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

The provision of grid electricity to households through the Electricity Access Roll-out Programme

Electricity Access Roll-out Programme (EARP) supported by the Netherlands through a multi-donor fund

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- Final Report -

Heft 96

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This final 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 mixed methods, that is, quantitative research techniques in combination with qualitative techniques. 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 serve as inputs to a policy evaluation of the "Promoting Renewable Energy Programme" (PREP) to be concluded in 2014.

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Summary

This 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 mixed methods, that is, quantitative research techniques in combination with qualitative techniques. 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 serve as inputs to a policy evaluation of the "Promoting Renewable Energy Programme" (PREP) to be concluded in 2014.

Impact evaluation of Energy and Development Cooperation in Rwanda

1. Introduction

Despite a noticeable effort by the Government of Rwanda and several donors to bring electricity to rural areas, the vast majority of households in rural Rwanda is still without access to modern forms of electricity. These households rely on traditional energy sources such as kerosene, dry-cell batteries, or candles for lighting purposes and dry-cell batteries for radio usage. Starting at an electrification rate of around six percent in 2009, the Rwandan Electricity Access Roll-Out Programme (EARP) connects around 60,000 households each year. By the end of 2013, 280,000 households have been newly connected (compared to 2009) implying that an electrification rate of 16 percent has been attained. In a second phase of the programme, 70 percent of households in Rwanda shall be connected to the grid by 2017.

Financed by the Government of Rwanda and a multi-donor group – with the Embassy of the Kingdom of the Netherlands being among the main donors – the programme is implemented by the national utility Energy, Water and Sanitation Authority (EWSA). The vast majority of the intended connections are to be achieved by on-grid extension and grid densification activities. In addition to direct access activities, parts of the EARP funds are also invested into the existing grid in order to improve grid stability.

Rwanda also participates in the United Nations initiative Sustainable Energy for All (SE4All). While today around 1.3 billion people in developing countries are lacking access to electricity, SE4All intends to ensure that universal access to modern energy including electricity is achieved by 2030. In line with that, the United Nations General Assembly has declared the years 2014-2024 to be the Decade of Sustainable Energy for All. The underlying assumption is that electricity is essential for achieving sustainable development and the Millennium Development Goals.

In this report, we present findings from an impact evaluation of EARP. Electricity service take-up in different beneficiary groups – households, micro-enterprises, health centres and schools – is evaluated as well as the effects electricity usage has on the different impact dimensions. For households, we look at general living conditions, time use and activity patterns, energy expenditures and attitudes with gender aspects as a cross-cutting issue. In micro-enterprises we examine firm performance in different ways and in health centres and schools we make an attempt to capture EARP's effect on the respective public service provision.

The evaluation comprises a baseline survey that was conducted between April and June 2011 and a follow-up survey conducted between May and July 2013. The study's focus is on households, the final beneficiaries of the intervention. Different identification strategies are applied for the different types of beneficiaries: For the household level, we employ a difference-in-differences approach based on the two survey waves in 2011 and 2013. In total, 974 households were interviewed in each wave using structured questionnaires. Complementarily, open interviews using semi-structured questionnaires were conducted. We visited 50 communities of which 15 were connected to the grid between the baseline and follow-up survey. For micro-enterprises, a qualitative case study approach was pursued. Around 100 enterprises were interviewed using semi-structured questionnaires during the follow-up. Health centres play an outstanding role in EARP since it is one of EARP's first phase objectives to connect all so far non-electrified health centres. The location of health centres is even one major determinant of how the power lines are planned. We therefore dedicated some efforts to evaluating EARP's effectiveness in these regards and the impacts it has on the health care provision by the centres. We first conducted semi-structured interviews with 16 health centres during baseline and 26 during the follow-up and, second, we administered a short questionnaire on connection status and appliance usage with all 442 rural health centres in the country. In addition, 23 schools were visited for semi-structured interviews during baseline and 38 schools during the follow-up.

The remainder of the report is organized as follows: Section 2 of the report introduces the country background, discusses its energy sector and the programme under evaluation. Section 3 presents the methodological approach and describes the implementation of the survey. Section 4 outlines relevant socio-economic characteristics of surveyed communities and households. Section 5 presents the take-up of electricity and electric appliances, energy consumption patterns and impacts on household level. Section 5 outlines electricity usage in micro-enterprises, health infrastructure and schools while Section 7 discusses the sustainability of the intervention. Section 8 is a register of the research questions. Section 8 concludes.

2. The Intervention in its Regional Context

2.1 Regional context

Rwanda is located in the Great Lakes region of East-Central Africa and only a few degrees south of the equator. With 10.5 million inhabitants, it is the most densely populated country in Africa and similar to Belgium in terms of dimension and population. Since its administrative reorganization in 2006, the country has been subdivided into 5 provinces, 30 districts and 416 sectors - areas comprising between 10,000 to 66,000 people. These are further subdivided into cells and so-called 'imidugudus', which are centres that regroup homes into community clusters around basic infrastructure, as opposed to traditionally dispersed settlements (all numbers from the 2012 Population and Housing Census).

After recovery from the genocide that devastated the country in 1994, Rwanda is now firmly on the path of resurgence and economic development. Primary export goods are coffee and tea, with the addition in recent years of minerals. At current prices, per capita GDP in 2012 was USD 1,500 (PPP) and in recent years the country recorded an annual GDP growth rate between 7 and 8 percent (in real terms) against an annual population growth rate of around 2.6 percent (all numbers from CIA World Factbook and the 2012 Population and Housing Census).

Consistent with the increase in incomes, there have been improvements in socio-economic conditions captured by, for instance, increases in life-expectancy and a reduction in malnourishment (a decline from 57 percent in 1997 to 32 percent in 2008). Notwithstanding this recent growth performance, in 2011, the latest year for which information is available, the incidence of poverty was pegged at 49 percent in rural areas and 22 percent in urban areas (all figures from World Development Indicators 2013).

Rwanda's economy is mostly agrarian with 80 percent of the population engaged in agricultural activities and with agriculture accounting for 32 percent of GDP. The service sector and the industrial sector contribute 53 percent and 15 percent of GDP, respectively, but employ only 10 percent of the labour force. In terms of demographics, the country has the highest population density in Africa (415 people per km2). Around 83 percent of the population are living in rural areas with an urbanisation rate of 4.5 percent (figures from CIA World Factbook and Rwanda Population and Housing Census 2012[1]).

