Impact Evaluation of the Lumière Project

Final Report

Anousheh Alamir
Tillmann Heidelk
Julia Jadin
Juan Carlos Muñoz-Mora
Rama Lionel Ngenzebuke

Philip Verwimp (Team Leader)

Université Libre de Bruxelles

UNICEF-Burundi

January 2018

Content

Executive Summary

Purpose of the evaluation

- UNICEF-Burundi asked ULB to undertake an impact evaluation of the Lumiere Project run in three provinces in the rural areas of the country
- Impact evaluation is defined as the change observed between baseline and endline values of selected indicators, at the level of the final beneficiaries as well as at the level of the village-based organisations
- The Lumière Project delivered re-chargeable lamps to rural households trough the model of a social enterprise, executed by FVS-AMADE, a Burundese NGO

Set-up

- A team of the Université libre de Bruxelles interviewed 1.000 rural households in 63 localities (collines) in three provinces (Bururi, Gitega and Makamba) in 2014 and again in 2017.
- The impact evaluation consisted of a randomized controlled trial (RCT) at the level of the colline, whereby 34 of the collines where assigned to receive a Powercycle machine (to re-charge the lamps), and 29 other were not.
- Within each colline we interviewed 18 households, of which 9 were randomly chosen members of the village-based organisations (VBO) that work with FVS-AMADE and 9 were randomly chosen non-members. Power calculations were performed in the baseline report.

Effective Treatment

- Of the 34 collines that were assigned to receive a Powercycle, 24 effectively received one. Seven out of the 10 collines that did not receive one were approached by FVS-AMADE to receive one, but declined, mostly because of financial reasons (Powercycle too expensive).
- We use the 24 effectively treated and the 34 assigned to treatment as well as the distinction between members and non-members to answer the following research questions:
    - Has the portfolio of household energy sources changed in villages that received the intervention ?
    - Have expenses on energy changed ?
    - What is the profile of the user of the Lumière lamps ?
    - How are the local groups organized to implement the intervention ?
    - Has the project increased the welfare in receiving villages or among member of the VBO ?
    - Are there any health or schooling effects ?

Findings at the level of the village-based organisations(VBO)

- The village-based organisations (VBO) working with FVS-AMADE request each member to contribute weekly an amount which varies between 500 and 2500 BIF.

- The profits generated by the Lumière Project are split proportionally to the number of re-charges of the lamps each member did. Concerning the re-charges of the non-members, it is divided equally between members.
- Management practices, prices asked as well as the functioning of the VBO vis-à-vis the FVS-AMADE leadership differ from groupement to groupement , causing confusion. In some VBO the seller of lamp gets a sales commission, which is not the case in others
- There is a direct link between the satisfaction the Lumière project brings and the number of lamps sold: In Wibamba for example, the groupement sold approximately 92 lamps since the implementation of the project; re-charges on average 70 lamps per week and assesses that the Lumière project is the main activity generating income. This is not the case in Gikana, where the group sold only 14 lamps, while recharging on average 8 lamps per week, and assesses that the Project Lumière does not lead to much income because of the low take up.

Findings on Energy Use among the final beneficiairies

- Lumière lamps mostly replaced battery lamps, kerosene and candles within surveyed households. A clear decrease in the use of battery torches and candles is observed amongst Lumière lamp users. User spent 32 BIF less per week on battery torches while non-users spent 71 BIF more.
- A general trend of decreasing use of kerosene is observed amongst all surveyed respondents, but more outspoken for users. The latter spent 189 BIF less per week, while non-users spent 148 BIF less. Wood and grass on the other hand, remain the most used energy sources amongst all observed groups.

Findings on Take-up

- Overall uptake of the technology is at about 12%, but increases to 18.5% among saving group members and to almost 30% among those HHs who live in collines which experienced the intervention. Membership of a savings group is a strong determinant of take-up. This means that the VBO act as clubs whereby members are either encouraged to purchase the lamps or either motivated to help the NGO pursue its goals, or both.
- The level of welfare (in 2014) is a key driver of uptake, indicating a possible uptake hurdle given the very deprived setting under consideration. Household size also positively affects uptake, but having a lot of children in the household does not. This may indicate the households do not acquire the lamps in first instance because of a need to have more light for child-related activities
- Having a female president of the local savings group increases the take-up in the colline, and this is also the case for groups with more male members. The effect of the size of the savings group vis-à-vis the size of the colline is non-linear.

Findings on Welfare

- We document that the Lumière Project is an important source of revenue at the local level for the VBO and it is responsible for the increase of welfare in the collines that are part of it. Due to our evaluation design (randomized allocation of the intervention at the colline level), we can say that the Lumière intervention *caused* the change in welfare. The point estimate of the increase in welfare is between 10 and 18%, depending on specification, with a preferred estimate of 14.5%.
- We did not find statistically significant effects on health or schooling, most likely because the Lumière Project did not address the most polluting source of energy – used by almost all households – which is wood.

1. Introduction

1.1 Context of the Evaluation

Located in the Great Lake region in Eastern Africa, Burundi is one of the poorest countries in Africa, commonly associated with civil war and mass violence in the nineties. The vast majority of the country's population comprises small farmers. With population density among the very highest in Africa, the average farmable land of a household is less than 0.5 hectare, resulting in persistent risk of food insecurity and fragile nutritional conditions. Due to conflict aftermath and drought, Burundi is also heavily dependent on development aid.

In rural areas of Burundi, a very small percentage of all households have access to the electricity grid, resulting in a high reliance on other sources of energy such as wood, batteries and kerosene. These sources are costly, inefficient, unhealthy and not friendly for the environment. The use of energy is an important indicator of the welfare level of a household, a village and an entire country.

By means of its Lumière Project, the UNICEF office in Burundi want to contribute to diminishing energy poverty by empowering communities with a reliable, clean and sustainable energy source. By implementing the project via the social enterprise model, the intervention aims to leverage the power of the market and create a chain reaction of mutual social and economic impacts. Access to clean energy technology enhances education, improves health and safety and provides economic opportunity for the communities, marking its relevance for UNICEF statutory objectives.

In the Lumière project, the UNICEF office in Burundi addressed energy poverty by introducing rechargeable lamps in villages. The introduction of these lamps is meant to increase the availability of light in the household, to reduce the cost, to render its use more efficient, to reduce the use of unhealthy sources and to reduce negative environmental impact. The intended beneficiairies of the project are households who are not linked to the grid in the rural areas of Burundi.

The vehicle for the intervention is FVS-AMADE, a Burundese NGO with many years of experience working in the rural areas. Working with them, UNICEF wanted to see the project as a social enterprise that over time could be self-financed. Rather than building new local groups, FVS-AMADE was able to work with existing village-based organisations (VBO), who had organized themselves as savings groups to support vulnerable children. In this report these organisations are also called "groupements" , the name used locally to identify them.

1.2 Object of the Evaluation

With this evaluation, the UNICEF office in Burundi wanted to obtain detailed information at two levels: (a) at the level of the village-based organisations: how are they working? How important are the activities supported by the Lumiere Project in the overall portfolio of the VBO? Is the project increasing the capacity of the VBO to support its other activities?

And (b) at the level of the final beneficiaries, defined the households residing in the rural areas chosen by the Lumière Project. In order to be able to judge the impact in the final beneficiaries, the evaluation team, in intense cooperation with UNICEF staff, has opted for the following indicators to study:

- Has the portfolio of household energy sources changed in villages that received the intervention ?
- Have expenses on energy changed ?
- What is the profile of the user of the Lumière lamps ?
- How are the local groups organized to implement the intervention ?
- Has the project increased the welfare in receiving villager or among member of VBO ?
- Are there any health or schooling effects ?

In order to answer these questions the team designed a Clustered Randomized Controlled Trial which was described in detail in the baseline report. Its main features are repeated in the Methodology section.

1.3 Purpose and Scope of the Evaluation

The report presents the impact evaluation, not more not less. Impact evaluation is defined in the academic literature as the measurement of a change in relevant indicators in the treatment group compared to the control group. In the case of the Lumiere Project that is at two levels, the level of the VBO and the level of the final beneficiaries. Both will be dealt with.

At the level of the VBO, presented in section (3) we analyse how the VBO works, how they cooperate with FVS-AMADE, how satisfied or dissatisfied they are with the Lumiere Project and what determines their (dis)satisfaction. In sections (4), (5) and (6) we deal with the beneficiary level. That means we first have to analyze the take-up of the new technology, then find out if those who have taken it up have changed their portfolio of energy sources and their expenditures for every source and finally we need to know if the program changed the welfare of the households in our treated sample. For the latter we use household expenditures on food and non-food items per adult equivalent as our main indicator of interest. And lastly, we also want to know if the program had an impact on the health and schooling of household members.

The above are the core ingredients of an impact evaluation. We do not present an overall evaluation as defined by OECD/DAC. This means we do not look at relevance, effectiveness, efficiency, or sustainability. Neither do we consider equity, gender and human rights. We only focus on observed changes among beneficiary households, which is the core of an impact evaluation. Reporting on other OECD/DAC criteria was outside of the scope of this evaluation.

1.4 Research Ethics

The UNICEF office in Burundi had 30 to 40 Powercycles in stock to distribute among as many communities. It was not possible to supply hundreds of village-based organisations with whom FVS-AMADE works with a Powercycle. Let alone all villages in the rural areas of Burundi. That would require a budget that is just not there. Hence, even without the design of an evaluation to measure the impact, some communities would receive a Powercycle and many others would not , at least not for the next few years. In the presence of many candidates and few supply, it is considered fair practice to let the flip of a coin decide which village will receive a Powercycle and which not.

The alternative to random assignment is purposeful assignment, whereby the NGO or the donor selects certain communities who exhibit certain characteristics (poor, rich, close to the road, far away, previous project area, new area, …) to receive a Powercycle and others not. This is a more arbitrary choice, for good or bad reasons, but in any case based on some characteristics. The latter will most likely have an impact on project performance, and on top, its assignment rule may not be regarded as fair.

A randomized controlled trial would also protect FVS-AMADE from criticism that the choice of locations and villages was unfair, the leadership could namely point to the flip of a coin procedure they were obliged to follow.

Permission to do the baseline and endline surveys was granted by the Ministry of Communal Development upon request by the UNICEF office in Burundi. This request included a review of ethical guidelines. No seperate review was performed. Université libre de Bruxelles does not have a IRB. No children were interviewed, informed consent was sought and obtained from all respondents and interviewers were trained in ethical behavior, including the informed consent procedure during a 5 day training course. Data collected in the field were not shared with FVS-AMADE nor with the UNICEF office. Data are stored anonymously with only the team leader in the possession of a key to link the data between different data files. Names are removed from data files.

2. Methodology

We use a mixed-methods approach in the evaluation, consisting of data collection at the level of the VBO, by means of focus group interviews of VBO members (termed savings group questionnaire later on in the report) in all locations under study. In each locations we also field a household questionnaire to members of the VBO and non-members.

Randomized controlled evaluations have the capacity to measure the causal impact of a program. This is the case because on average the treatment and control groups are the same, which is a great outcome of the procedure of random selection into treatment and control. This procedure avoids selection into treatment/control based on a series of background characteristics, motivation, distance, political affiliation, wealth or any other. Accordingly the only difference between the two groups is that one of them will receive the intervention while the other does not. Changes at the end can then be attributed to the intervention.

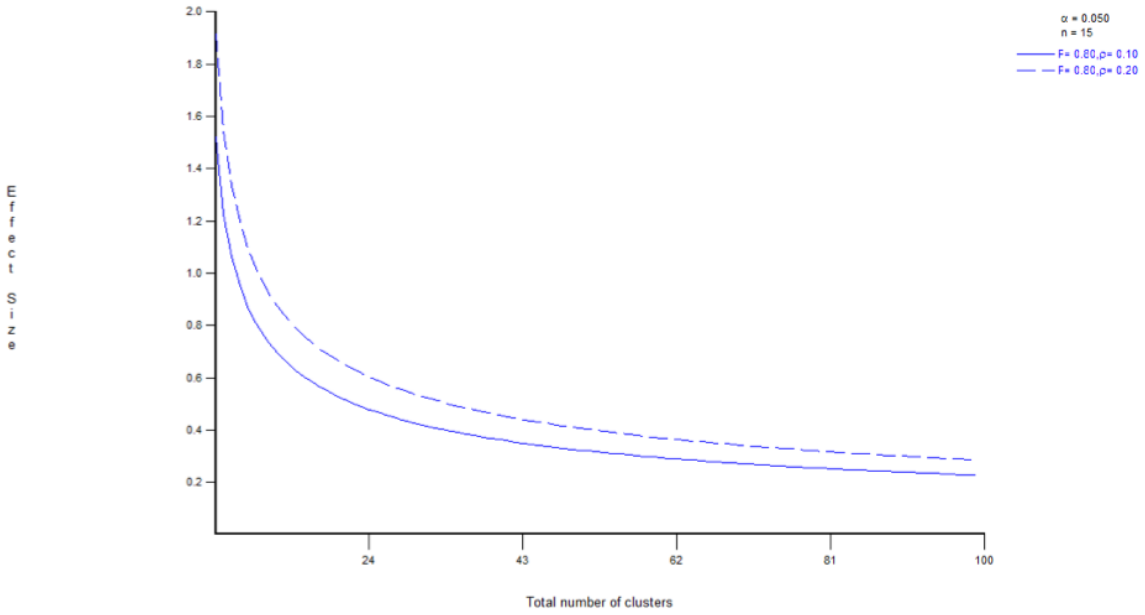
In order to design a randomized evaluation, and in particular the sample size that we need, we need to know the magnitude of the following parameters:

- The Minimum Detectable Effect Size (MDE). This is the size of the effect you want your evaluation design to detect. If you want to detect very small differences between your intervention and control communities, then you need a very large sample, or a very strong intervention. The MDE is expressed in standard deviations of the outcome variable. Cohen (1988) proposes that an effect of 0.2 standard deviation is 'small', 0.5 is 'medium' and 0.8 is "large."
- The Power we want to achieve (=the probability that we will avoid Type II errors, or in other words, it is the probability that – if the true effect is of a given size – we will find an effect that is statistically different from zero, Glennester and Takavarasha, 2013, p.251). In the literature this is usually set at 80%;
- The level of significance of the design (usually 95%);
- The number of clusters to visit and the number of households with a cluster to interview. The former has more impact on the power of the design than the later;
- The intra-cluster correlation. This is the proportion of the overall variance explained by within sous-colline (=cluster) variance. Meaning we have to take account of the fact that the outcomes of members of the same cluster are not independent of one another, they have a degree of correlation. The higher this intra-cluster correlation, the more villages we need to detect an effect of a given size.

