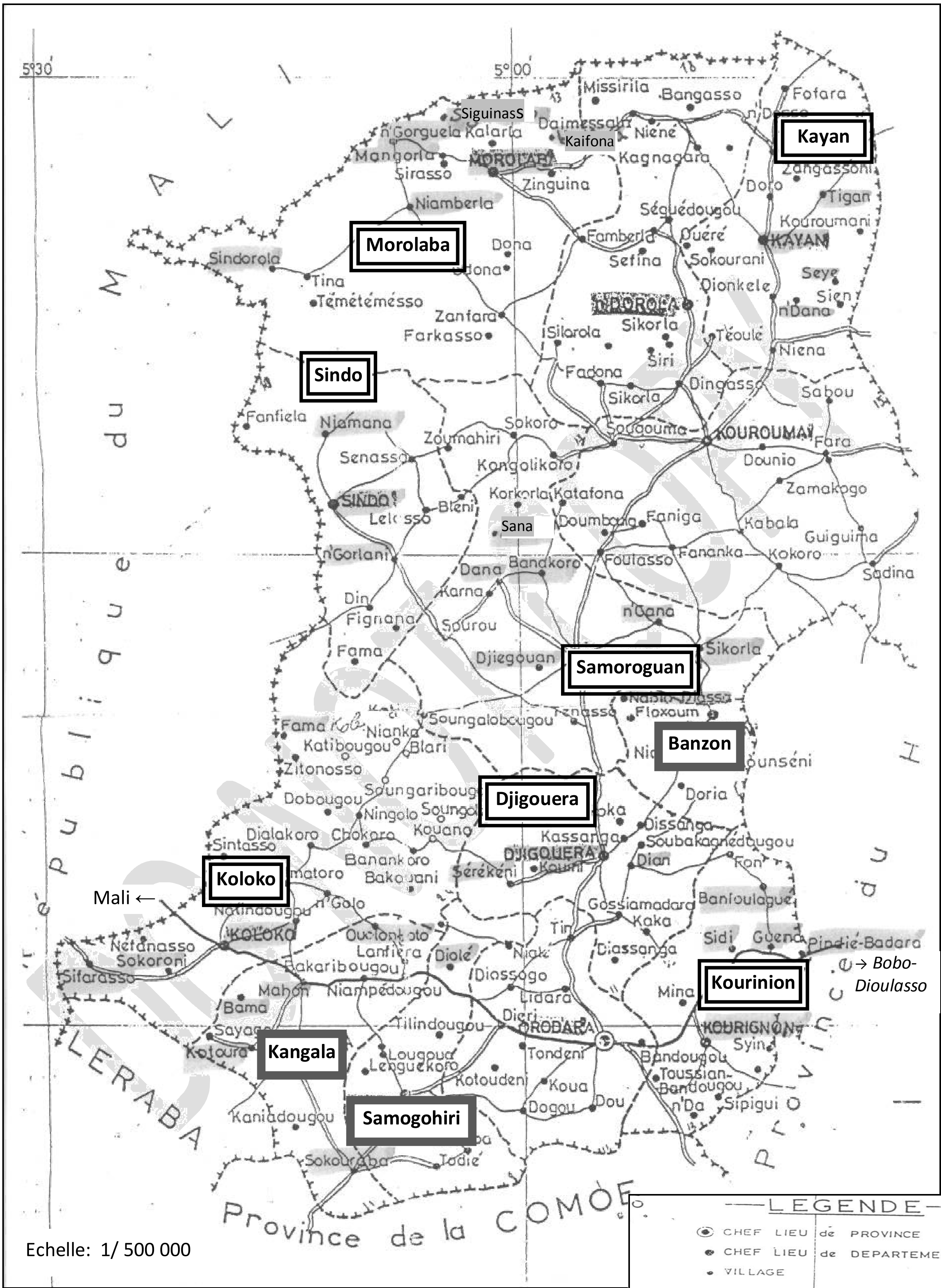
Survey schedule and implementation

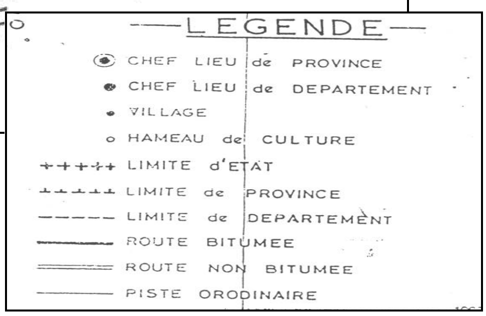
For the implementation of the two survey waves in 2010 and 2012 as outlined in the table below RWI/ ISS teamed up with a local research institute, based in Ouagadougou and experienced in the field of energy surveys, called *Bureau d'Etudes des Géosciences, des Energies et de l'Environnement* (BEGE). BEGE was responsible for the logistical organization of the survey including, for example, the recruitment of the interviewers and the hiring of cars. Moreover they were responsible for the quality assurance of the survey, i.e. that the households were sampled properly, the questionnaires were completed consistently, and the data entry was done accurately. The survey was conducted by two teams, each consisting of 5 interviewers and one supervisor. Throughout the survey an ISS/RWI team member stayed with the survey team to act as supervisor, ensure the proper implementation and to conduct interviews and FGD on the community level.