1 http://statistics.gov.rw/publications/rphc4-thematic-report-population-size-structure-and-distribution

In its planning document called Vision 2020, the government has formulated its long term strategy for the development of the country. The objective is to transform Rwanda into a middle-income country and increase the GDP by the factor 4 until 2020 compared to 2000. This is supposed to be based on a transition from subsistence farming to higher value added agriculture and non-farm activities. This ambitious goal is expected to be realized by promoting private sector development, infrastructure development and the transformation of the country from an agricultural based economy to a knowledge based society.[2]

2.2 Energy Sector Rwanda and the intervention

Given the nature of the intervention under study, this section focuses on Rwanda's electricity sector. The country has a very low electrification rate and there are electricity generation bottlenecks. Before EARP started in 2009, only about 6 percent of households had access to grid-supplied electricity making it a country with one of the lowest electrification rates in the world.[3] Furthermore, electricity was almost entirely consumed in the main cities. Only about 1 percent of the rural population was connected, while Kigali alone accounted for over 70 percent of the total low-voltage electricity consumption (Bensch and Peters 2010). The map in Figure 1 indicates the electrification rates by districts in 2011 by referring to the share of households that use electricity for lighting.

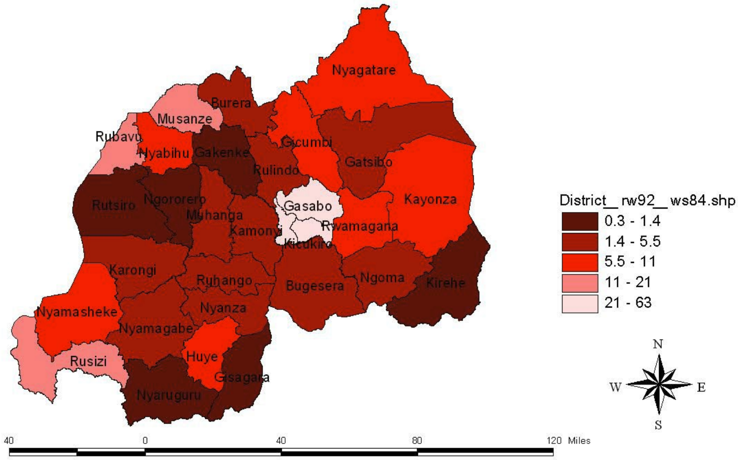
On the supply side, electricity is mostly generated by hydroelectric power plants (47 percent) and thermal power generators (52 percent). The extremely costly thermal power capacities were installed in order to address the supply shortage (CIA World Factbook). Due to these initiatives the overall installed electricity generation capacity has increased from 69.5 MW in 2007 to 110 MW in 2012 (MININFRA 2011, GoR 2012). The country's own hydropower contributes 41.7 percent of the installed capacity, imported hydropower 15.7 percent, diesel and heavy oil generators around 38.7 percent and Kivu methane gas around 3.6 percent. A small fraction of 0.3 percent is contributed by solar power. Rwanda's electricity network is interconnected with Burundi, Uganda, and the Democratic Republic of Congo. Around one fifth of the consumed electricity is imported from these countries (CIA World Factbook).

2 *http://www.minecofin.gov.rw/index.php?id=81*

3 *See http://mininfra.gov.rw/index.php?option=com_content&task=view&id=114&Itemid=142*

Figure 1

Percentage of households using electricity for lighting by district



Source: National Institute of Statistics Rwanda 2011

A huge investment programme shall lead to a further increase of the installed capacity up to 563 MW by 2017 (GoR 2012). It is planned to be achieved leveraging large-scale private investments. Currently, the Government of Rwanda (GoR) is working on a roadmap for investment into electricity generation aiming at a balanced mix of energy sources and a gradual elimination of public subsidies to the electricity tariff in order to free up public funds for other investments (GoR 2012). The Electricity Development Strategy 2011-2017 furthermore specifies the increases by different energy sources. The increase in generation capacity is principally coming from large investments in methane gas, hydropower, geothermal power and peat power plants (EWSA/ MININFRA/ RDB 2012). Moreover, the interconnection of the network with neighbouring countries is planned to be strengthened and upgraded through the NELSAP power interconnection project.[4]

Regarding the transportation of electricity, the current electricity grid consists of around 380 km of high voltage lines and 4,900 km of medium and low voltage lines (MININFRA 2011). The Government of Rwanda is planning to increase access to electricity through the national Electricity Access Roll out Programme (EARP, see Section 2.3) that is being implemented by the national utility Energy, Water

4 *http://www.afdb.org/en/projects-and-operations/project-portfolio/project/p-z1-fa0-032/*

and Sanitation Authority (EWSA, previously called ELECTROGAZ and RECO).[5] As the sole integrated electricity supplier in the country, EWSA is responsible for the generation of electricity, its transmission, distribution, and the connection of customers as well as the general coordination of grid extension and new exploitation projects.[6]

2.3 Description of the EARP intervention

The Rwandan Energy Access Roll-Out Programme (EARP) is the central effort of the Government of Rwanda to combat low electrification rates within the framework of the Economic Development and Poverty Reduction Strategy (EDPRS). During its first phase from 2009 to 2013 it aimed at increasing the number of electricity connections from around 110,000 in 2009 to 360,000 connections by May 2013, which corresponds to an increase in the national electrification rate from 6 percent to 16 percent. The EARP strategy put special emphasis on connecting social infrastructure: by 2012, all health stations, all administrative offices and 50 percent of schools were supposed to be electrified (Castalia 2009: 5ff).

EARP is implemented by the Rwandan Ministry of Infrastructure (MININFRA) and the national utility EWSA. It is supported by donors and endowed with a budget of USD 377 million for the first phase. Apart from the Netherlands, the World Bank (lead donor), Belgium, the European Union, the African Development Bank, the Japan International Cooperation Agency (JICA), OPEC Fund for International Development (OFID), and the Saudi Fund form part of the donor consortium (MININFRA 2011: 69) [7]. The Government of Rwanda also contributes with own funds. The Dutch contribution is USD 40 million. In total, the donor support makes up 80 percent of EARP's investment costs. While the Word Bank, OFID, and part of the AfDB contribution are concessional loans, JICA, Belgium, the European Union and the Netherlands provided grants. In addition, EWSA contributes 10 percent from its retained earnings. Customers contribute the remaining 10 percent through connection charges (World Bank 2009: 48).

5 EWSA will be split into two agencies in the near future, the Energy Holding Company and Water and Sanitation Company.

6 See www.ewsa.rw for further information.

7 Parts of the fund are earmarked for specific activities like electrification of social infrastructure or rehabilitation of power stations. Originally, the Arab Bank for Economic Development in Africa (BADEA) was also part of the donor consortium but in the end never disbursed the loan.

EARP focuses on connecting households to the national grid by both grid extension and grid densification activities. While the former implies substantial new medium and low voltage line installations to reach communities further away of the existing grid, the latter rather connects communities very close to existing grid by installing transformers and low voltage lines. In addition, EARP also includes off-grid connections in principle. In practice, however, off-grid connections have not been implemented under EARP so far.