This information can then be plugged into software that computes power and sample size under different scenarios. Figure 1 does exactly this. For a given power of 80%, level of significance of 95%, intra-village correlation (set at 0.1 or 0.2), and number of households at 15, it shows that we need 62 villages if we want to detect an effect size of 0.3 standard deviations (which is a relatively small effect size), with intra-cluster correlation of 0.1. With a higher (but maybe more realistic) intra-cluster correlation of 0.2, and with 64

villages, we are able to detect an effect size of 0.4 standard deviations (medium effect size).

Graph 1. Plot of MDE and the number of clusters needed, given a power of 80%, statistical significance of 95%, intra-cluster correlation 0.1 (full line) or 0.2 (broken line) and the number of households to be interviewed per village set at 15.



Thus, with this information in mind we computed our sample size with the following two commands in STATA:

sampsi 0.50 0.52, power (0.8) sd(0.05)

sampclus, obsclus(8) rho(0.2)

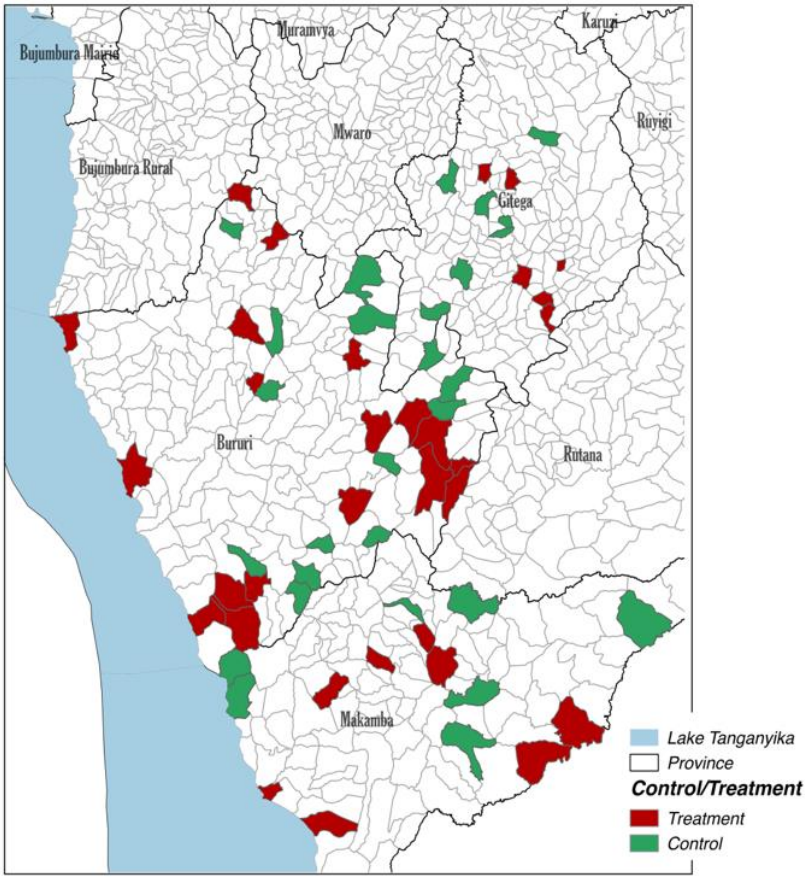
Which yielded the result that we needed at least 60 clusters where we would interview 8 households in each cluster. The MDE = (0.52-0.50)/0.05= 0.4 (small to median size) and we would have 240 hh in the treatment group and 240 in the control.

An additional feature of the Lumière project however is that the provision of the alternative energy source occurs through a local NGO (FVS-AMADE), who works with village-based organisations (VBO) in each of the sous-collines (clusters) that will be visited. In order to take advantage of this opportunity, and to avoid that we sample a lot of VBO members in one cluster and none or just a few in another cluster, we decided to stratify the sampling within each cluster by membership of the VBO. The rationale behind this is that VBO members could take up new technology much faster in a community compared to non-members, be it through their network, or even under pressure for other members to 'contribute' to the success of the project. There is robust evidence available in the academic literature that shows that the take-up of new technology is driven by network

membership and network mechanisms. See for example Crane-Droesch (2015) and Beamon et al (2014).

While the NGO works with the VBO at the sous-colline level, its organisational structure (mainly to fund larger expenses) was at the zonal level, in which all groupements within the zone are supposed to collaborate with one another. For our evaluation design this means that once a sous-colline is selected into treatment or control, the entire zone was treatment or control. This to avoid having both a treatment and a control sous-colline within the same zone. In order to do this systematically, we first randomly divided all zones in the three provinces in treatment or control zones and that randomly sampled treatment sous-collines from the first group of zones and control sous-collines from the second.

Map 1. Treatment and Control Sities in Gitega, Bururi and Makamba Provinces



Hence, via the NGO and the village-based organisations we obtained list of the VBO membership in each sous-colline and drew a random sample of 9 members (one more than 8 as ordered by the STATA calculation to be on the safe side) of each list. Then, we excluded all members (not only the selected ones) from the entire list of households residing in the sous-colline and randomly drew 9 non-members in each sous-colline. We

ended up with 18 households in 34 treatment clusters and 29 control clusters. Map 1 gives the spatial distribution of the clusters.

The field work for the baseline was carried out from July to September 2014 by a team of dedicated Burundese interviewers and supervisors, all of whom had previous interview experience. The went trough of week of intense training on the questionnaire. The later was field tested in an out-of-sample community before final adjustments were made. Data where entered in the field immediately after (but not during) the interview by the data entry persons using portable laptops. The data entry program was designed using ODK (Open Data Kit) software. The endline was done in March-April 2017.

3. Local Organisation of the Lumière intervention

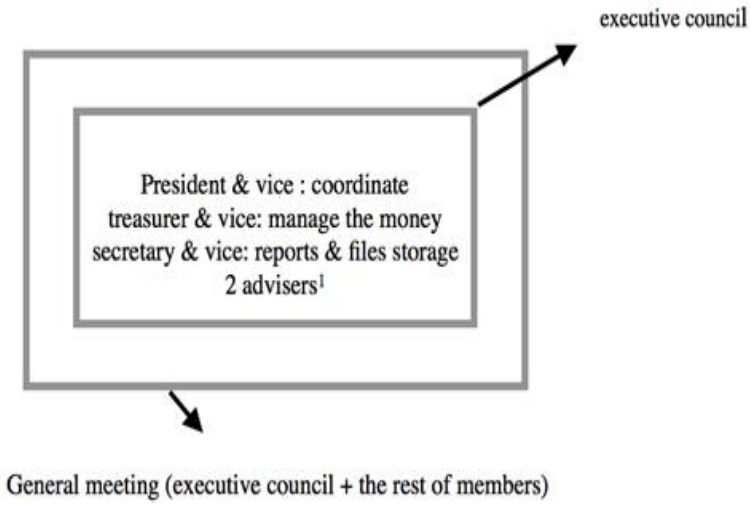
The aim of this section is to try to have an overview about how the different groupements are organized. In the saving group questionnaire, 63 groupements from different sous-collines have been interviewed with the use of a qualitative questionnaire.

We first give a general idea about how groupements are implemented; this point does not make a difference between control and treatment groups, since the overall organisation is the same. It also highlights the kind of activities generating revenues the groupements participate in. Point 3 is about several details concerning the groupements, beginning with majority gender, reasons of leaving the groupement, the advantages of being a member, and finally the relation between FVS-AMADE and the different groupements. Point 4 concerns the Project Lumière and its implementation in the groupements.

3.1 General Organisation of a groupement

The main activity of the different groupements is taking care of OEV children. Out of 63 groupements interviewed, 59 are in charge of a few children. Each saving group is in charge of a certain number of children, by providing school supplies and uniforms in all cases. For some groupements, they are also in charge of their health care (9 groupements out of 63 analyzed). For a small minority, legal assistance for the children is also taken care of (4 groupements), as some orphans are victims of land robbery, and the groupement's goal is to ensure the orphans have access to their lands.

Graph 2. Groupment Organisation



The overall organisation of all the groupements can be described as following:

The executive council meets every week, offering new decisions. They put forward new ideas or new projects, and discuss the budget as well; The General meeting has all the power, seeing as every final decision is made by a majority voting. There must be 2/3 of the General meeting present for any decision to be made. Every month all the members have to meet during the monthly general meeting in order to decide which decisions are made.

In order to enter a groupement, a certain amount of money is needed, additional to the future contributions. The required payment varies between 5000 and 8000 BIF among the different groupements interviewed. For some treatment groups, it is also compulsory to buy a Lumière lamp (5 out of 24 groupements who possess a power station asked the potential members to buy a lamp in order to enter the groupement).

3.1.1 Main revenue-earning activities among different groupements:

- **Savings and loans.** This is the main activity generating profits through interest rates. All the groupements interviewed grant loans to all their members and save the money earned. The interest rates vary between groupements, from 2% in Mudaturwa (commune Kayogoro) to 15% in Ruyumbu (Mugamba). Interests are shared at the end of the year proportionally to the actions each member invested in.

- **The Lumière project.** Out of the 24 treatment groups where a power cycle was implemented, 6 declared the Lumière project was the activity generating the most important part of their profits. The executive committee of the VBO collects

money for saving and buying power cycle and lamp purposes. At the end of the financial year, the saved money is to be shared between among members of the groupement after deduction of the contribution in the orphans' fund.

- **Agriculture and breeding** (taking care of others crops). Out of the 63 groupements, 32 use agriculture and breeding as a tool to make profits. Agriculture is not only about having crops, but also giving a hand to any farmer who needs help with their crops.

In order to get to know the saving groups' functionalities better, it is important to know all the ways they generate revenues. Even though it's a small part in an absolute value, the following 2 are nonetheless non-negligible, since many cases have been mentioned: members which do not act properly in the groupement do have to pay fees: 200 BIF for non-justified absences; 200 BIF and 500 BIF for causing chaos during meetings.

3.1.2 Member participation:

In order to finance their expenses, every member has to contribute to the funds of the groupements. The amounts they do pay vary from one groupement to another. There is however a common scheme which can be observed for all the saving groups: members have to contribute for 3 different sectors:

- **Shares:** Broadly speaking, each member must contribute weekly to a chosen amount which varies between 500 and 2500 BIF. Even though the amount is flexible and varies between a minimal and a maximal amount, some groupements ask for a specific contribution. This is the case in Mujigo (Buyengero), where each member has to pay 1000 BIF per week. This money is used to invest in new projects. The more shares you have, the more you will benefit from the gains of the different projects.

- **Mutual aid:** The amount needed is heterogeneous for different saving groups as well. However, members do not have any choice, the amount is specific and the general meeting decides on it. It varies between 50 BIF in Gahera (Gishubi) and 300 BIF per week in Karengane (Nyanrusange).

- **OEV participation:** Just as the mutual aid and the shares, it varies between different saving groups and like the mutual aid, it's a specific amount. The amount is either 100 BIF, which is the case in 10 groupements out of 27 which were able to answer the question, or 200 BIF per week for the remaining groups. In Mujigo (Buyengero), the groupement highlighted the fact that 25% of the revenues generated by the Lumière project was also for the OEV. Ruhinga (Mugamba) is also an exception since they put aside 5% of the total benefits for the OEV children.

3.2 Main findings from the saving groups questionnaire

3.2.1 Saving groups majority gender

Even though there is a clear majority of women compared to men in all the groupements, the presidency is managed equitably between men and women: Out of the 63 groupements, there are 31 male presidents and 32 women presidents. However, there is a clear majority of women in terms of number of members: the example of Cigome (Mugamba) can be taken in order to illustrate this majority: 35 women out of 42 are part of the groupements. Kabira (Songa) is also a good example with 41 women out of 47 members.

3.2.2 Leaving the Group

Being part of a saving group is not compulsory, and it can be observed that members can decide to leave the group, but can also be expelled from it. Below are some reasons found that justify the reason for which a member leaves the group:

- contributions per week are too expensive (Out of 55 groupements which gave reasons why their members were leaving, **22** groupements saw the number of their members decrease because they could not afford the contributions anymore).
- being rejected by the other members: **11** groupements decided to ask some members to leave the groupement mainly because of the incapacity to reimburse the money borrowed. Thefts were also seen as a cause, such as in Cunda (Mugamba).
- finding a new groupement that is more interesting in terms of return on investment: **8** groupements used this reason in order to justify a loss in members.
- time consuming: being part of a groupement asks for participation in meetings quite often, some members were not able to assist every meeting anymore. This is the case for **4** groupements.
- death: **3** groupements lost members because of death of the members.
- distance: the general meeting being sometimes too far from home, it asks for a large investment in order to be present. In **3** groupements, some members could not afford it anymore.
- people fleeing Burundi to Tanzania : **2** cases in Makamba province and one case in Rumonge.

They can also be expelled from the groupement, as soon as their behavior might not be accepted by the rest of the group, for example being dishonest, trying not to pay the contributions, or trying to steal money, but cases have not been declared yet, even though they gave the possible reason.

There is also an exception in Wibamba (Rutovu), where groupments have introduced solar energy as a new activity. Members from groupements without access to solar energy are seen joining groupements which do have access to this energy resource.

3.2.3 Advantages of being in groupment

Being part of a groupement is directly linked to some advantages members benefit from; They were similar in all the 63 groupements analyzed:

- **great source of income:** The income of different projects are shared proportionally to the shares each member has, by investing an amount that normally varies between 500 BIF and 2500 BIF per member per week. The profits generated by the Lumière Project are split proportionally to the number of re-charges of the lamps each member did. Concerning the re-charges of the non members, it is divided equally between members.

- **access to savings and loans:** The main activities of all the 63 groupements interviewed are savings & loans, which allow members to borrow money from the groupement. Even though a loan is supposed to be linked to some interests, some groupements also implemented a rule which assesses the fact that members do not have to pay any interests for the money they borrowed, which is the case for example in Muniga (Ryansoro).