Pre-Departure Preparation of the Studies	*until October 1, 2010*
Desk Study of relevant project documents and literature; adaptation of existing survey methodology; questionnaire design in French; Excel matrix for data entry; coordination with local partner BEGE	
In-Country Preparation of the Studies (RWI/ISS Mission – Solar Home Systems and Improved Stove Study)	*between October 10 and 24, 2010*
▪ Coordination with local partner BEGE, project staff and national partners concerning both Solar Home Systems (Yeelen Ba) and Improved Stove (FAFASO) study; ▪ Field trips to Yeelen Ba sites not included in the sample; ▪ Choice on survey sites and planning of survey organisation and logistics, with the assistance of the supervisors and project staff; ▪ Design details of the study; ▪ Revision of the questionnaire; ▪ Four-day Training in Orodara of a survey team consisting of two survey supervisors, ten enumerators and four operators for the data – the training included interview simulations in the local language Dioula, a pre-test of the questionnaire and an introduction to data entry; ▪ Final review of questionnaire and survey organisation and logistics in cooperation with the supervisors and a Yeelen Ba staff member.	
Realization of the Yeelen Ba Survey	between November 1 and November 25, 2010
Survey implementation of the study of solar home systems by RWI research assistant and enumerators.	
Data Compilation	*until February 08, 2011*
Data entry by operators for the data	

Source: Own illustration

Annex 4: Map of Kénédougou (survey region)





Note: Districts whose names are in bold grey boxes have only been sampled in the baseline, those in double-line boxes have been sampled both in baseline and in the follow-up; marked in grey are the sampled villages.

Annex 5: Comparison of Yeelen Ba households with and without baseline information

	Yeelen Ba household		Test on difference in means
	already interviewed in baseline	**additionally included in follow-up**	***p*-value**
Household size	10.01	9.47	0.45
Share of polygamous households, in %	74.1	64.8	0.15
Age of head of household, in years	46.2	42.2	0.02**
Head of household with formal education, in %	26.8	27.3	0.94
Sector of activity of head of household is farming, in %	98.3	86.6	0.00***
Sheep ownership, in % of households	50.0	44.4	0.44
Monthly household expenditures excluding energy, in CFA F	135.290	107.710	0.13
Ownership of a motorized vehicle, in % of households	89.7	81.1	0.07*
TV ownership, in % of households	48.3	50.7	0.73
Total lighting hours per day	11.47	10.00	0.07*
Number of observations	58	270	-

Source: Solar Home System follow-up dataset 2012.

Annex 6: Quality of balancing as achieved by matching

The most straightforward way to assess the quality of the balancing properties of a matching procedure is to compare covariates before and after matching in order to see whether differences between the two compared groups are attenuated or even vanish due to the matching. Yeelen Ba households are separately compared to no solar panel households (left side of the tables) and to private panel households (right side of the table).

Usually, one would use baseline data as covariates. Given the present sample structure with a good part of treated households newly included only in the follow-up, it was decided to match on follow-up covariates. These are tabulated in the following. It becomes obvious that significant differences before matching actually vanish. So-called likelihood-ratio tests, furthermore, revealed that the set of the covariates is also jointly highly insignificant after matching. This means that even when accounting for potential interdependencies between the different covariates, they do not differ between any of the compared groups.