In terms of allocation of EARP funds, two principal approaches exist: one is a more demand driven bottom-up approach and requires the community or local authorities to apply at the local EWSA branch by providing the number of potential customers. Alternatively, the local branch identifies promising potential communities. The local branches submit a list of suggested communities to the EWSA headquarters in Kigali where the decision is taken according to the least cost-per-connection criterion and after reviewing the network distribution capacities. In some cases, preliminary surveys in the field are conducted by EARP technicians (personal communication, EWSA April 2011).

The other follows more a top-down approach. Here, the EARP team in the EWSA headquarter in Kigali identifies communities and regions for connection, also taking into account cost criteria. Factors include the proximity of the respective communities to the existing grid, population density and inter-household distances, existence of social infrastructure, road access, and ability-to-pay (Castalia 2009:16).

The physical roll out is implemented as follows: in case only low voltage (LV) lines are needed to connect a selected area, EARP provides all required materials and man-power to the EWSA branch to install the power lines. In case where medium voltage (MV) lines are required, EARP first conducts in-depth engineering surveys to explore the conditions on the ground and tenders out the civil works to contract a private company for installations of the MV-lines.

The effective connection of households within the reach of the grid is done by private companies subcontracted by the respective EWSA branch. Households seeking electricity services need to pay a connection fee of around 80 EUR in total and are equipped with pre-paid meters. The connection fees can either be paid upfront or by instalments over a one year period at a 10 percent interest rate. In any case, the households have to pay an upfront minimum amount of 22 EUR. In-house installations have to be organized by the households themselves. In order to enable the poorest households to connect as well, EARP has developed a connection type that forgoes in-house wiring and the pre-paid meter and only includes a so-called “ready board” with two lamps and two sockets. It is up to the local authorities to identify those households that qualify as poor to obtain a ready board. In 2013, electricity tariffs were around 130 FRW per kWh (approximately 15 EUR cents).

During its first phase from 2009 to 2013, EARP has outperformed its target and by May 2013, the total number of electricity connections amounted to 360,000 - 10,000 connections more than expected. As for social infrastructure, the goals of connecting all health stations, all administrative offices and 50 percent of schools by 2012, though, have not been met. By May 2013, only 36 percent of schools, 56 percent of health facilities and 58 percent of administrative offices had been connected. Furthermore, transmission and distribution lines were constructed or rehabilitated, which results in an increase from 180,000 km in April 2009 to 350,000 km in May 2013, thereby achieving the corresponding project targets.[8]

These overall very successful results encouraged the GoR and several donors to extend the EARP activities to a second phase of the electrification programme (EARP Phase II). The target has been lifted up to a national access rate of at least 70 percent by 2017, of which 45 percent should be connected to the national grid, while the remaining households will be served by off-grid solutions, mainly solar panels and micro-hydro mini-grids. Furthermore, all health centres, hospitals and administrative offices should be connected as well as at least 80 percent of schools.[9] Additional funds have been approved by several donors, including the World Bank (USD 60 million) and the African Development Bank Group (USD 41 million)[10]. Further additional funding of USD 12 million was approved by the British

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8 The World Bank (Jul. 2013): “Implementation Status and Results – Rwanda Electricity Access Scale-up and Sector Wide Approach Development Project” , available at: http://www-wds.world-bank.org/external/default/WDSContentServer/WDSP/AFR/2013/07/07/090224b081cf4e50/1_0/Rendered/PDF/Rwanda000Rwand0Report000Sequence007.pdf p. 01ff

9 The World Bank (Jan. 2013): “Project paper on a proposed additional credit in the amount of SDR 39.0 million to the Republic of Rwanda for an electricity access scale-up and sector-wide approach (SWAp) development project”, available at http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2013/01/31/000356161_20130131152511/Rendered/PDF/741420PJPR0P120Official0Use0Only090.pdf p. 15

10 http://www.afdb.org/en/news-and-events/article/afdb-supports-energy-access-project-in-rwanda-12064/

Department for International Development (DFID), and by the Netherlands (USD 4 million[11]). The Belgium Technical Cooperation (BTC) plans to provide 17 million EUR for grid extension in the Eastern Province. [12]

3. Evaluation Approach

3.1 Evaluation objective

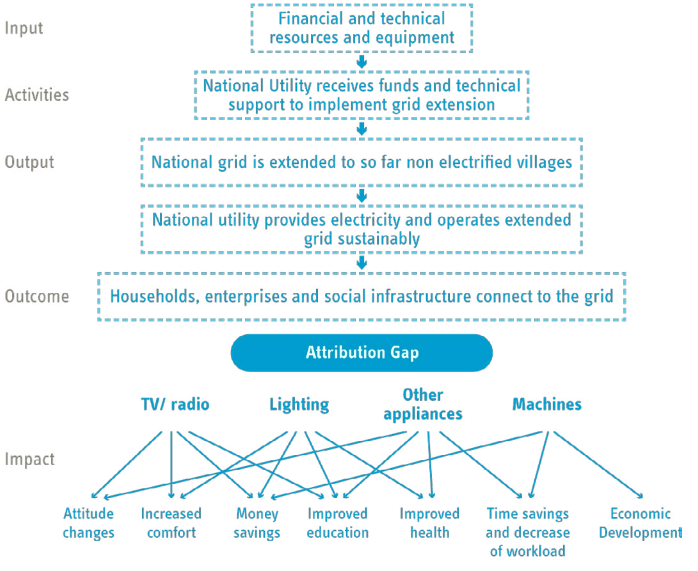
This evaluation aims at assessing positive and negative impacts – intended or not – related to EARP. The evaluation's major part focuses on households as the most important intervention's beneficiary and addresses questions related to the outcome and impact level as well as sustainability. Beyond the household level, the evaluation comprises modules that look at effects that evolve via health centres, schools and micro-enterprises. The research questions pursued by this evaluation follow the Theory of Change of the intervention, which is illustrated in the results chain in Figure 2.

On the outcome level, we address the following questions: (i) What is the connection rate of households, enterprises and social infrastructure institutions in the project area? (ii) How reliable is electricity supply? (iii) Who (gender-specific) in the household has made the decision to connect to the electricity grid? (iv) Which socio-economic groups (incl. income groups) benefit from availability of electricity? (v) How much electricity is used, by whom, and for which purpose?

11 *http://www.rwandaeye.com/featured/3385/netherlands-grants-rwanda-e4m-for-electricity-boost/*

12 *The World Bank (Jan. 2013): "Project paper on a proposed additional credit in the amount of SDR 39.0 million to the Republic of Rwanda for an electricity access scale-up and sector-wide approach (SWAp) development project" p. 09*

Figure 2
Results chain



Source: Own representation.