- **mutual help:** Being part of the groupements allows the members to be helped financially in case of any problems (i.e. hospitalisation 20 000 BIF, death 5000 BIF).

- **possible to buy the Lumière lamp with credit,** which is not possible when you're not part of the groupement.

- **social life:** Even though the main reason is about money, there is also a social reason, seeing as being part a groupement is an opportunity for the members to learn how to live and make decisions together. Moreover, another small advantage observed in Kaganza (Vyanda) is that after each general meeting, the groupements budget allows for free food and drinks, which can be seen as fringe benefits.

3.3 Different features across groupements

3.3.1 Working with FVS-AMADE

Table 1. Pros and Cons of working with FVS-AMADE

Pros	Cons
help for implementation & functioning of the groupement	hidden management of the Lumière project
help for organisational problems	different prices implemented for the selling of the power stations)
propose new projects	selling the lamps themselves
not strict with reimbursements	
advisor role	

FVS-AMADE are known in all of the interviewed groupements. Most of the time, they have a positive image to the members, mostly in the control groups, since they meet with the groupement for all the reasons mentioned in the table above.

Out of the 24 treatment groupements analyzed, 5 told the evaluation team that they were able to benefit from the loans FVS-AMADE gave in order to be able to afford the power station. FVS-AMADE however maintains it does not provide loans itself, and believes these loans were contracted from an MFI.

However, there is still an incertitude about the type of the impact of FVS-AMADE when it comes to the power cycles:

- 2 groupements in sous-collines , Bukirasazi and Kinyonza (both commune Bukirasazi) assessed that the management of the Lumière project from FVS-AMADE is unclear to them. In these 2 sous collines, FVS-AMADE collected the money from the re-charging and the selling of the lamps, and promised to redistribute it to the groupement, as it is with the re-charging that a groupement makes profits. Nothing has been redistributed yet in these 2 sous collines. FVS-AMADE however contests this and maintains that only the executive committee of the VBO is in charge of, first, collecting contributions and, later, distributing profit.

- After analyzing the different prices implemented, price heterogeneity of the power station was observed, even though it's the same machine which is sold in every groupement. More details about price heterogeneity are developed below.

- In 2 sous-collines, Rugabano and Kinyonza (commune Bukirasazi) , the way of working has been implemented differently since the groupements are not in charge of selling the lamp at all: they can simply buy it, as it is FVS-AMADE who is in charge of selling the lamps. Again, FVS-AMADE sees things differently.

Overall, what can be observed is the fact that for several groupements, the relationship with FVS-AMADE is not clear, which leads to misunderstandings and accusations.

3.3.2 Access to power cycles

The different groupements chosen as treatment groups can have access to power stations via FVS-AMADE which is in charge of selling the power station to them. In order to be the owner of the power station, groupements do have to buy it from FVS-AMADE. 3 ways of buying have been observed:

- Paying the entire sum of money directly: this is the case for 18 groupements.

- Credit by FVS-AMADE: 5 groupements benefited from credit given by FVS-AMADE in order to have access to the power station. Such an arrangement is seen as a payment in tranches. This is the case in Giheta (commune Rumonge), Ruhandanyi (Rutovu), Gatumba (Bukirasazi), Murehe (Gishubi) and Nyangugo (Gishubi). Tranches are heterogenous among these 5 groupements, and they can decide individually how much they are willing to pay back every month. FVS-AMADE does not impose a certain amount of money, as long as it's reimbursed in the end. In Nyangugo(Gishubi) for example, each member has to contribute to 2000BIF per month in order to reimburse the power station.

- -More than 1 groupement. The idea of 1 groupement being the owner of its own bike is not always true. 8 groupements out of the 24 benefiting from a power station bought the power station with other groupements in order to gather the needed sum on money. It varies between 2 groupements buying the same bicycle, which is the case in Mujigo (Buyengero), to 12 groupements in commune Bukirasazi. Arrangements are also observed between 4 and 6 groupements.

Out of 24 power cycles, just one has been damaged and is not working anymore. This is the case in Wibamba (Rutovu). The maintenance is made by FVS-AMADE, which takes care of any reparation. A power cycle can charge 5 lamps maximum at the same time, and the duration depends on the skills of the person in charge of re-charge. On average, a lamp takes 8 minutes to charge, but it varies between 5 minutes in Bukirasazi (Bukirasazi)and 18 minutes in Myukwe (Matana).

3.3.3 Prices

While the price for a power cycle should normally be the same for all the groupements, in practice the price stated during the interviews was different for some groups: for 17 groupements, it's worth 670 000 BIF. For 1 group in Myukwe the price they had to pay was 650 000 BIF, and 640 000 BIF in Bukirasazi.

There are also cases where the price turns out to be higher than 670 000. This is the case in Gatumba and Rugabano (both in commune Bukirasazi), where the price asked is 750 000 BIF per power station. In Nyangugo (Gishubi) it costs even 800 000 BIF.

The official price for a lamp is 8000 BIF, even though it became 6000 BIF for a short period of time since the lamps provided were assumed to be of lower quality. Nowadays, it is 8000 BIF.

However, in 2 groupements, Mwange and Giheta (both in commune Rumonge), in order to benefit from a lamp, an amount of 15 500 is needed (8000 is the value of the lamp, and 7500 is an advance for forthcoming re-charges of the lamps). This means that once a person buys a lamp, the next 25 refills (25 x 300 = 7500) do not need to be paid.

While in Gikizi (Rutovu) the re-charge of the lamp costs 100 BIF, the official cost is 300 BIF per re-charge in the rest of the groupements.

The person assigned to the cycling is getting 50 BIF of the 300. The groupement therefore earns 250 BIF net. However, this is not the case in every groupement: In Mwange (Rumonge) , the cyclist is paid a fixed amount of 27 000 BIF per month. In Ruhandanyi (Rutovu), he earns 15000 BIF per month, and in Wibamba (Rutovu) 20 000 BIF per month. There is also an exception in Gikana (Rutovu) where the re-charge of the lamp is not paid, and the task is done by every member, who needs to help the groupement by re-charging the lamps when they have time.

3.3.4 The details matter for satisfaction

First of all, FVS-AMADE gives the lamps for free to the groupements, waiting for them to sell it to members and non-members.

Sales of the lamps are not supposed to benefit the groupements, but the re-charge of the lamps do directly enter their funds, therefore giving incentives to the members to sell lamps.

However, in some cases, the seller of a lamp does have a sales commission of 1000 BIF per lamp (therefore giving back 7000 BIF to FVS-AMADE). This is the case in 9 groups, while the other ones do not have any advantages to sell the lamps, excepting the fact they will benefit from recharges. Here are the 9 sous-collines where the members do have a

commission on sold lamps: Muzima, (commune Bururi) Mujigo (Buyengero), Ruhinga (Mugamba), Gikana (Rutovu), Nyakibari (Vyanda), Gatumba (Bukirasazi), Murehe (Gishubi), Nyangugo (Gishubi), Musanga (Makamba).

Since the benefits from the Lumière project depend only on the re-charges of the lamps, the income satisfaction of this project is more important in groups where the re-charges are weekly frequent. This number varies from one group to another. While some groupements re-charge on average 12 lamps per week, which is the case in Nyangugo (Gishubi), others recharge 70 lamps per week.

There is a direct link between the satisfaction the Lumière project brings and the number of lamps sold: Wibamba (Rutovu), the groupement sold approximately 92 lamps since the implementation of the project; re-charges on average 70 lamps per week and assesses that the Lumière project is the main activity generating income. This is not the case in Gikana (Rutovu), where the group sold only 14 lamps, while recharging on average 8 lamps per week, and assesses that the Project Lumière does not lead to much income because of the low take up.

In order to be part of the groupement, most of the groupements do not ask the -future- members to buy lamps. However, in 5 groupements, it is compulsory to buy a lamp before being a member. This is the case in Muzima (Bururi), Gikizi (Rutovuà, Ruhandanyi, (Rutovu), Gatumba (Bukirasazi) and Kibirizi (Kayogoro).

Even though in the sous-collines assigned as treatment everyone is allowed to buy lamps, there is an extreme case in Nyakibari (Vyanda) where non-members do not have access to the lamps, unless they decide to become a member. It is therefore a way for the groupement to attract new members.

4. Changes in the use of energy sources

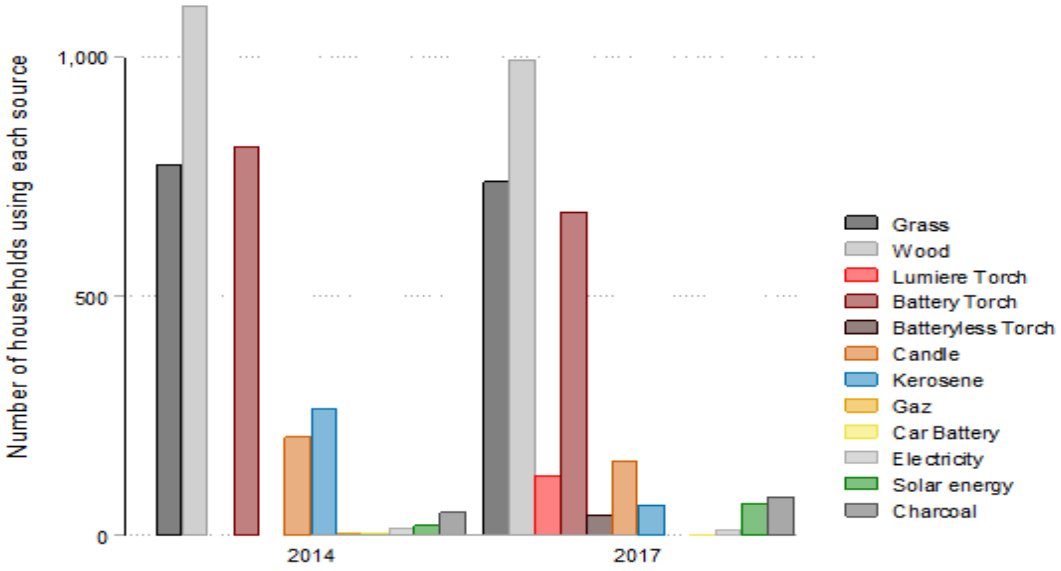
The Lumière project aims at introducing alternative sources of energy at the household level. The main rationale for that is the very low use of electricity in Burundi, and the disadvantages that come with the use of combustible energy sources such as kerosene (cost, smell, danger, irritation, supply).

In Burundi, a large part of the population lives in energy deprivation, relying on kerosene lanterns and candles for light, and on wood for cooking and heat. In rural areas, an important part of household income is spent on energy that, in most cases, remains insufficient, hazardous and unhealthy. Inhaling kerosene fumes is damaging for the health of women and children. And kerosene–related accidents are a frequent cause of burns. Since kerosene and candles cannot be domestically produced, supplying them incurs high transaction costs (expenditure on travel plus time investment). Lack of access to electricity is thus both a cause and an effect of unremitting poverty.

The underlying assumption of the Lumière Project is to contribute to diminishing energy poverty by empowering communities with a reliable, clean and sustainable energy source.

We estimate possible changes in the energy use between baseline and endline, firstly by asking each household whether they use each listed energy source or not. We observe that grass, wood and battery torches remain the most popular energy sources. Meanwhile an increasing number of households use solar energy and charcoal, while kerosene and candles use drastically decreased over the years.

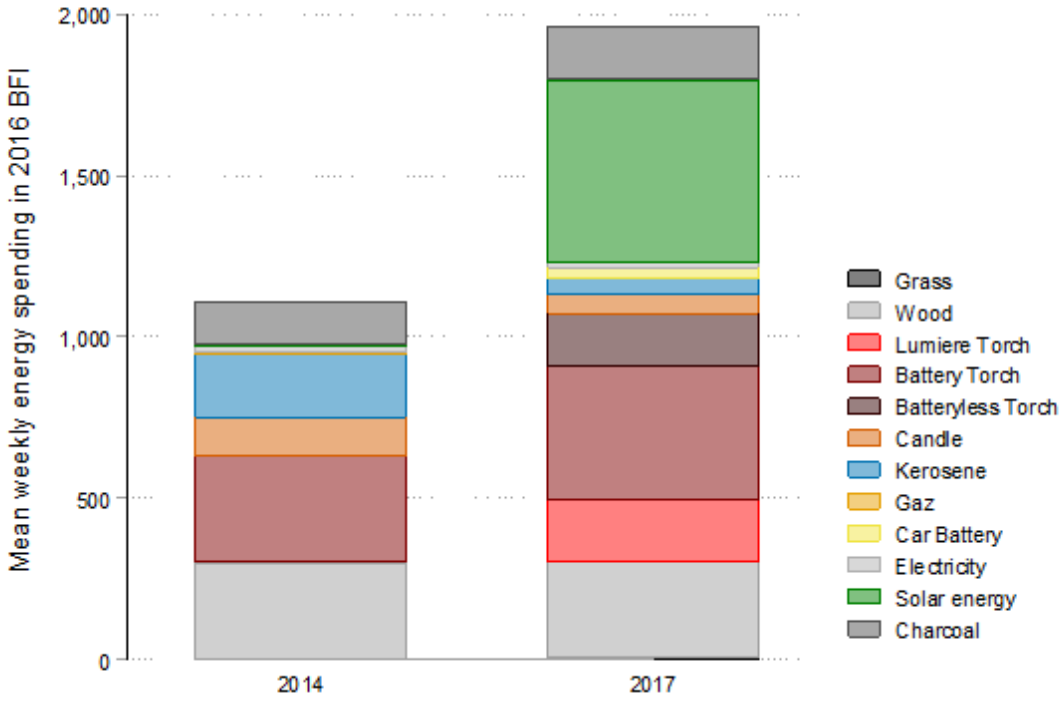
Graph 3. Number of households reporting the use of each energy source



When observing the weekly household spending linked to each energy use in 2016 constant Burundian Francs (BIF), we find that solar energy expenditure met by far the greatest increase, with an average of 565 in 2017, compared to 4.42 in 2014. On the other hand, the average spending on kerosene decreased from 194 to 49, and that of candles dropped from 116 to 58 BIF per week. Spending in grass, wood and battery torch remain relatively stable over the years.