Follow-up data		**Compared hh**		Test on difference in means	**Compared hh**		Test on difference in means
		Yeelen Ba	**No Solar Panel**	***p*-value**	**Yeelen Ba**	**Private Panel**	***p*-value**
Household (hh) size	before	2.11	1.90	0.00***	2.11	2.02	0.05**
	after	2.08	2.09	0.88	2.12	2.11	0.94
Share of polygamous hh, in %	before	66.5	48.5	0.00***	66.5	62.6	0.34
	after	65.1	67.7	0.52	66.8	68.2	0.72
Age of head of hh, in years	before	43.0	44.6	0.09*	43.0	42.8	0.86
	after	43.1	43.4	0.78	42.3	42.6	0.73
Squared age of head of hh, in years	before	1981	2139	0.10*	1981	1954	0.78
	after	1992	2026	0.75	1899	1939	0.64
Sector of activity of head of hh is farming, in %	before	88.7	92.7	0.07*	88.7	92.5	0.14
	after	90.3	91.6	0.60	88.8	91.8	0.23
Head of hh with formal education, in %	before	27.2	26.2	0.77	27.2	31.8	0.24
	after	26.3	29.1	0.45	27.8	27.4	0.93
Asset index	before	0.69	0.56	0.00***	0.69	0.69	0.64
	after	0.67	0.68	0.81	0.69	0.68	0.66
Monthly hh expenditures excluding energy, in logarithmic terms	before	11.29	10.70	0.00***	11.29	11.25	0.58
	after	11.25	11.21	0.56	11.32	11.32	0.95
Number of observations		328	330		328	238	

Source: Solar Home System follow-up dataset 2012.

(continues next page)

Applying the same matching procedure to the baseline data used for the difference-in-differences approach as well brings to light that no differences can be observed after matching for the baseline data either.

Baseline data		**Compared hh**		Test on difference in means	**Compared hh**		Test on difference in means
		Yeelen Ba	**No Solar Panel**	***p*-value**	**Yeelen Ba**	**Private Panel**	***p*-value**
Household (hh) size	before	2.13	1.93	0.00***	2.13	2.07	0.08*
	after	2.25	2.24	0.91	2.25	2.27	0.77
Share of polygamous hh, in %	before	68.7	49.8	0.00***	68.7	64.5	0.20
	after	80.7	82.5	0.81	81.0	87.9	0.31
Age of head of hh, in years	before	43.3	43.7	0.57	43.3	41.9	0.08*
	after	44.7	43.2	0.42	44.9	44.6	0.85
Squared age of head of hh, in years	before	2005	2066	0.43	2005	1882	0.10
	after	2118	1950	0.37	2139	2099	0.84
Sector of activity of head of hh is farming, in %	before	88.3	92.7	0.02**	88.3	91.8	0.09*
	after	87.7	86.0	0.78	86.2	86.2	1.00
Head of hh with formal education, in %	before	26.7	25.3	0.63	26.7	32.3	0.08*
	after	24.6	21.1	0.66	24.1	27.6	0.68
Asset index	before	0.68	0.53	0.00***	0.68	0.67	0.33
	after	0.64	0.62	0.54	0.64	0.66	0.54
Monthly hh expenditures excluding energy, in logarithmic terms	before	11.29	10.76	0.00***	11.29	11.26	0.60
	after	11.25	11.27	0.91	11.26	11.39	0.35
Number of observations		58	330		58	238	

Source: Solar Home System baseline dataset 2010.

The identification strategy in Section 3.2 additionally proposes a propensity score weighted regression approach (PS-w OLS). Propensity scores as weights are derived using the same probit model with the same covariates as above, with the only difference that the probit model emulates the decision to acquire a Yeelen Ba panel or not instead of a pairwise comparison to private and no solar panel households. Similar to the likelihood-ratio tests conducted above, Hotelling's T-squared test underpins that PS-weighting yielded a weighted sample with the desired property that relevant covariates are jointly insignificant.

Joint set of follow-up covariates	Hotelling's T-Squared	Test on difference in multivariate means	Number of observations	
		***p*-value**	**Yeelen Ba**	**other households**
Before PS-weighting	76.2	0.00	308	550
After PS-weighting	1.6	0.99	308	550

Source: Solar Home System follow-up dataset 2012.

Annex 7: Pictures of encountered types of lighting devices

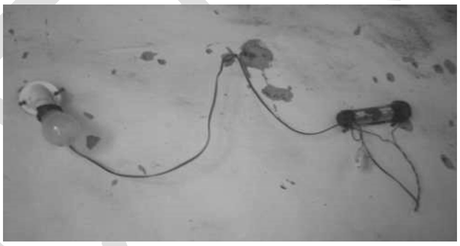
a. Light Bulb

b. Neon Tube

c. Energy Saver

d1. Mobile LED lamp

d2. Fixed Torch



d3. Gas Lamp

d4. Hurricane Lantern

d6. Oil Lamp

[Photo not available]

d5. Traditional Tin Lamp

Source: Own illustration

Electronic Appendix

Appendix 1 (file): Household questionnaire, baseline and follow-up

Appendix 2 (file): Women questionnaire, baseline and follow-up

Appendix 3 (file): Village questionnaire, baseline and follow-up

Appendix 4 (file): FGD questionnaire