On the impact level: (i) How have expenditures for energy changed? (ii) To what extent has safety/protection changed? (iii) To what extent has comfort/convenience changed? What monetary value do households attribute to this increased convenience, disaggregated by gender? (iv) 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? (v) To what extent has indoor air pollution been reduced (according to the perception of dwellers)? (vi) How have, in response to the possibly increased media exposure, attitudes and behaviours, such as women's status, fertility, children's school enrolment changed? (vii) Has the availability of electricity triggered new economic activities or displaced old ones? (vii) Has school attendance changed as a result of electricity use? (viii) How are benefits distributed across different income groups? Has the activity had an effect on gender equity in access to, use of and benefits from energy sources? (ix) What (if any) positive and/or negative unintended effects have occurred?

On the household level we expect that the major impact is on 'softer' levels such as increased convenience and comfort induced by using electric lighting and appliances such as radio, TV, or a mobile phone charger as well as on the level of expenditures. The questionnaire we used for the survey covers several socio-economic aspects that characterise a household's living conditions with a particular focus on the use of appliances and energy expenditure. Two features address the convenience and comfort aspects: (a) Direct questions on satisfaction and perceived convenience. These questions are similar to those used in the happiness and subjective poverty literature and in the marketing/business school literature. (b) A willingness-to-pay analysis (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 the endline survey, the questionnaire contains a willingness-to-accept (WTA) module asking for the price at which connected households would accept to disconnect. The WTA and the WTP approach have been designed in line with the literature.[13]

Furthermore, we will examine impacts on activities after nightfall, which might be affected due to increased usage of lighting and television. For instance, the time children dedicate to studying at home is an indicator. As the result chain shows, in principle, effects on health because of reduced household air pollution are also possible. However, even if this impact exists, it may be rather small given that household air pollution is largely induced by cooking fuels. Cooking habits, in turn, are normally not affected by an electrification intervention in rural Africa. For certain high exposure groups, though, kerosene smoke might nonetheless have health effects. School kids, for example, study in direct proximity to kerosene lamps (Epstein et al. 2013, Fullerton et al. 2009, Pokhrel et al. 2010, Schare and Smith 1995).

In addition, we will study the impact on behaviour and attitudes resulting from increased media exposure, such as on women's status, reproductive behaviour, and children's school enrolment. Some studies suggest that the information and exposure provided by radio and in particular television can influence a wide range of attitudes and behaviour (see Gentzkow and Shapiro 2004, Olken 2006, La Ferrara, Chong and Duryea 2008, Chong and La Ferrara 2009, Peters and Vance 2011, Jensen and Oster 2008). A possible unintended negative effect could be the one of television on trust and social capital as observed in Olken (2009). Using Indonesia data, Olken finds that social interaction in various forms within villages is decreased with the introduction of television because people prefer to watch TV.

13 Refer to the following sources to see how this approach can be used to assess benefits from access to energy: Devicienti et al. (2004), Abdullah and Jeanty (2009) and FAO (2000).

Table 1
Different Study Modules

Study module	Content	Sample Size	Interview Type
Household study			
Large household survey	Comprehensive socio-economic questionnaire covering most household characteristics (revenues, expenditures, education, health and gender issues, activities at night-time) with focus on energy and lighting usage. Additional questionnaire administered to women in the households.	974 (baseline and follow-up)	Structured questionnaire
Qualitative household survey	Open discussions about intended and unintended effects of electrification.	20 (follow-up)	Open interviews
Micro-enterprise study			
Qualitative micro-enterprise survey	Energy usage, bottlenecks of firm development and role of electricity. Customer basis and market access.	around 100 (follow-up)	Semi-structured interviews
Community study			
Community chief survey	Connection rates, number of enterprises, community size, infrastructure and market access, availability of energy sources, major community particularities, etc.	50 (baseline) 44 (follow-up)	Structured questionnaire
Social infrastructure survey			
Qualitative health centre survey	Connection status, appliance usage, health care provision and role of electricity.	16 (baseline) 26 (follow-up)	Semi-structured questionnaire
Qualitative school survey	Connection status, appliance usage, role of electricity in service provision.	23 (baseline) 38 (follow-up)	Semi-structured questionnaire

Study module	Content	Sample Size	Interview Type
Full census health centre survey (via telephone)	Connection status, year of connection, appliance usage, fuel on which appliance runs, cases of kerosene burns.	442 (follow-up)	Structured questionnaire (short)
Sustainability			
Survey of EWSA agencies	Number of connections in the region, selection process for regions to be connected, organization of maintenance and capacities to provide maintenance services.	all 12 agencies in survey area (follow-up)	Semi-structured interviews

soure: own representation

The question of sustainability of the intervention on the household level in the present case is not a technical one. Unlike, for example, Solar Home Systems or biogas digesters a connection to the electricity grid does not fail technically at the end-user level. Electricity supply is warranted as long as the electricity grid is properly managed at a central level. On the household level, the sustainability question that arises is whether all households are able to pay the electricity bill and how many of them get disconnected. Since pre-paid metering is applied and the account can be recharged by small amounts, it is easier for households to administer the funds and the risk of not being able to pay bills is reduced. We will investigate whether households are satisfied with the provided service. At the institutional level, the crucial question will be if generation capacity bottlenecks in the electricity sector can be solved – in particular in light of the thousands of new projected connections that will further increase electricity demand. For this purpose, we elicit information on the frequency of blackouts.

On the **micro-enterprise level**, various effects are possible. While manufacturing firms like carpenters or welders might use electricity to run new machinery, shops and service firms like hair cutters can use smaller appliances like fridges, radios or electric haircutting machines to improve services or attract customers. Electric lighting can improve processes in all type of companies and might lead to an increase in operation hours. For **rural health centres,** the major impact is on the quality of health care provision via allowing for using appliances such as electric lighting or diagnosis appliances like microscopes and centrifuges that are required to detect simple infectious diseases such as malaria. **Schools** can be expected to benefit most from lighting in order to offer evening hour courses or improve class quality during rainy season. In exceptional cases, also computers might be acquired. It is also frequently argued that it is easier to recruit and keep staff for rural schools if the area is electrified. Teachers are usually coming from urban areas so that they are used to urban infrastructure provision, including electricity.

The different study modules employed to provide evidence on impacts on the different beneficiary levels are summarized in Table 1.

3.2 Identification strategy

The different groups of beneficiaries are examined by different methodological approaches using different identification strategies. The focus is on assessing the programme's effects on **households.** The major challenge in evaluating an on-grid electrification programme like EARP is the selection into treatment that happens on two levels: First, on the community level where certain types of communities are given priority by EARP to be chosen as treatment community, for example those that exhibit better business opportunities over more remote communities without market access. Second, once the community is connected, households self-select into the treatment. Since households are not connected for free, the connection decision becomes one of an investment. For obvious reasons, certain types of households – the richer or the more modern – are more inclined to connect than others.