When separating the surveyed households in two groups: those who reported using a lumière lamp in 2017 (the take-up group) with those who did not, we observe that almost all households use wood as an energy source (see graph 5).

Graph 4. Average weekly spending per energy source



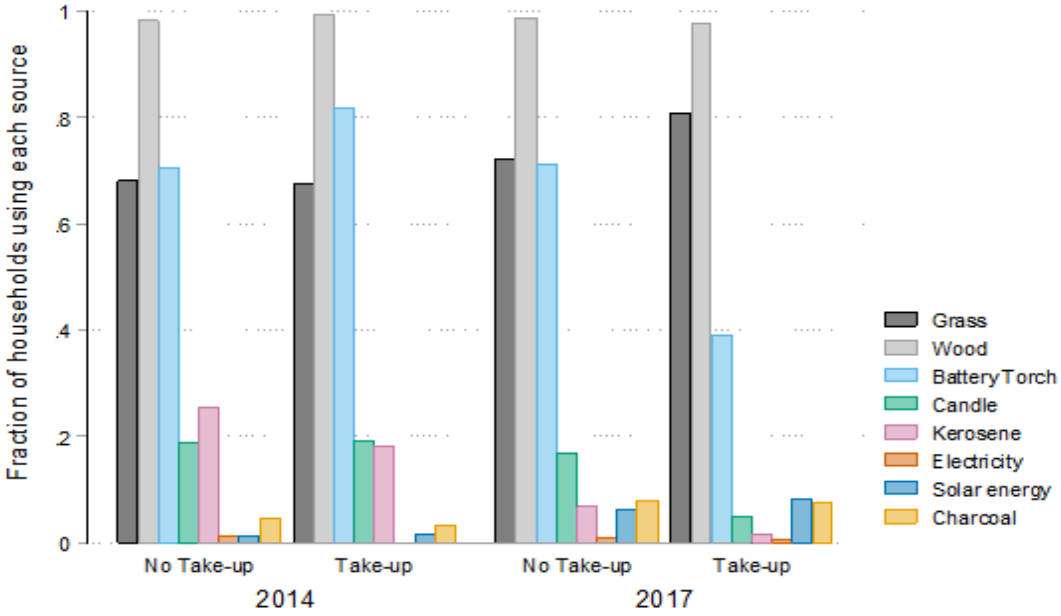
On the other hand, during both periods, the percentage of households using kerosene seems to be much lower amongst Lumière-lamp users. There is also a clear decrease in the percentage of households using candles amongst lumière lamp users, as 19% of households reported using them in both groups in 2014, while 17% of non-Lumière lamp users still use them in 2017, compared to 5% in the other group.

Likewise for battery torches, while 71% of households in both groups were using them in 2014, this went up to 82% in non-Lumière lamp users in 2017, while we observe a drop to 39% amongst Lumière lamp users. Solar energy on the other, is increasingly being used in both groups.

Thus as expected, lumière lamps seem to mostly replace battery lamps, kerosene and candles within surveyed households.

Looking more closely at kerosene use, we observe a decrease in kerosene spending amongst both Lumière lamp users and non users, although the drop is clearer within the former group (with an average decrease of 189 BFI per week between base- and endline, compared to 148 for non-Lumière lamp users).

Graph 5. Fraction of households using each energy source over Lumière lamp take-up status



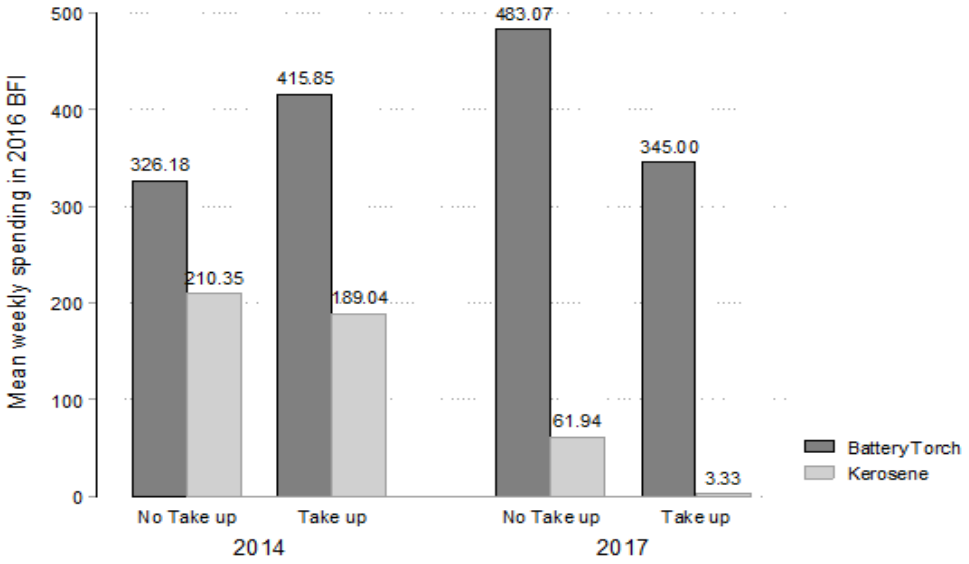
On the other hand, households that did not take-up the Lumière lamps seem to have increased their weekly spending on battery torches by 32 BFI, while the take-up group decreased this spending by 71 BFI per week, thereby hinting that the use of Lumière lamps seem to have replaced less ecological lightning options.

When estimating the proportion of energy spending (see graph 7) out of total energy for each energy source, we find that weekly spending on battery torch is the highest amongst households living in collines both with and without a Lumière lamps power cycle (i.e. both the actually treated and control collines).

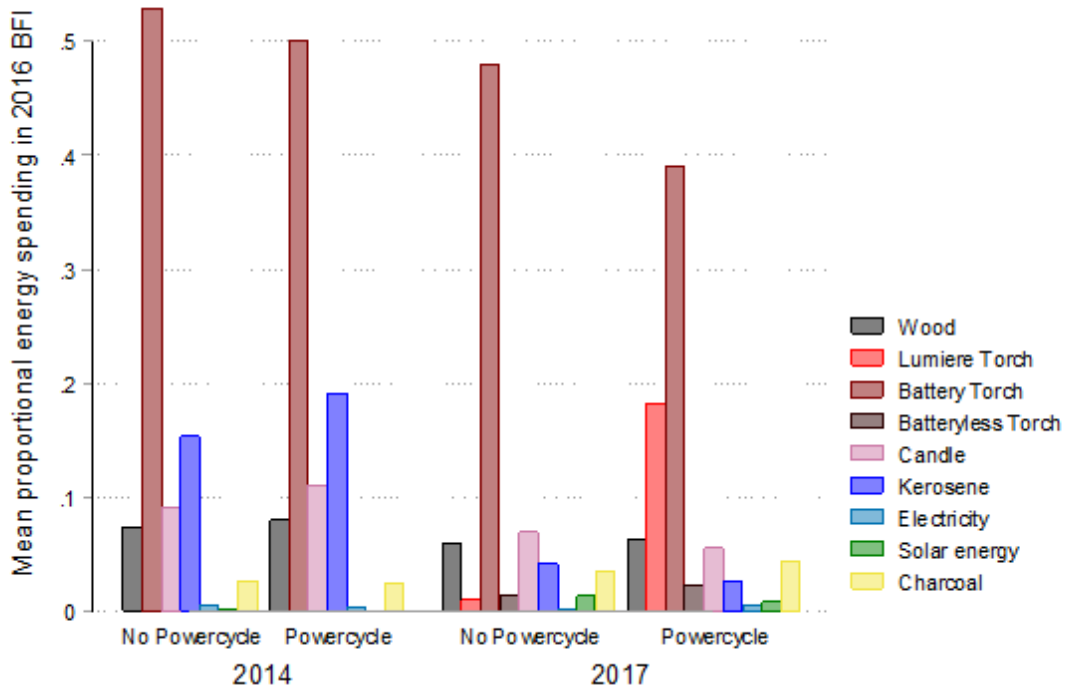
There also seems to be a small evidence of treatment spillover, as respondents living in collines without power cycle nonetheless report spending 1% of their overall energy budget on Lumière lamps, while those living in treated collines spend around 18%.

When observing the evolution between base- and endline (graph 8), we see that the drop in kerosene spending is strongest in collines that have a power cycle in place. We observe the same trend with battery torches and candles, thereby hinting that those sources were at least partly used for artificial lighting, and could thus be replaced by the Lumière lamps.

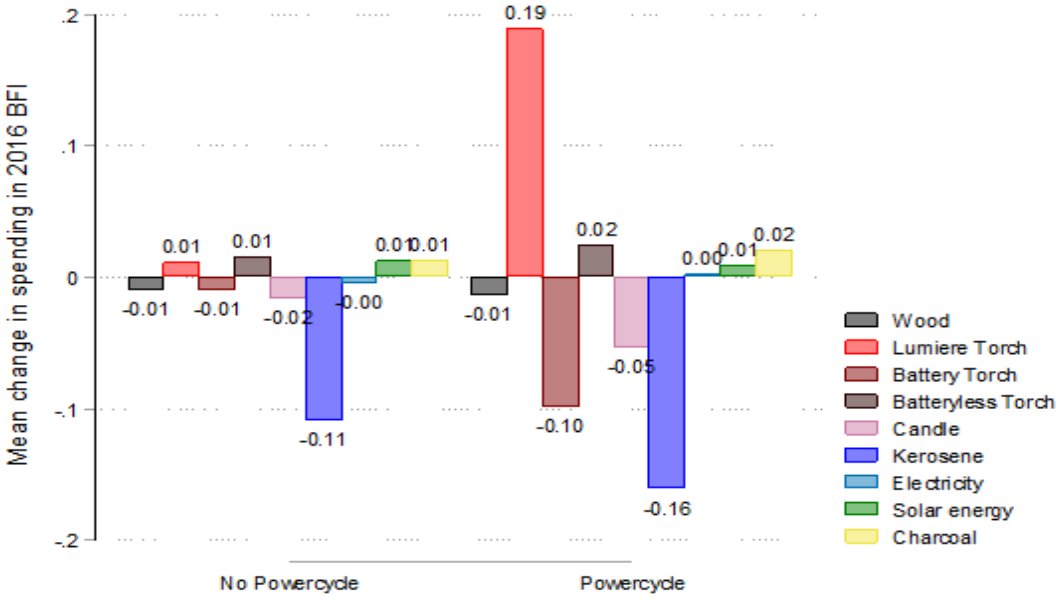
Graph 6. Weekly battery torch and kerosene spending over Lumière lamp take-up



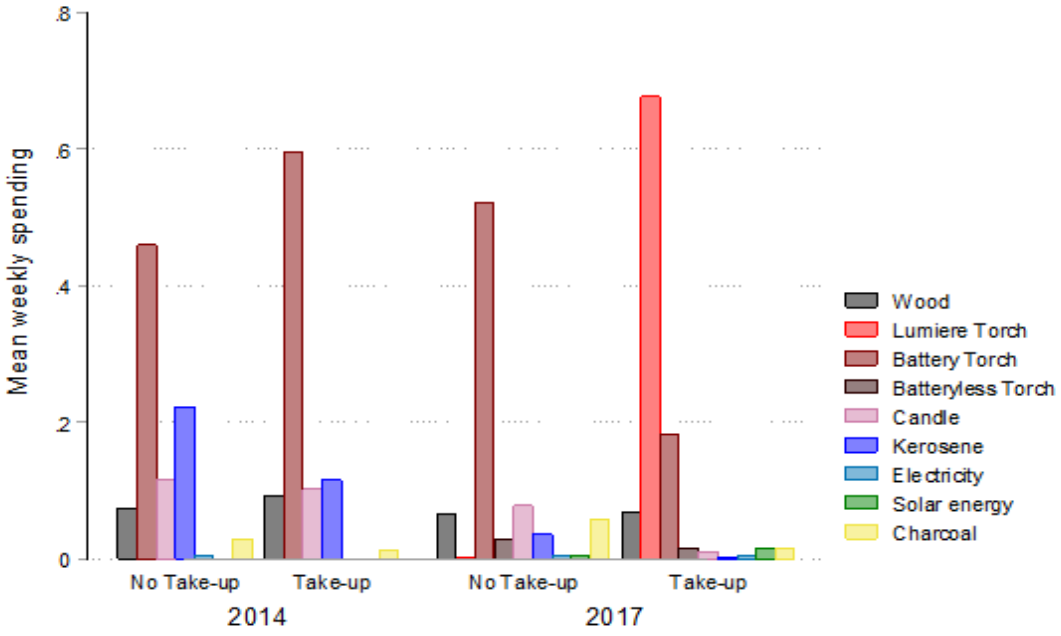
Graph 7. Proportional household spending per energy source by collines with and without power cycle



Graph 8. Evolution of proportional household spending per energy source between base- and endline



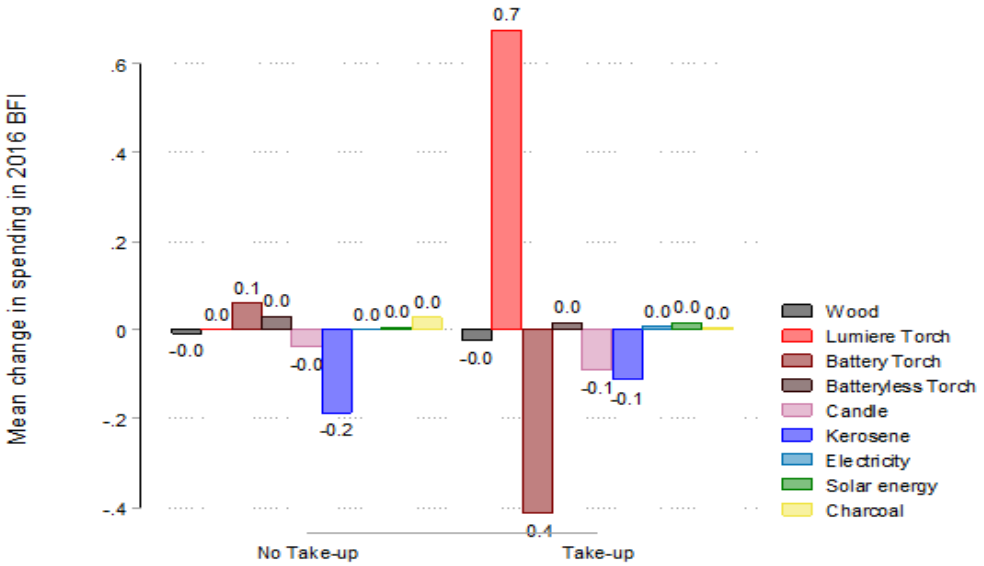
Graph 9. Proportional household spending per energy source over Lumière lamp take-up in treated collines only



Finally, we concentrated on collines that had access to a Lumière lamp powercycle (were treated). We then compared the energy use of households that actually bought the Lumière lamps with those who did not, within those treated collines. We observed that the use of kerosene was very low amongst all of those households in 2017. Meanwhile, Lumière

lamps seem to have mainly replaced battery torches, as this is the energy source that experienced the most drastic decrease over the period (see graphs 9 and 10).