Methodologically the best way to handle this would be to randomly assign the electrification treatment to communities and subsequently to households within the electrified communities. While for obvious reasons, randomly connecting one group of households and refusing the connection to another group of households is politically not a feasible approach, the random assignment of communities, in contrast, could have been possible in a large programme like EARP by applying a random phasing-in design for which the sequence of electrification would be determined randomly across communities. We contemplated this briefly during the preparation of the baseline survey and found that a controlled random phasing-in would not be possible in the EARP set-up, because EWSA's effective roll-out was determined by many practical factors ranging from logistical issues to contractual matters with construction companies. Hence, it would have been impossible for them to stick to a controlled randomized schedule.

The second best option is to mimic a randomized treatment assignment in a non-randomized difference-in-differences approach, which was pursued for this impact evaluation. For this purpose, the communities to be surveyed need to be selected in a way that treatment and control group communities are similar in the before situation, which would basically be the outcome of a successful randomization. Hence, at the baseline stage in 2011 we took a random draw of 30 treatment communities from the list of EARP target regions that had been scheduled for connection in 2011 and early 2012. The control group communities were selected from the remaining sub-population of EARP communities in the same region as the selected treatment communities that had been scheduled for connection in 2013 (so, after the follow-up survey). There is good reason to expect these communities to be quite similar since both have been selected for electrification and it is only the sequence that differs. For some treatment communities, such 2013-EARP control communities did not exist in the region. As an alternative, we visited other communities in the region, scrutinized them with regard to their similarity as compared to the respective treatment communities and picked the most comparable ones. The criteria were road access, community size, and income pattern (number and type of businesses, prevailing agricultural activities, etc.). Around half of the control communities were selected from the sub-population of EARP communities which will not be electrified before the follow-up. The other half was picked from non-EARP communities according to the comparability criteria.

We surveyed both treatment and control communities in May and June 2011 and in June and July 2013, which allows us to employ a difference-in-differences (DiD) estimation of effects on households and the community level. Unlike a randomized phasing-in approach a DiD comparison requires an identification assumption to hold in order to obtain unbiased impact estimates: in the hypothetical absence of the electrification both groups of communities and households need to be on the same trend in terms of the indicator under evaluation (parallel trend assumption). In other words, DiD then controls for unobserved differences between the households and communities in the two groups as long as they are time invariant or change in the same way in both groups. Effectively, changes in the impact indicator under evaluation will thus only be measured as an impact in the treatment group if they have not occurred similarly in the control group.

For most classical household level unobservables such as the household's attitude towards technology this seems to be a very plausible assumption since they do not change substantially over time. To further reduce the risk of confounding factors, we will balance the groups by controlling for a set of potential confounding variables by using regression techniques.

As outlined above, not all households in a newly connected community will obtain a connection. Based on experiences in Rwanda and other countries, between 40 and 80 percent of the households within the access area of the grid can be expected to get connected. Methodologically, this brings up the question of who is considered as treated: households that are located in a connected community (irrespective of their connection status) or only households that are directly connected themselves. The answer in fact depends on the indicator one looks at. For a certain type of indicators the treatment clearly is at the community level, because effects can be expected to spillover from connected households (or enterprises) to non-connected households in the same community (for example, security issues like burglaries). For other indicators, one is rather interested in how effects evolve in households that are connected (for example consumed lighting hours).

Therefore, we develop identification strategies for both comparisons. Identifying impacts of the community treatment is straightforward. The variable of interest is either observed at the community level (for example enterprise creation) or averaged across all households – connected and non-connected ones – in the community. For the household level, identifying impacts requires comparing connected households from the treatment community to similar, counterfactual households from the control communities. We identify these counterfactual households by estimating the propensity of control group households to connect.

To implement this we first estimate a probit model including only households from the treatment communities and regress the connection status of a household on a number of covariates. These covariates need to influence both the connection decision and the indicators under evaluation. The coefficients from this probit model will be used to predict the probability of getting connected for each household in the whole sample, including the control communities. These predicted probabilities or propensity scores will then be used to stratify the de facto non-connected control households into "hypothetically connected" and "hypothetically non-connected" households. The "hypothetically connected" households would be expected to get connected if the grid was available, the "hypothetically non-connected" would not.[14]

The identification strategy for **micro-enterprises** and **schools** is restricted by the small sample size and resorts to a qualitative way of assessing the firm's behaviour in the counterfactual situation. The interviewer asked questions on first the before situation and second in a 'what would have happened'-manner. While this

14 In a cross-sectional set-up this approach was originally applied in Bensch, Kluve, and Peters (2011) and Peters, Vance, and Harsdorff (2011).

in comparison to the household identification strategy is obviously less robust and more prone to different sources of bias, it nonetheless offers insights into how access to electricity affects the micro-enterprises' scope of work and the extent to which schools are able to improve their classes.

Since **health centres** play an important role in the design and the ambition of EARP, we apply an identification approach comparable to the one for households. We combine a qualitative in-depth interview approach with a quantitative approach based on a large sample size survey. The former is conducted in the 50 communities we visited physically for our household survey were we interviewed in total 26 health centres by means of a semi-structured questionnaire.[15] For the latter we contacted all 387 rural health centres in the country for a telephone interview using a short structured questionnaire. During the telephone interviews we elicit the connection status and the appliance take-up of the health centres and compare appliance usage rates in connected centres to the before situation which is obtained from retrospective questions. In the absence of a control group, this before-after comparison does not suffer from a selection bias, but might be distorted by other secular changes not related to the EARP intervention. For example, the public health budget might have been increased leading to appliance uptake.

3.3 Sampling

Except for the health centre full census survey conducted by means of telephone interviews, all elicited information is coming from 50 communities we surveyed in 2011 and 2013. A two-stage random sampling was applied with the first stage at the community level and the second at the household level. In 2011, the treatment communities were randomly drawn according to probability-proportional-to-size sampling from community lists obtained from EWSA. These lists also contained information on the planned household connections for each community. We used this information to assign probabilities to each community to be selected for the survey that were proportional to the number of envisaged household connections. After the 30 treatment communities had been selected, we chose 20 control communities as described in Section 3.1.

In 2011, out of the 50 communities, 30 were designated to be connected, which turned out to be true in all but 16 cases. The non-connection of these 16 communities is due to a delay in the implementation caused by logistical constraints like

15 In twelve cases there is no health centre in the survey community, in five cases two communities are sharing one health centre. In all other communities, the health centre was visited if time was available in the field supervisors' schedule.

material availability or delays in the tendering process. All of these communities are still foreseen to be connected. The 16 communities were shifted to the control group for the impact analysis in this report. From those communities foreseen for the control group, one was eventually connected and hence shifted to the treatment group. The reason for oversampling the communities foreseen for electrification in 2011 was to make sure that we have a sufficiently large number of electrified communities in the follow-up survey, anticipating that some of the designated treatment communities will remain untreated. At the time of the follow-up survey we therefore had 15 treatment and 35 control communities potentially to be included in the second survey wave. Since obviously control community information was abundantly available we decided to randomly pick 6 communities from the eventual control communities and dropped them from the study (in order to stick to budget restrictions).

The random selection of households within a community was implemented as follows: Arriving in a treatment community to be surveyed, the survey team first identified the area to be covered by the future grid. A corridor of 50 metres was determined along the planned distribution line. According to MININFRA and EWSA this is the area in which households will get connected at the normal connection fee (i.e. without extending the distribution line at their own expenses). The households within this corridor formed the population of the study from which the sample of 30 households per community was drawn using simple random sampling. For control communities, we applied the same approach and sampled from a corridor of 50 metres along the main roads in extension communities, while sampling the entire agglomeration close to the already electrified community for densification communities. Again, 30 households were randomly selected from each community.

In some cases, we noticed at the time of the follow-up survey that the low voltage lines had effectively been installed in a different part of the community (note that what we refer to as communities in Rwanda are agglomerations of small settlements that might effectively be spread over a few kilometres) than originally announced by EWSA branches, local authorities or predicted by community chiefs.[16] In these cases, we did only include households in the follow-up survey that were in the catchment area of the lines since the other households beyond the reach of the grid do not carry any additional information compared to the control group.

16 See the baseline report Bedi et al. (2012) for a detailed description on how the sampling areas were initially determined.

In total, 1,486 households were interviewed for the baseline survey. In 929 of them, a female member was additionally interviewed using the women's questionnaire. The follow-up survey in 2013 was conducted a few weeks later than the baseline survey (but harvest wise still in the same season) in order to avoid logistical problems we encountered during the baseline when certain communities were extremely difficult to access due to the rainy season. 156 households in the purposefully excluded control communities were not visited again. Furthermore, we excluded 142 households that live in treatment communities but outside the catchment area of the grid. Attrition is modest at around 18 percent. Accordingly, 974 households have been interviewed during the follow-up.

3.4 Survey implementation

The two survey waves were implemented jointly by Inclusive Business and Consultancy (IB&C), a Kigali-based consultancy, and ISS/RWI. IB&C managed the logistical organization of the survey including 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. IB&C was supported by two junior ISS/RWI team members during the implementation of both survey waves. All details on logistical arrangements are provided in Annex 2.

The preparation of the baseline surveys was undertaken by senior ISS/RWI researchers in the beginning of April 2011 and May 2013. Four-day training workshops were held prior to both surveys to prepare the twelve interviewers for the field work and data entry. After a presentation of the study's objective and a discussion of the questionnaires, the role of the interviewer was discussed including how they had to present themselves when visiting a household. Afterwards, the interviews were practiced through role playing games in the local language (Kinyarwanda). Normal interviews, best-case and worst-case interviews were tested. In a one-day pre-test in the field the interviewers administered the survey together with the ISS/RWI and IB&C team members. These pre-tests also served to verify the feasibility of the different questionnaires to make further improvements regarding their content and in order to account for unconsidered impacts. The trainings focused also on data entry as a crucial part of the survey cycle and after the pre-tests, the enumerators were trained to enter the data in the Excel data entry sheet.

The baseline survey took place between April 25th and May 30th 2011 and the follow-up survey between May 30th and August 9th 2013. The survey was conducted by two teams, each consisting of six interviewers in 2011 and five interviewers in 2013 and one supervisor. Throughout the survey, two junior ISS/RWI team members stayed with the survey team to ensure the proper implementation of the household survey and to conduct interviews with micro-enterprises, schools and health centres. Around a month after the survey, IB&C submitted the entered data to ISS/RWI. The accuracy of the entered data was checked and necessary revisions were made by IB&C in Kigali. The final versions of the data were handed over to RWI/ISS at the end of October 2011 and the end of August 2013.

4. Household and community level: Descriptive Statistics and Balancing

This section presents the point of departure in the EARP target regions by showing basic community and household characteristics at the baseline level. This conveys the socio-economic living conditions of the target population and allows for scrutinizing the balancing of the treatment and control group in terms of these observable characteristics. This balancing is the precondition for the identification assumption to hold. All values are baseline values collected during the baseline before EWSA had started its activities in the communities.

4.1 Community Characteristics

The survey includes in total 44 communities whereof 15 are treatment and 29 are control communities. The average distance to the principal route that connects several communities and towns is almost 11 km both among treatment and control communities. According to qualitative judgments of community officials the treatment communities are slightly easier to access than control communities.

As can be seen in Table 3, no strong differences between the two groups exist in terms of social infrastructure. In around 75 percent of all communities is at least one school, normally a primary school. The share is slightly higher in treatment communities than in control communities. Health infrastructure (mostly health stations) exists in only around 40 percent of the communities. Here, the share is higher among control communities. Around 30 percent of control households and 50 percent of the treatment communities have a regular market.

4. Household and community level: Descriptive Statistics and Balancing

Table 2

General statistics on sampled communities (assessment of community chief)

Variable		Control		Treatment	
		#	Share	#	Share
Number		29		15	
Distance to principal route (km)		10.95		10.63	
Accessibility of main road during rainy season	Good	6	0.21	5	0.33
	Average	10	0.34	7	0.47
	Possible with difficulties	10	0.34	2	0.13
	Possible in case of emergency	3	0.10	1	0.07

Source: EARP baseline dataset 2011.

Table 3

Social Infrastructure in sampled communities

Variable	Control		Treatment	
	#	Share	#	Share
No. Communities with Schools	21	0.72	12	0.80
No. Communities with a Primary School	13	0.45	7	0.47
No. Communities with a Secondary School	4	0.14	3	0.20
No. Communities with a Group of Schools	8	0.28	3	0.20
No. Communities with Health Infrastructure	13	0.45	5	0.33
No. Communities with Market	9	0.31	8	0.53

Source: EARP baseline dataset 2011.

The two groups are also quite homogeneous in terms of signal availability and quality for radio, television and mobile phone networks (Table 4). Radio and mobile signals are available in all the surveyed communities and the quality of the signal is reported to be good. Television and internet signal are not always available in the study areas. A substantial proportion of the community chiefs were unaware of internet and TV availability.