Graph 10. Evolution of proportional household spending per energy source over Lumière lamp take-up in treated collines only



In conclusion, a clear decrease in the use of battery torches and candles is observed amongst Lumière lamp users, while a general trend of decreasing use of kerosene is observed amongst all surveyed respondents. Wood and grass on the other hand, remain the most used energy sources amongst all observed groups.

Finally, solar energy seems to start spreading within the surveyed regions, although the price reported seems to be much higher than all other energy sources enquired on. This could be linked to the installation prices, which should be expected to hamper over time.

5 Results for take-up, intensity and speed

The section explores the determinants of using a Lumière lamp in the household. We address 3 questions: what type of households use a lamp, how intensive is their use and how fast does the technology spread in the colline. The analyses assess which factors drive the outcomes of interest, considering on the one hand household level variables such as income or the level of education of the head of the household, and on the other hand savings group determinants such as the size of the group or if the members have received financial incentives to sell lamps.

For all elements of the analysis, four samples are considered: (1) the full sample including all households; (2) only households who were members of a savings group membership in 2014; (3) all households located in sous-collines which should have received a power cycle according to our evaluation design and; (4) all households located in sous-collines which actually have received a power cycle (called ‘the intervention’ or ‘the treatment’).

The number of households included in the analyses will thus vary according to these four samples as well as the missing variables in each of the samples.

The assessments are undertaken using multivariate cross sectional regression analyses which all apply the same framework: $y_i = X_i\beta + Z_i\gamma + \varepsilon_i$ with y_i being the outcome of interest of household i observed in 2017, X_i is a set of variables of interest such as household income in 2014 or size of the savings group in 2014,[1] the coefficients of interest are the β. Z_i are control variables such as dummies for each province to take regional differences into account, accordingly the γ are the coefficients for the control variables, and ε_i is the error term.

Subject to the outcome at hand different regression approaches are being followed: (1) general uptake of the Lumière lamp is assessed by a yes/no dummy, hence a binary response model (probit) is applied; (2) intensity of usage is measured in discrete steps of 2-7 times/week, 1 time/week, and bi-weekly/less, hence an ordered probit model is being used; and (3) the speed of uptake is being measured in days, hence an ordinary least squares model is estimated. Within the four samples, 8 specifications have been assessed. The first regression in each sample only includes household level variables and the second regression adds the savings group variable. All regression results apply cluster robust standard errors at the colline level and province dummies.

5.1 Take-up

Overall uptake of the technology is at about 12%, but increases to 18.5% among saving group members and to almost 30% among those households who live in collines which experienced the intervention. We depict this striking relationship in graph 11. The variable 'membership of a savings group' is therefore our first determinant of take-up: it is much higher than for non-members. This means the VBO act as clubs whereby members are either encouraged to purchase the lamps (most likely) or motivated to help to NGO pursue its goals, or both.

Continuing with the household level variables, we show that the level of welfare (approximated by consumption as is usual, and more reliable, in development economics) is a key driver of uptake, indicating a possible uptake hurdle given the very deprived setting under consideration. Household size also positively affects uptake, but having a lot of children in the household does not. This may indicate the households do not acquire the lamps in first instance because of a need to have more light for child-related activities. This result is supported by the finding that the likelihood to acquire a lamp is increased when the household complains about the lack of light to go to bed, an event that is not limited to children. In addition, we do not find much support for the importance of individual background of the head of the household, such as age, sex or education in explaining take-up.

[1] Using the correlates from 2014 assures orthogonality of the regressors vis-à-vis the regressands and avoids problems of reverse causality, i.e. the fact that the observed outcomes (y_i) may drive the variables of interest (X_i).

As for the characteristics of the savings group, several interesting findings turn up: having a female president increases take-up in the colline, and this is also the case for groups with more male members (possibly hinting to opposing gender effects). The size of the savings group (number of members) as well as the size of the collines (number of households residing), in absolute number, has a negative effect. In terms of percentage however (relative effect), we find a non-linear relationship: for small groups (% of members in relation to the size of the colline), an increase first has a negative effect, but that turns around and becomes positive ones the threshold of 21% has been reached.

Graph 11. Lumière lamp take-up in different samples

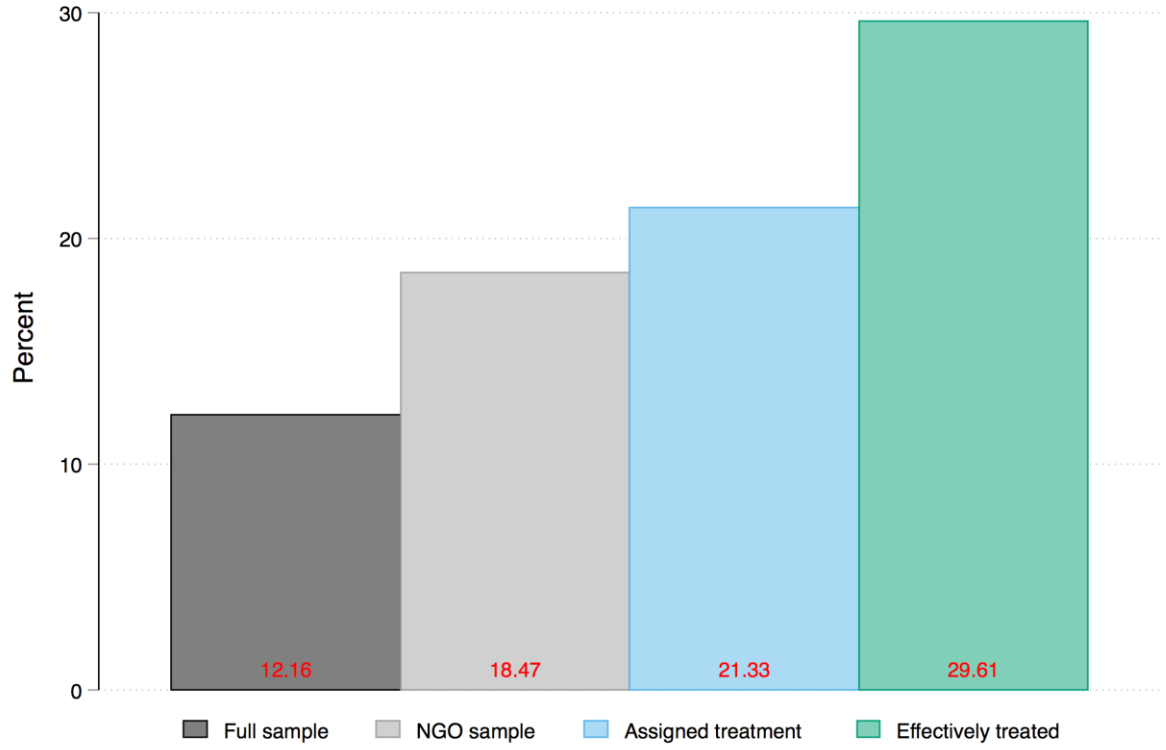


Table 2. Determinants of take up

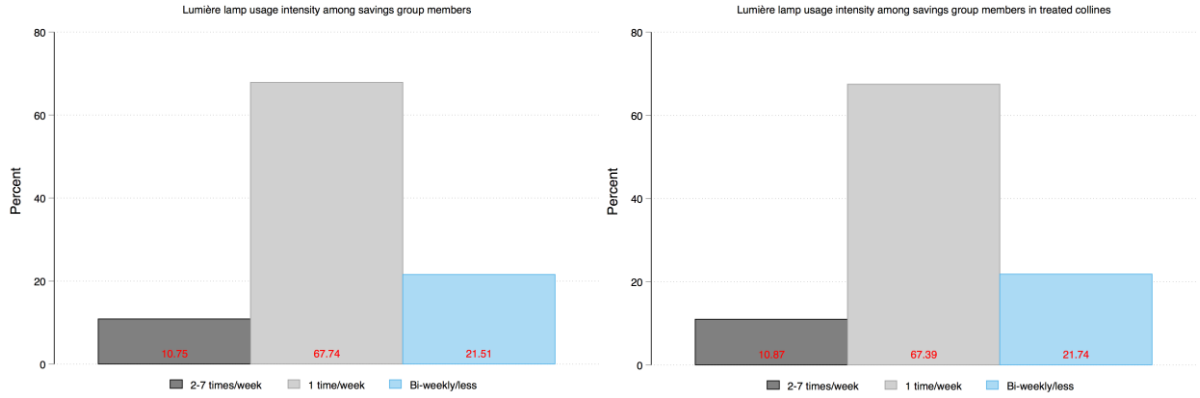
	Full sample		VBO sample		Assigned treatment		Effectively treated	
	R1	R2	R3	R4	R5	R6	R7	R8
HH member of SG	0.69***	0.78***			0.90***	1.18***	1.10***	1.42***
	(0.000)	(0.000)			(0.000)	(0.000)	(0.000)	(0.000)
HH head sex	-0.03	-0.16	0.04	-0.01	-0.02	-0.27	0.01	-0.35
	(0.899)	(0.515)	(0.889)	(0.979)	(0.948)	(0.275)	(0.986)	(0.131)
HH head age	0.04	0.02	0.07*	0.01	0.05	-0.02	0.05	-0.06
	(0.250)	(0.631)	(0.053)	(0.766)	(0.205)	(0.734)	(0.321)	(0.476)
(HH head age) squared	-0.00	-0.00	-0.00**	-0.00	-0.00	0.00	-0.00	0.00
	(0.251)	(0.536)	(0.046)	(0.617)	(0.216)	(0.792)	(0.326)	(0.605)
HH head married	-0.20	-0.50*	-0.03	-0.31	-0.26	-0.77**	-0.49	-1.01***
	(0.444)	(0.099)	(0.923)	(0.445)	(0.460)	(0.037)	(0.249)	(0.004)
HH head years schooling	-0.01	-0.00	-0.03	-0.03	-0.00	-0.00	-0.01	-0.03
	(0.538)	(0.911)	(0.258)	(0.301)	(0.824)	(0.887)	(0.799)	(0.143)
HH exp.	0.18**	0.30***	0.10	0.24*	0.21**	0.43***	0.30***	0.44***
	(0.032)	(0.008)	(0.349)	(0.080)	(0.024)	(0.001)	(0.000)	(0.002)
HH members age 6-16		-0.13**		-0.23**		-0.18**		-0.26**
		(0.032)		(0.010)		(0.047)		(0.023)
HH size		0.08**		0.09*		0.09*		0.16***
		(0.020)		(0.081)		(0.070)		(0.002)
Lacking light: Going to bed		0.88***		1.18**		0.86***		1.02**
		(0.004)		(0.023)		(0.009)		(0.011)
SG female president		0.38		0.33		0.96***		0.71
		(0.162)		(0.304)		(0.009)		(0.108)
% males in SG		0.03***		0.04***		0.03***		0.02***
		(0.000)		(0.000)		(0.000)		(0.000)
Size SG		0.03**		0.05**		0.02		0.00
		(0.040)		(0.044)		(0.126)		(0.861)
HHs in sous-colline		-0.00**		-0.00**		-0.00***		-0.00**
		(0.016)		(0.030)		(0.001)		(0.012)
% SG members in sous-colline		-0.25**		-0.32**		-0.32**		-0.17
		(0.041)		(0.043)		(0.048)		(0.450)
(% SG members in sous-colline) sq		0.01***		0.01***		0.01**		0.01
		(0.005)		(0.004)		(0.023)		(0.389)
Province FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	945	713	497	381	510	362	357	241
R2 (pseudo)	0.08	0.26	0.02	0.29	0.11	0.34	0.16	0.35

White-Huber robust standard errors, clustered at colline level. p-values of t-statistics in parentheses. Sex (Male=1, Female=0); Household head married (Married=1, All other=0). 2014 HH expenditures are log of total household expenditures, in constant 2016 BIF. X indicates an interaction term. Significance: * p<0.10, ** p<0.05, *** p<0.01. All household variables measured at baseline (2014)

5.2 Intensity / Recharging Frequency

Subject to initial take-up, all households use the lamp on a regular base.[2] Hence we find only few determinants of the intensity of usage. Among those households who were members of the savings group in 2014, about 78.5% of the households recharge their lamps at least once a week. In total about 11% recharge more than once a week. In contrast to those high intensity users, about 21.5% recharge their lamps no more than every other week, hinting to relatively low usage. When considering exclusively households living in collines where a power cycle was placed, the number of high and low intensity users slightly increases. In total, about 73% of the households recharge their lamps at least once a week. This is depicted in graph 11.

Graph 12. Lumière lamp recharging frequency in different samples.



The rate of recharging appears to be affected by similar characteristics as the take-up, i.e. welfare, size of the household, and size of the savings group. This is shown in table 3. We remark that the samples here are much smaller given that we only work with households who have effectively purchased a lamp.

Table 3. Determinants of Recharging Frequency

	VBO sample		**Effectively treated sample**	
	R1	R2	R3	R4
HH member SG			0.41	1.31***
			(0.269)	(0.000)
HH head sex	0.53	0.24	-0.12	-1.39
	(0.241)	(0.265)	(0.786)	(0.209)
HH head age	-0.07	-0.22*	-0.01	-0.12
	(0.213)	(0.054)	(0.913)	(0.257)
(HH head age) squared	0.00	0.00**	0.00	0.00
	(0.150)	(0.040)	(0.680)	(0.171)
HH head married	0.70	1.42**	0.03	-0.37
	(0.158)	(0.048)	(0.932)	(0.730)
HH head years schooling	0.07*	0.01	0.06	0.04
	(0.089)	(0.943)	(0.122)	(0.614)

[2] Note, usage as such has not been observed but is proxied via recharge intensity. It is assumed that households do recharge their lamps because they need to, i.e. because they have used the lamp.