Table 4

Availability and quality of mass media in sampled communities (assessment of community chief)

Variable		Control		Treatment	
		#	Share	#	Share
Reception of Radio		29	1.00	14	0.93
Quality Reception of Radio	Good	23	0.79	11	0.73
	Average	6	0.21	3	0.20
Reception of Mobile		29	1.00	15	1.00
Quality Reception of Mobile	Good	24	0.83	10	0.67
	Average	5	0.17	5	0.33
Reception of TV	Yes	16	0.55	10	0.67
	Does not know	5	0.17	3	0.20
Quality Reception of TV	Good	11	0.38	5	0.33
	Average	3	0.10	2	0.13
	Bad	2	0.07	3	0.20
Internet Connection	Yes	7	0.24	3	0.20
	Does not know	5	0.29	3	0.25
Quality of Internet Connection	Good	6	0.21	2	0.13
	Average	1	0.03	1	0.07

Source: EARP baseline dataset 2011.

The communities have similar access to various energy sources that are typically used by the households (Table 5). Candles, kerosene, charcoal, and batteries are available in virtually all communities. Diesel and petrol are available only in few communities and liquefied petroleum gas is not available in any community.

Table 5
Source of energy available in local shops

Variable	Control		Treatment	
	#	Share	#	Share
No. Communities where [energy source] is available				
Candles	28	0.97	15	1.00
LPG	28	0.97	15	1.00
Diesel	4	0.14	2	0.13
Petrol	8	0.28	5	0.33
Kerosene	24	0.83	14	0.93
Charcoal	21	0.72	12	0.80
Firewood	27	0.93	15	1.00
Batteries	28	0.97	15	1.00

Source: EARP baseline dataset 2011.

The economy in rural Rwanda and, hence, also in the surveyed areas is dominated by agricultural activities. Consequently, agriculture is the main source of income in the majority of communities. The cultivated crops are by and large for auto-consumption or to be sold and consumed on local markets. The major cash crops are manioc, potatoes, maize, coffee and tea, of which only coffee and tea can be expected to end up on supra-regional or world markets. Only few communities report to have other main sources of income like mining or commerce.

Table 6
Main source of income

Variable	Control		Treatment	
	#	Share	#	Share
Main Income source				
Agricultural Activities	21	0.72	10	0.67
Non-Agricultural Activities	4	0.14	2	0.13
Animal husbandry	4	0.14	5	0.33

Source: EARP baseline dataset 2011.

4.2 Household characteristics

This section shows basic characteristics of the surveyed households that cannot be expected to be affected by the electrification treatment. Like in section 4.1 we thereby verify the comparability assumption of our identification strategy. Obviously, we only include those households that were interviewed for both the baseline and the follow-up survey (remember that we dropped 298 households before the follow-up survey). We look at two comparisons: first, we compare control households to all households from the treatment group. Second, we compare connected to non-connected households within the treatment group. In both cases, *t*-tests or *chi-squared* tests on the differences in means are conducted. In order to keep information manageable, standard deviations or p-values are not reported. Only in case of statistically significant differences the significance level is indicated by asterisks. All variables are reported for the baseline period.

For the comparison between treatment and control communities, we generally find only very few substantial differences. In line with expectations, it also becomes evident that households within treatment communities who are connected in 2013 and those who are not connected in 2013 were already quite different before they got the grid connection.

Table 7

Household structure variables

Household's structure variables (baseline values)	Control	Treatment		
		all	connected	non-connected
N	686	288	180	108
HH size	4.98	5.24*	5.70	4.47***
Share of HHs with female head of HH	0.17	0.18	0.18	0.17
Share of HH members under 6 years	0.19	0.16	0.17	0.17
Share of HH members under 15 years	0.39	0.39	0.41	0.36*
Share of elderly over 65 years	0.02	0.03*	0.02	0.06***

*Note: The asterisks refer to the significance level detected by t- and chi-squared tests on differences in means between the treatment and control group as a whole and between connected and non-connected households within treatment communities. *, ** and *** indicate significance levels of 10%, 5% and 1%, respectively.*

Source: EARP baseline dataset 2011.

4. Household and community level: Descriptive Statistics and Balancing

Looking at basic households structure variables (see Table 7), we see that the average household size is around five persons with almost 20 percent of them being small children under six and another 20 percent of children between six and 15 years old. Elderly over 65 years are very rare. Households are mainly headed by males. Only 17 percent of the head of households are female. Comparing treatment and control communities, households in treatment communities turn out to be significantly larger than households in control communities. Furthermore, within the treatment communities, especially larger households connected to the grid. Another difference between treatment and control communities is the share of elderly. While the share of elderly is slightly bigger in treatment communities compared to control communities, within the treatment communities connected households exhibit a substantially lower share of elderly. In turn, more children under 15 live in connected households.

Table 8

Educational distribution (in shares of all households)

Head of the household, highest education level (baseline values)	Control	Treatment		
		all	connected	non-connected
Without education	0.23	0.16**	0.14	0.20
Alphabetization	0.02	0.04	0.04	0.04
Primary School	0.56	0.58	0.56	0.61
Higher Education	0.18	0.22	0.26	0.15**

*Note: The asterisks refer to the significance level detected by t- and chi-squared tests on differences in means between the treatment and control group as a whole and between connected and non-connected households within treatment communities. *, ** and *** indicate significance levels of 10%, 5% and 1%, respectively.*

Source: EARP baseline dataset 2011.

More than half of the heads of household went to primary school (see Table 8). In treatment communities we observe less head of households that did not receive any education. The difference is statistically significant, but with only seven percentage points negligible in size. It does not come as a surprise that comparably better educated households are more inclined to get connected.

Table 9
Household's assets

Household's asset (baseline values)	Control	Treatment		
		all	connected	non-connected
Share of HH cultivating land	0.79	0.73*	0.75	0.66
Share of HH owning livestock	0.67	0.63	0.64	0.57
Number of cows	0.72	0.64	0.86	0.35***
Number of goats	0.36	0.25	0.29	0.17
Number of poultry	0.61	1.11	1.72	0.29
Share of households with vehicle	0.29	0.25	0.32	0.17***
Share of households with bicycle	0.26	0.21*	0.26	0.15**
Share of households with motorcycle	0.03	0.04	0.02	0.06*

*Note: The asterisks refer to the significance level detected by t- and chi-squared tests on differences in means between the treatment and control group as a whole and between connected and non-connected households within treatment communities. *, ** and *** indicate significance levels of 10%, 5% and 1%, respectively.*

Source: EARP baseline dataset 2011.

Most households are farmers and cultivate arable land (see Table 9). The share is lower in treatment communities, with the difference being statistically significant but again small in size (73 percent vs. 79 percent). Livestock is kept by around 65 percent of the household. While this overall share does neither differ between control and treatment communities nor between connected and non-connected households, the number of cows – the most common animal – is significantly lower for non-connected treatment households. The ownership of vehicles again shows that connected households are significantly wealthier. They own more bicycles and motorcycles than non-connected households.