HH exp.	-0.13	-0.17	-0.11	-0.20
	(0.356)	(0.629)	(0.435)	(0.559)
HH members age 6-16		-0.07		-0.27
		(0.715)		(0.122)
HH size		0.06		0.20
		(0.654)		(0.171)
Lacking light: Going to bed		0.66		0.77
		(0.279)		(0.170)
SG female president		0.72***		0.78***
		(0.008)		(0.004)
% males in SG		0.02***		0.02***
		(0.008)		(0.006)
Size SG		-0.14***		-0.17***
		(0.000)		(0.000)
HHs in sous-colline		0.00***		0.01***
		(0.002)		(0.000)
% SG members in sous-colline		1.03***		1.24***
		(0.000)		(0.000)
(% SG members in sous-colline) sq		-0.03***		-0.03***
		(0.002)		(0.000)
Province FE	Yes	Yes	Yes	Yes
Observations	92	62	112	76
R2 (pseudo)	0.03	0.30	0.03	0.32

White-Huber robust standard errors, clustered at colline level. p-values of t-statistics in parentheses. Sex (Male=1, Female=0); Household head married (Married=1, All other=0). 2014 HH expenditures are log of total household expenditures, in constant 2016 BIF. X indicates an interaction term. Significance: * p<0.10, ** p<0.05, *** p<0.01. All household variables measured at baseline (2014)

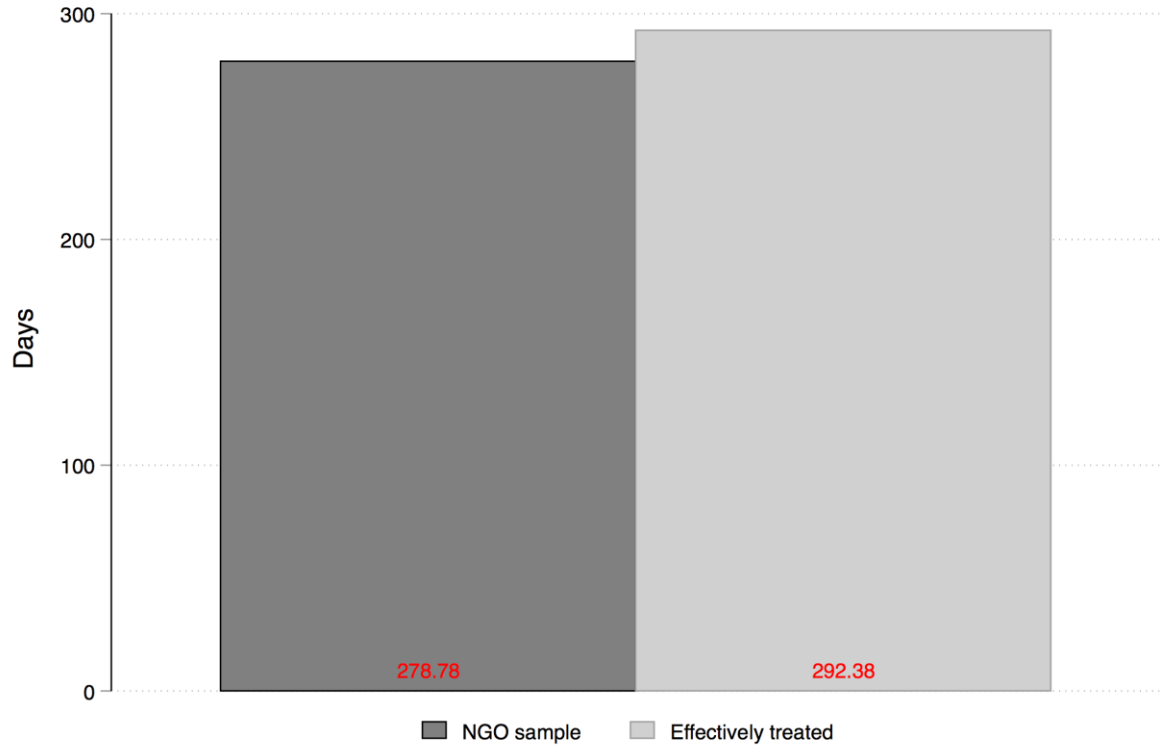
5.3 Speed of uptake

The speed of uptake within the collines is approximated by deriving the time difference of lamp purchase between the first and current user. In particular, the following steps are being taken: (1) among the households in the survey, find the household who bought the lamp first[3]; (2) take the date when a household in our sample acquired the lamp; (3) find all other households who bought the lamp and also note their date of purchase; (4) for each of these households, calculate the difference in days between the date of the first household and all others. Hence, the variable will be zero for all "first movers" (the first ones in the sample to buy the lamp) and greater than zero for all other users. The variable is only an approximation for the "true" first mover in the colline as the data do not indicate when he first lamp was sold in the colline. Nevertheless, it gives an indication for the speed of spread of the technology among the members of the settlement.

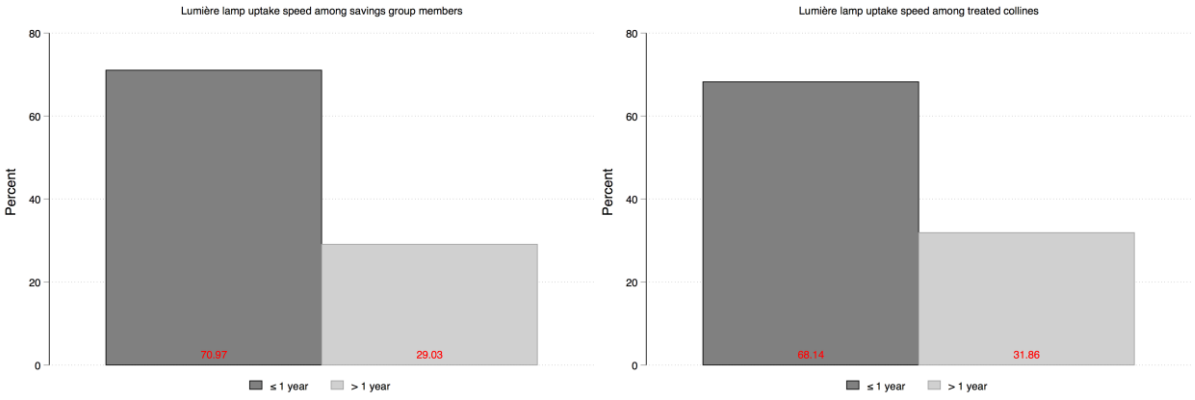
The data indicate that the speed of uptake is slightly faster among those households who were member of the savings group in 2014. However, overall the distribution is very similar.

[3] Ideally we would have the date of arrival of the powercycle in the colline or the date of purchase of the first lamp in the colline.

Graph 13. Lumière lamp speed of uptake in different samples



Graph 14. Share of households purchasing Lumière lamps less\more than 1 year after the first user



Few household-level characteristics explain speed and the size effects again show a non-linear pattern (in table 4). For small groups, an increase has a positive effect but once the group size exceeds 21% the speed is affected negatively (inverse effect compared to uptake).

Table 4. Determinants of the speed of uptake

	VBO sample		Effectively treated sample	
	R1	R2	R3	R4
HH member SG	0.00	0.00	-13.32	29.79
	(.)	(.)	(0.844)	(0.728)
HH head sex	-214.30***	-328.01***	-326.26***	-321.31***
	(0.007)	(0.000)	(0.000)	(0.008)
HH head	-22.63	-14.74	-13.00	-13.18
	(0.313)	(0.644)	(0.564)	(0.620)
(HH head age) squared	0.20	0.08	0.12	0.07
	(0.334)	(0.813)	(0.572)	(0.773)
HH head married	-245.58**	-225.79	-352.72***	-194.93*
	(0.022)	(0.179)	(0.000)	(0.082)
HH head years schooling	13.35	9.65	13.47	0.57
	(0.227)	(0.552)	(0.223)	(0.962)
HH exp.	-24.04	29.06	-24.90	55.96
	(0.688)	(0.673)	(0.678)	(0.269)
HH members age 6-16		8.84		22.30
		(0.864)		(0.526)
HH size		-43.64		-44.89
		(0.269)		(0.189)
Lacking light: Going to bed		102.04		154.79
		(0.560)		(0.251)
SG female president		-87.34		-51.87
		(0.294)		(0.595)
% males in SG		-2.91*		-3.85***
		(0.057)		(0.005)
Size SG		1.74		-2.09
		(0.662)		(0.695)
HHs in sous-colline		-0.90***		-0.68**
		(0.004)		(0.011)
% SG members in sous-colline		-108.84*		-27.56
		(0.092)		(0.666)
(% SG members in sous-colline) sq		2.35		-0.00
		(0.175)		(0.999)
Province FE	Yes	Yes	Yes	Yes
Observations	92	62	112	76
R2	0.07	0.43	0.07	0.38

White-Huber robust standard errors, clustered at colline level. p-values of t-statistics in parentheses. Sex (Male=1, Female=0); Household head married (Married=1, All other=0). 2014 HH expenditures are log of total household expenditures, in constant 2016 BIF. X indicates an interaction term. Significance: * p<0.10, ** p<0.05, *** p<0.01. All household variables measured at baseline (2014)

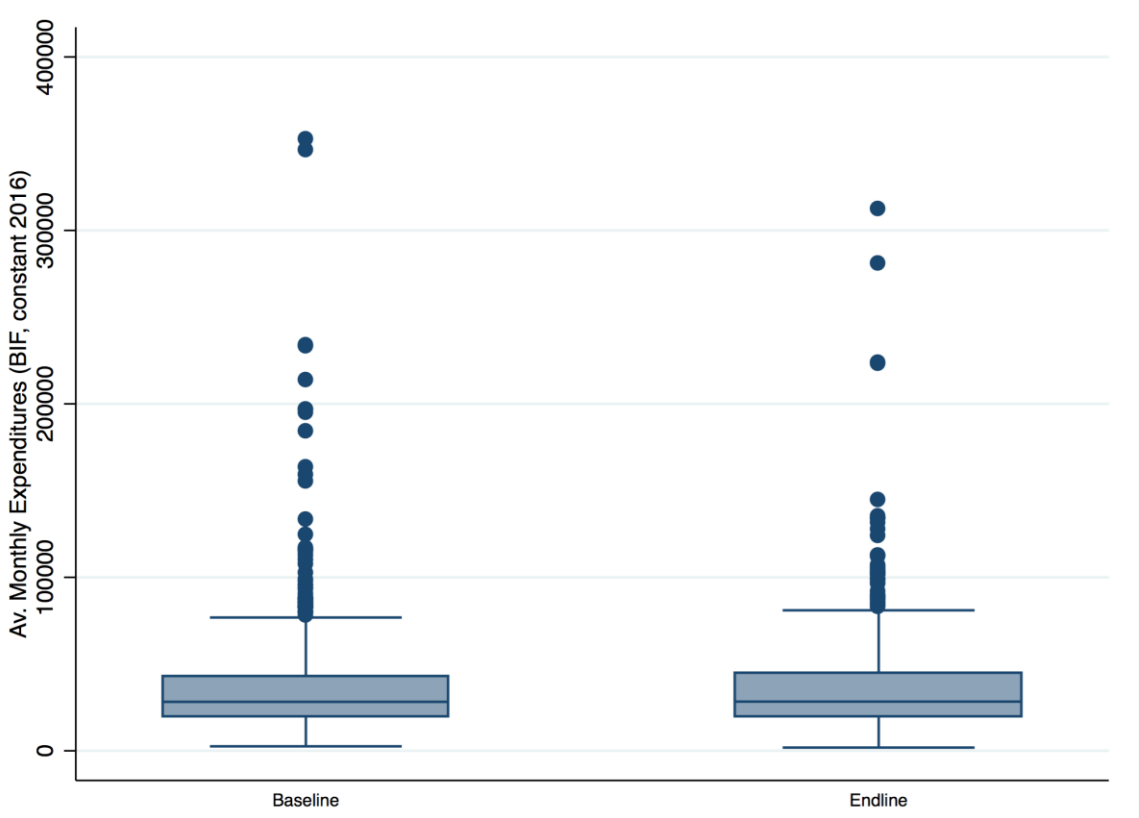
6 Household Consumption and Welfare

In order to approach the welfare dynamic between baseline and end-line, we estimate the monthly amount of consumption per adult equivalent, in constant Burundian Francs 2016. So, we study the self-reported expenditures for food consumption (reported by households for the last 7 days and then re-scaled to one month), usual non-food consumption, such as expenditures for communication (reported for the last 15 days and then re-scaled), and

more exceptional expenditures, for instance purchases of durable goods (reported for the last year and re-scaled).

On average, in 2016 the household's monthly consumption is 35,746.46 BIF (constant 2016) per adult equivalent in 2002, which corresponds to 22 US dollars. It implies more than 89% of the households in the sample live under the 1.25 US dollar per day poverty line either during the baseline and endline. When comparing the information with the baseline, we don't observe any statistically significant difference. In fact, despite that in 2014 the average household's monthly consumption was around 35,592.11 (constant 2016), the difference is not significant (see graph 15).

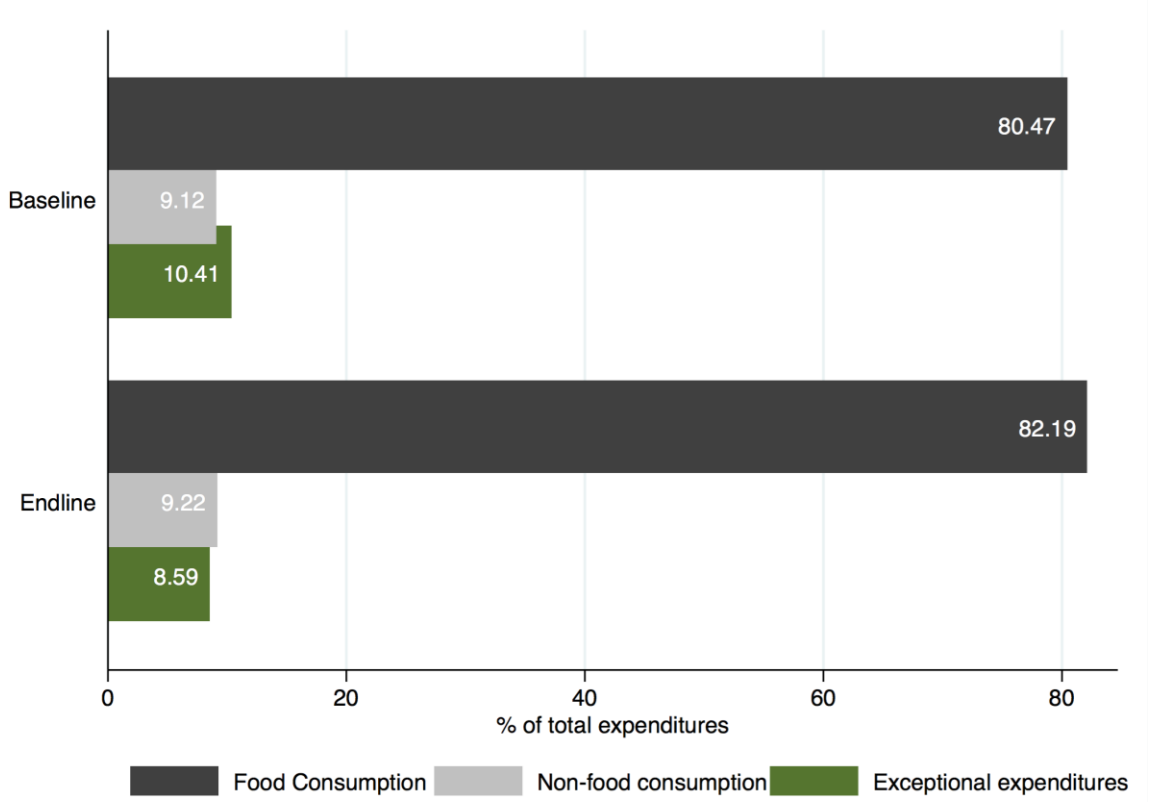
Graph 15. Household's expenditures



Notes: Total households=996. Average monthly expenditures in 2014 (baseline)= 38,500 BIF (constant BIF 2016) - Average monthly expenditures in 2014 (baseline)= 38,000 BIF (constant BIF 2016).

The repartition of monthly consumption between the three expenditure categories is further documented in graph 16, which splits the total sample across the three categories. Specifically, households' are spread into three groups of equal size in function of their total amount of consumption per month and per adult equivalent. As expected, around 81% of the total monthly expenditures is allocated to food consumption, followed by non-food consumption with around 9% and 10% on exceptional expenditures. These shares are not statistically different across the two waves.

Graph 16. Household's expenditures by category

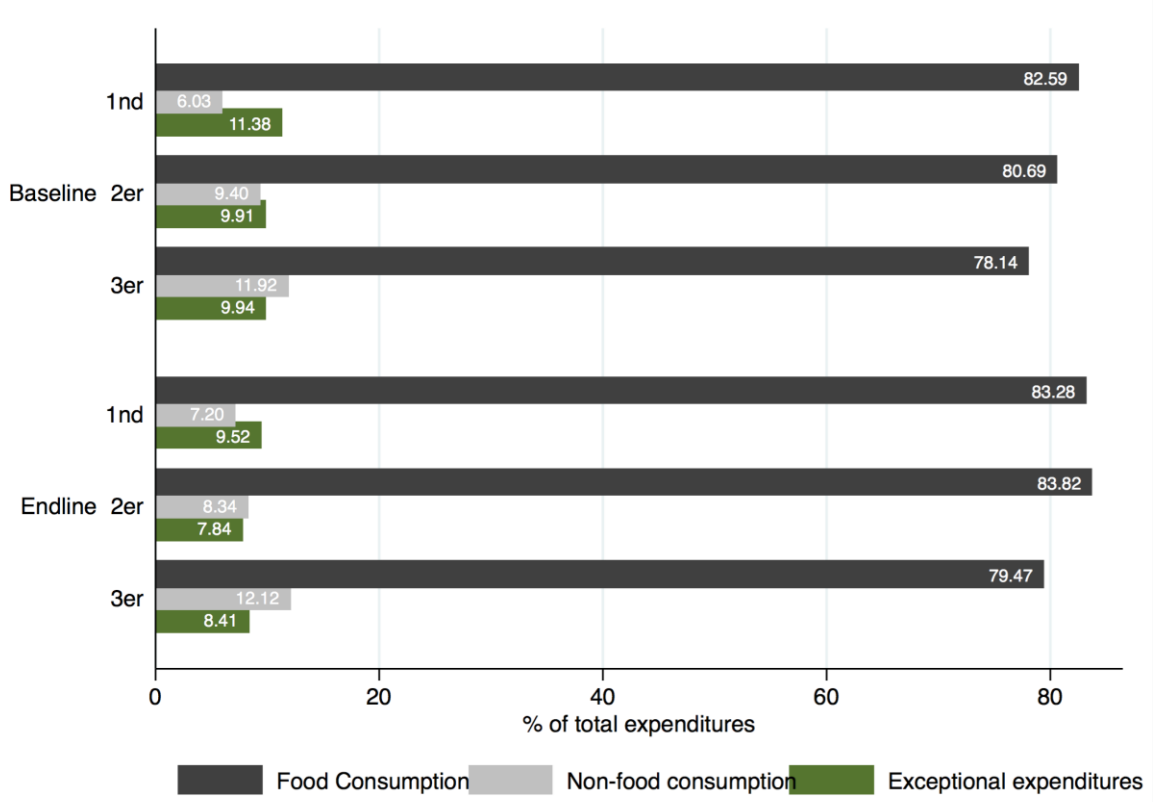


Notes: Total households=995. Average monthly expenditures in 2014 (baseline)= 38,500 BIF (constant BIF 2016) - Average monthly expenditures in 2014 (baseline)= 38,000 BIF (constant BIF 2016).

Now, in order to understand the distribution on expenditure across the different level of welfare we built the welfare tertile. The average level of monthly consumption in the poorest tertile equals 14,862.45 and 15,971.88 BIF (constant 2016) for the baseline and endline respectively (around 9 US dollars), 28,213.72 and 29,095.15 BIF in the second tertile (slightly more than 17 US dollars), and 60,710.55 and 62,172.34BIF in the richest tertile (nearly 36 US dollars).

Expectedly, the share of food consumption over the total amount of monthly consumption is the largest among the poorest tertile (more than 82%), and the lowest among the richest tertile (78%). The opposite is true for usual non-food consumption, which accounts for slightly more than 6% of the poorest tertile's average budget, 9.5% of the medium tertile's average budget, and more than 12% of the budget of households who belong to the richest tertile. Interestingly, exceptional expenditure is the category which share over total consumption is the most stable across the three tertiles: it represents slightly more than 11% of the monthly consumption of the poorest households, and slightly less than 10% of the monthly consumption of the households who belong to the medium and richest tertiles.

Graph 17. Household's expenditures by category, over tertile



Notes: Total households=995. Average monthly expenditures in 2014 (baseline)= 38,500 BIF (constant BIF 2016) - Average monthly expenditures in 2014 (baseline)= 38,000 BIF (constant BIF 2016).

Household-level welfare might depend on the composition of the household. In this perspective, Table 5 presents pairwise coefficients of correlation between:

- welfare (measured by aggregate consumption) and the main characteristics of the household and of the household head (column I);
- The three different dimensions of consumption and the main characteristics of the household and of the household head (columns II to IV);

Column I reveals that larger households, as well as households counting more children, are significantly worse-off on average either in the baseline as well as the endline. On the other hand, the average age of the members and the share of working members are significantly correlated with higher levels of consumption.

Regarding the characteristics of the household head, it appears that his age is positively correlated with the household's level of welfare. On the other hand, households headed by a married individual exhibit a significantly lower average level of welfare (column I). Both correlations are driven by food consumption (column II). The fact that the household head went to school is not significantly correlated with aggregate welfare, but it is positively associated with the amount of exceptional expenditures per adult equivalent (column IV). We remind that Table 3 only gives pairwise correlation between the welfare level and selected household characteristics, it does not present regression analysis where

one controls for the effect of multiple variables. No significant correlation appears between monthly consumption and the fact that the household is or is not member of the VBO.

Table 5. Household's characteristics and the different dimensions of welfare: pairwise correlation coefficients

		Endline (2016)				Baseline (2014)			
		Monthly consumption per AE	*Food consumption per AE*	*Usual non-food consumption per AE*	*Unusual consumption per AE*	*Monthly consumption per AE*	*Food consumption per AE*	*Usual non-food consumption per AE*	*Unusual consumption per AE*
Household Composition	Number of members	-0.2075*	-0.2737*	-0.0369	0.0284	-0.2339*	-0.2216*	-0.1280*	-0.0666
	Average age of members	0.1927*	0.2491*	0.0253	-0.0019	0.2043*	0.2230*	0.0451	0.0209
	Gender ratio(#Female /#Male)	-0.0308	-0.0138	-0.0342	-0.0143	-0.0227	-0.0208	-0.0223	0.0037
	Nb of biological children	-0.2154*	-0.2636*	-0.0582	0.0119	-0.2422*	-0.2275*	-0.1270*	-0.0863
	% of members attending school	-0.1141	-0.1835*	-0.0026	0.0643	-0.1326*	-0.1423*	-0.0596	0.0208
	Nb of members working per AE	-0.1663*	-0.1997*	-0.026	-0.0267	-0.1406*	-0.1313*	-0.0905	-0.0286
Household head	Woman	0.0978	0.0986	0.0759	-0.0288	0.0465	0.051	0.0386	-0.0392
	Age	0.1058	0.1121	0.0551	-0.0049	0.0791	0.1061	-0.025	-0.0204
	Married	-0.0999	-0.1023	-0.0762	0.0313	-0.0729	-0.0778	-0.0424	0.0244
	Went to school	0.0735	0.0563	0.0071	0.09	0.0299	-0.0102	0.0576	0.1272*

6.1 Determinants of Consumption Changes: impact analysis

When performing the analysis and interpreting the results, we have to carefully distinguish between **three definitions of treatment**.

6.1.1 Intention-to-treat analysis

As we pointed out above, 34 collines were randomly selected to be treated by the Lumière Project (i.e receive a Powercycle) after the baseline survey and 29 collines were assigned as control groups. As we explained above, in 10 of the locations assigned for treatment, we did not find a Powercycle at the moment of the visit of our survey team for the endline. In one of these 34 collines the Powercycle was broken and not repaired. In 7 of the 10 collines, FVS-AMADE had presented the project, but the local groupement has declined to participate, either because they could not come up with the necessary financing or they did not find the project interesting enough. This means we are dealing with a case of partial compliance whereby 1/3 of the groups assigned for treatment did not get the

intervention. In a first approach we thus estimate the impact of being allocated to receive the intervention on welfare (consumption):

$$\Delta\, Change\ Welfare_{2017-2014} = \alpha + \beta_1 Welfare\ at\ Baseline_{2014} + \beta_2 Initially\ Assigned\ Treatment + HHcontrols * \gamma + \boldsymbol{FE}$$

We do this for total household expenditures and weighted per adult equivalents. The results are presented in Table 6. Our results shows that the point estimate of the average effect of the intervention is a 10% increase in welfare, in a 95% confidence interval between 0 and 20%. The coefficient of interest (β_1) is statistically significant from zero at the 5% level. Remark that this and all subsequent regressions are clustered at the survey site (63 sites) to obtain robust standard errors and that we used fixed effects at the province level to control for all province invariant effects.

We also remark that consumption at baseline, for which we control, has a negative effect on consumption growth, which corresponds with findings in the literature on growth and convergence. Including household level control variables does not alter the picture very much (still 10% impact), but shows that the size of the household as well as the education of the head of the household has a positive and statistically significant effect on consumption growth. The gender and the age of the head do not seem to matter for consumption growth. When we repeat the estimation with consumption per adult equivalent as dependent variable we obtain a slightly lower effect (7%) and the characteristics of the head of the household all become statistically significant.

Table 6. Intention-to-treat: The household-level determinants of change on welfare household, 2014-2017

Dependent variable:	*Change on Monthly consumption (I)*	*Change on Monthly consumption (II)*	*Change on Monthly consumption per AE (III)*
Monthly consumption (2014)	-0.539***	-0.636***	-0.670***
	[0.037]	[0.037]	[0.037]
Treated Colline (yes=1)	0.102**	0.103**	0.078*
	[0.102]	[0.047]	[0.046]
Household Size		0.070***	-0.032***
		[0.007]	[0.007]
Household head sex (female=1)		0.007	0.078
		[0.058]	[0.054]
Household head Age		0.001	0.005***
		[0.058]	[0.001]
Household head Schooling		0.218***	0.213***
		[0.437]	[0.043]
Observations	996	996	996
R-squared	0.311	0.357	0.371
Province FE	Yes	Yes	Yes

Notes – Standard errors in brackets cluster at survey site. * Significant at 10%, ** significant at 5%, and *** significant at 1%. Source: Lumière Baseline Study, ULB-UNICEF (2014).

6.1.2 Effectively treated analysis

As we pointed out above, 24 collines that did receive a Powercycle at the time of our endline visit are considered as effectively treated. No Powercycle was found in collines that were assigned to the control group after the baseline. Since this is a case of partial compliance we are interested in estimating the effect of the intervention on the compliers (those who received the treatment), also called the effect of the treatment on the treated

This is estimated via a 2 stage least-squares IV procedure (following Glennester and Takavarasha, 2013, "Running randomized evaluations", p.324-371)

In the first stage we predict effective treatment by regressing it on assignment to treatment:

$$Effectively\ treated\ = \alpha + \eta_1 Initially\ Assigned\ Treatment$$

And in the second stage we use the estimate of the first stage to infer the effect of the intervention

$$\Delta\ Change\ Welfare_{\ 2017-2014} = \alpha + \beta_1 Welfare\ at\ Baseline_{2014}\ + \beta_2 \underline{Effectively\ treated}$$

This IV procedure is needed because the effective treatment in not a random process, whereas the assignment to treatment is. We therefore use the random assignment to predicts which colline will be effectively treated. Our random assignment is a valid instrument if the only way it affects our outcome is through the take-up (exclusion restriction). Results are presented in Table 7.

The results show that we have a good first stage: our assignment variable predicts very well the effective treatment (73%, stat.sign at the 1% level) and the F-stat is also very good. The second stage yields an effect of 18% (conf interval between 3 and 33%) statistically significant at the 2% level. Our IV estimate is thus larger than our OLS estimate (see table 1), but this is always the case, as another way to calculate the effect of the treatment on the treated is

Intention-to-treat-effect / (rate of take-up in treatment group – rate of take-up in control group)

Importantly, the test-statistics for underidentification (Kleibergen-Paap rk LM statistic) and for weak identification (Kleibergen-Paap Wald rk F statistic) confirm that our instruments are relevant, that is uncorrelated with the endogenous regressors

Table 7. Effect of the treatment on the treated

	First Stage	***Second Stage***
Dependent variable:	*Effectively treated colline (yes)*	*Change on Monthly consumption*
	(I)	*(II)*
Monthly consumption (2014)	0.005	-0.488***
	[0.031]	[0.035]
Original Treated Colline (yes=1)	0.731***	
	[0.075]	
$\widehat{Effectively\ treated\ collines}\ (yes)$		0.180**
		[0.076]
Observations	996	996
F-Excluded Instruments	47.22	
Kleibergen-Paap rk LM Statistics		563.767 (p-value=0.00)
Kleibergen-Paap Wald rk F Statistics		1362.225 (p-value=0.00)
Province FE	No	No

Notes – Standard errors in brackets cluster at survey site. * Significant at 10%, ** significant at 5%, and *** significant at 1%. Source: Lumière Baseline Study, ULB-UNICEF (2014).

6.1.3 Membership as a channel

Since the Lumière Project works via the VBO's, it is intuitive to assume that **the impact of the treatment at the local level will be channeled through this membership.** We therefore include a dummy variable for membership AND we interact this dummy with the treatment variable. Since this is not a randomized variable, we only add its interaction with the treatment variable as an additional instrument. Results are in table 8.

In the first stage we predict effective treatment by regressing it on assignment to treatment

$$Effectively\ treated = \alpha + \eta_1 Initially\ Assigned\ Treatment + \eta_2\ Int.Asg.Treatment * FVS\ membe. + FVS\ membership$$

And in the second stage we use the estimate of the first stage (with two instruments) to infer the effect of the intervention

$$\Delta\ Change\ Welfare_{2017-2014} = \alpha + \beta_1 Welfare\ at\ Baseline_{2014} + \beta_2 \underline{Effectively\ treated} + HHcontrols * \gamma + \boldsymbol{FE}$$

As before we have a good first stage. The results obtained in the second stage in table 3 confirm those obtained in table 3, meaning an effect of 18% on welfare. Table three adds to that membership of VBO (which we recall is the case for half of our sample in each colline) increases welfare with 10% in addition to the effect of the project.

Table 8. Effect of the treatment on the treated, with VBO membership as channel

	First Stage	***Second Stage***
Dependent variable:	*Effectively treated colline (yes)*	*Change on Monthly consumption*
	(I)	*(II)*
Monthly consumption (2014)	0.005	-0.497***
	[0.031]	[0.086]
Original Treated Colline (yes=1)	0.731***	
	[0.076]	
VBO Member (yes=1)	-0.001	0.115***
	[0.007]	[0.037]
VBO Member (yes=1) * Original Treated Colline (yes=1)	-0.001	
	[0.230]	
$\widehat{Effectively\ treated\ colline}\ (yes)$		0.181**
		[0.077]
Observations	996	996
F-Excluded Instruments	23.59	
Kleibergen-Paap rk LM Statistics		562.606 (p-value=0.00)
Kleibergen-Paap Wald rk F Statistics		680.333 (p-value=0.00)
Province FE	No	No

Notes – Standard errors in brackets cluster at survey site. * Significant at 10%, ** significant at 5%, and *** significant at 1%. Source: Lumière Baseline Study, ULB-UNICEF (2014).

In the most complete model we include household level characteristics in the estimation, results are in table 9. Results of the first stage as before. Results in the second stage show an effect of 14.5% (which one also obtains via the other procedure 0.10/(0.70 - 0). With the caveat that membership of VBO as well as size of the household and education of the head also have positive and statistically significant effects on consumption growth.

Table 9. Effect of the treatment on the treated, with VBO membership as channel and additional household level controls

	First Stage	***Second Stage***
Dependent variable:	*Effectively treated colline (yes)*	*Change on Monthly consumption*
	(I)	*(II)*
Monthly consumption (2014)	0.005	-0.669***
	[0.030]	[0.039]
Original Treated Colline (yes=1)	0.707***	
	[0.080]	
VBO Member (yes=1)	-0.014	0.094***
	[0.013]	[0.035]
VBO Member (yes=1) * Original Treated Colline (yes=1)	-0.013	
	[0.018]	
$\widehat{Effectively\ treated\ collines}\ (yes)$		0.144**
		[0.067]
Household Size	0.005	0.067***
	[0.004]	[0.007]
Household head sex (female=1)	0.004	-0.009
	[0.043]	[0.060]
Household head Age	-0.001	0.001
	[0.001]	[0.001]
Household head Schooling	-0.027	0.218***
	[0.248]	[0.041]
Observations	996	996
F-Excluded Instruments	24.92	
Kleibergen-Paap rk LM Statistics		532.606 (p-value=0.00)
Kleibergen-Paap Wald rk F Statistics		633.013 (p-value=0.00)
Province FE	Yes	Yes

Notes – Standard errors in brackets cluster at survey site. * Significant at 10%, ** significant at 5%, and *** significant at 1%. Source: Lumière Baseline Study, ULB-UNICEF (2014).

6.1.4 What does this mean?

In order to fully grasp the extent of these findings we have to go back to the organisation of the Lumière project at the local level and the benefits it yields for the members of VBO. Indeed, as we have discussed above, the Lumière Project is an important source of revenue for the local groups. In several of them it is even the most important one. Next to Lumière, the local groups also have other income earning activities such as agriculture, livestock breeding, combined with financial services on loans and savings. It is possible, even likely

that these other activities have also increased in size and scope as a result of Lumière (because more money is available), but we were not able to verify that.

Importantly, the income of different projects is shared proportionally to the shares each member has, by investing an amount that normally varies between 500 BIF and 2500 BIF per member per week. The profits generated by the Lumière Project are split proportionally to the number of re-charges of the lamps each member did. Concerning the re-charges of the non-members, it is divided equally between members.

Thus, what we document in the analysis is that the Lumière Project is an important source of revenue at the local level and it is responsible for the increase of welfare in the villages that are part of it. Due to our evaluation design (randomized allocation of the intervention at the colline level), we can say that the Lumière intervention caused the change in welfare. The point estimate of the increase in welfare is between 10 and 18%, depending on specification, with a preferred estimate of 14.5% (IV regression with two instruments and household level controls).

In addition to the effect of the intervention, the membership of VBO also brings additional benefits to the households in the order of a 10% increase, most likely due to mutual aid, social effects and other revenue increasing activities.

These results also correspond with the answers the survey team received on our question "what are for you the most important results of the Lumière project?". Households answered that income earning was one of them.

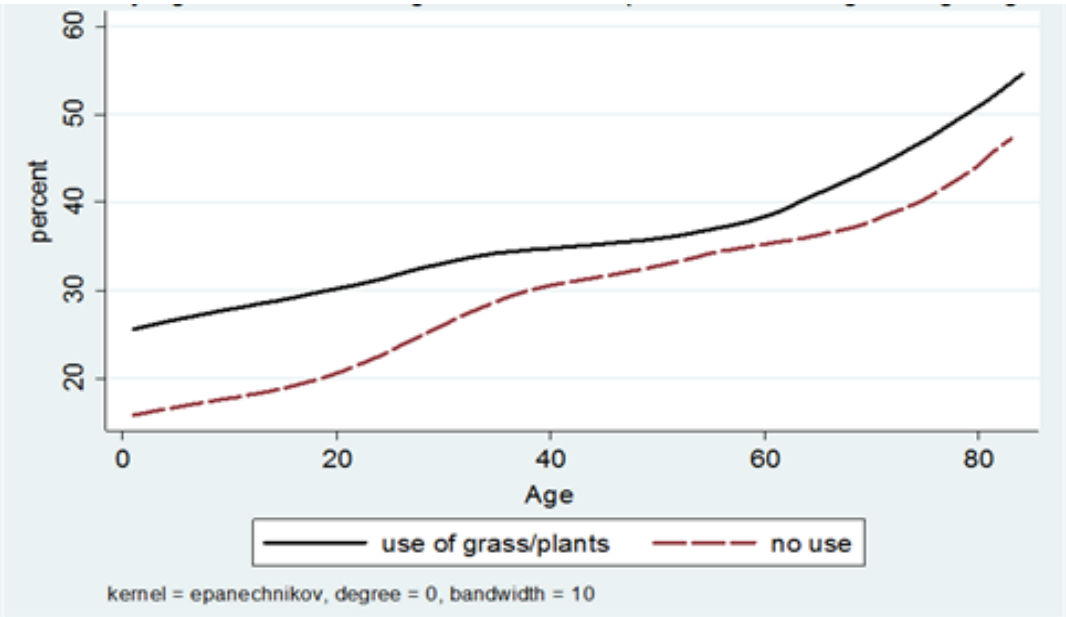
6.2 Health or Schooling Effects

We asked all household members if they suffer from eye or coughing diseases. Many household members suffer from one or both. Both diseases are directly related to the material used for cooking, in particular grass, herbs and wood. Graph 18 below shows that households who do not use grass and herbs (almost everyone uses wood), are much less confronted with eye and coughing disease. The latter of course increases with age for all household members, regardless of cooking material. The difference for children is the largest.

Unfortunately, the Lumière project does not address the cooking habits and cooking material used by the households. Hence we do not expect that the introduction of the Lumière lamps changes the cooking habits. And indeed we do not find such correlation. We do not find a reduction in the frequency, duration or severity of these diseases between households who purchased a lamp and households who did not.

Using the same IV regression as for the welfare analysis above, we also checked whether the intervention had a health impact on the treated, and we did not find any statistically significant change. Our interpretation is that the increase in welfare observed has not changed cooking habits.

Graph 18. Percentage of individuals having eye or coughing problems, by age and the use of grass and small plants for cooking and lighting



The same type of analysis was also performed on the years of schooling observed as well as on the delay in school (defined as the difference between the actual age of the child in a given grade and the 'normal' age for that grade in the absence of delay. Example, if a child of 10 years old is in grade 2, (s)he has a delay of 10-7=3 years. While there is a lot of delay in Burundese schools, we do not observe a statistically significant impact of the intervention. The average delay observed in treatment and control areas (both intention-to-treat as well as effective treatment) was 2.6 years. Neither do we find a smaller delay for children who have a Lumière lamp in the household.

Conclusions and Recommendations

Conclusions

- This report presents an impact evaluation of the Lumière Project at the level of the final beneficiaries as well as the level of the village-based organisations (VBO);
- The evaluation used a mixed-methods approach, whereby the quantitative part consisted of a cluster randomize-controlled trial, with 34 treated villages and 29 control villages, interviews with 1.000 households at baseline and at endline, with half of the households members of the VBO and the other half not. The qualitative part consisted of focus group interviews with members of the VBO;
- Based on our quantitative analysis, we find an increase in welfare expressed as consumption per adult equivalents in treated villages compared to control villages of between 14 and 18%, relative to the baseline. Because of our research design and the use of IV econometric methods we are able to say that this effect is causal, meaning that the increase has taken place *because of the project. This means the Lumière Project has had a positive impact on the welfare of treated households;*
- Membership of a VBO carries small, but statistically significant effects (+11%) in comparison to baseline. Members benefit from a network effect as well as from the revenue generated by the Project Lumière;
- The corollary of that is that the uptake of re-chargeable lamps outside the members of the VBO remains very limited. This means that the VBO functions as club with certain benefits for its members, but with few impact on non-members;
- Among households who use re-chargeable lamps, we find a clear decrease in the use of kerosene, battery lamps and candles;
- The effect of the project on children in general and vulnerable children in particular was not directly addressed by this impact evaluation. Indireclty however, an increase in welfare in the household as well as in increase in revenue at the level of the VBO is likely to have benefited children. At least we can exclude a negative impact. Children are also among the users of the re-chargeable lamps.

Recommendations

- Working through the VBO ensures a certain take-up among its members, but limites take-up outside. Indeed non-members perceive the re-chargeable lamps as club goods, accesible only to members, even when this is not the case. Hence, VBO should be encouraged to open-up and change this perception;
- The role of FVS-AMADE, an organization who was not cooperative at all during the evaluation up to the point of obstructing it, remains obscure. At the headquarters they maintain to work in a very hands-off way, facilitating where they can, helping the VBO as much as possible. At the local level, the messages are mixed, perceived as positive by some, and negative by others. The evaluation team never received a clear and transparent answer from them on the many questions they asked. The donor, if it wishes to continue working with the NGO should

demand full transparency, both on its finances as well as on the way it works with the VBO;

- Given the speed of technological evolution the Powercycles are already outdated, as solar energy is proving cheaper, more durable and more efficient. Some households in the endline survey were already using it, and do not wait for an NGO or a VBO to help them. We recommend a full transition to solar energy if the project continues;
- The business model, whereby a VBO is responsible for the sales of lamps, their re-charge as well as the management of the Powercycles, worked well. However, with the arrival of solar energy, households will not need a centrally or village-level managed supply anymore and the current business model will not stand a chance;
- The project does not address the use of wood as the main source of energy used in the household, for cooking. This source is responsible for health problems and air pollution. We recommend a (new) project to address alternatives for cooking with wood. As learning from peers is crucial here, the VBO could play an important role in showcasing alternative energy sources for cooking. It may have the potential to replace the current business model around the use of a Powercycle. Exactly because the use of solar for lighting does not have this potential (see above).