Table 10

Share of total expenditure on various categories

Expenditure category (baseline values)	Control	Treatment		
		all	connected	non-connected
Food	0.38	0.36	0.33	0.41***
Energy	0.10	0.12**	0.11	0.13*
Schooling (in percent)	0.09	0.09	0.09	0.08
Clothing (in percent)	0.07	0.06	0.06	0.08*
Transportation (in percent)	0.06	0.05	0.06	0.04**
Telecommunication (in percent)	0.04	0.04	0.05	0.04
Health (in percent)	0.02	0.02	0.02	0.02
Restauration (in percent)	0.01	0.01	0.02	0.00***
Total annual household expenditure (in 1000 FRW)	778	784	1016	456***
Per capita annual expenditure (in 1000 FRW)	173	160	202	109***

Note: Expenditures do not account for self-consumption.

*The asterisks refer to the significance level detected by t- and chi-squared tests on differences in means between the treatment and control group as a whole and between connected and non-connected households within treatment communities. *, ** and *** indicate significance levels of 10%, 5% and 1%, respectively.*

Source: EARP baseline dataset 2011.

Expenditures are dominated by money spent on food. It makes up almost 40 percent of the total expenditures that amount to around 780,000 FRW (ca. 910 EUR[17]). The second most important expenditure category is energy, accounting for around eleven percent of household expenditures. This share is higher in treatment communities compared to control communities. Again, while the difference is statistically significant, it is small at two percentage points.

17 *Exchange rate as of 1st May 2013: 1 EUR=818 FRW.*

Comparing connected and non-connected households within treatment communities, we observe that connected households spend substantially more than non-connected households. While the share of expenditures for food, energy and clothing are lower for connected households, they spend relatively more on transportation and eating and drinking outside home (restauration).

Table 11

Subjective Assessment of living conditions

Subjective Assessment of living conditions (baseline values)	Control	Treatment		
		all	connected	non-connected
Living conditions in comparison to three years ago have...				
Improved	0.64	0.62	0.70	0.50***
Have not changed	0.26	0.23	0.17	0.34***
Deteriorated	0.11	0.15*	0.14	0.16
Perception of HH income				
Sufficient	0.04	0.05	0.06	0.04
Tight	0.05	0.04	0.06	0.00**
Not sufficient	0.91	0.91	0.88	0.96**

*Note: The asterisks refer to the significance level detected by t- and chi-squared tests on differences in means between the treatment and control group as a whole and between connected and non-connected households within treatment communities. *, ** and *** indicate significance levels of 10%, 5% and 1%, respectively.*

Source: EARP baseline dataset 2011.

In addition to consumption information, which may be used to create objective measures of poverty, we asked households about their perceived living conditions. Most households think that living conditions had improved during the three years prior to the baseline survey. Nevertheless, more than 90 percent of households state that household income is not sufficient. We observe only slight differences between control and treatment communities. Those households that have connected to the grid had in general painted a more optimistic picture of their situation at baseline than households that have not connected.

5. Household and community level: Outcomes and Impacts

5.1 Take-up

This section presents an impact assessment on all relevant household indicators. Follow-up values are shown and differences-in-differences estimations are presented, without explicitly showing baseline values. As outlined in the identification strategy in Section 3 we look at effects at the community level and the individual household level. Two models are estimated:

The **DiD community** model compares treatment and control communities averaging the respective variable across all households in the respective group. A regression model is used that controls for baseline values of the impact indicators and further pre-intervention characteristics of the households. These are the households' energy expenditures, lighting hours, household size, educational level, occupation and sex of the head of household, ownership of a bank account, a subjective assessment of the dynamics of the last three years and the distance of the households to the main road.

The **DiD household** assesses the effects of electrification on the households that are effectively connected to the EWSA grid. This is why we display mean values for connected households and estimate a difference-in-differences model using the same control variables as for the community DiD. The control group for the DiD household is identified by means of propensity score matching as described in Section 3.2. The underlying probit model, the included covariates and details on the predictive quality of the probit model are displayed in Annex 6.

Box 1
Guidance to results tables

In the following section we will display all results in tables specifying

- *(1) the DiD community*
- *(2) the DiD household*
- *(3) the mean follow-up value for the whole control group*
- *(4) the mean follow-up value for the whole treatment group*
- *(5) the mean follow-up value for connected households in treatment communities*

For the DiD community and DiD households we indicate significance level (6). In order to keep information manageable standard deviations or p-values are not reported. Only in case of statistically significant differences the significance level is indicated by asterisks.

Energy Source	DiD community	DiD household	Control	Treatment	
				all	connected
Number of lighting devices	2.38***	4.33***	1.9	4.7	6.4
Daily lighting hours per lamp	-0.64	0.65	3.88	3.35	4.1

Interpretation:
Among treatment communities the number of lighting devices increased on average by 2.38 per household. The result is statistically significant on the 1 percent level

Interpretation:
Among connected households the number of lighting devices increased on average by 4.33 per household. The result is statistically significant on the 1 percent level

Interpretation:
Households in treatment communities (connected and non-connected) use on average 4.7 lighting devices at follow-up

Interpretation:
Among control communities, households use on average 1.9 lighting devices at follow-up

Interpretation:
Connected households in treatment communities use on average 6.4 lighting devices at follow-up

5. Household and community level: Outcomes and Impacts

5.1.1 Electricity usage

Between baseline and follow-up, EWSA installed low voltage electricity lines in all treatment communities. All households in the treatment group have had the possibility to connect to the electricity grid at a connection fee of 65,000 FRW (80 EUR), of which at least 15,000 have to be paid upfront and the rest in instalments. According to interviews with EWSA branch managers it normally takes households around 12 month to pay the complete connection cost. Only around 15 percent pay the 65,000 FRW upfront. Households are obliged to pay part of the remaining connection fee any time they charge their pre-paid electricity system, i.e. households cannot consume electricity if they do not start to repay the connection cost.

By November 2013, 360,000 official connections have been installed. Official connections only include households that have at least paid the first instalment of the connection fee of 15,000 FRW (irrespective of whether they have ever bought electricity for consumption or not). In our study we follow this EWSA definition and count all households as connected that have paid at least 15,000 FRW no matter whether they consume electricity or not. In our sample, on average 60 percent of households living in the treatment communities got connected to the grid and use electricity. At the time of the follow-up survey, they have been connected to the grid for on average one year and five months. The minimum connection time is one month and the maximum two years and four month.

Generally households are satisfied with their electricity connection, in spite of some outages that 93 percent of all connected households have experienced during the last month. 28 percent of these households say such outages only occur rarely and are not able to specify how often they experience an outage per month. The average number of outages per month reported by the remaining households amounts to 3.8. Furthermore, many households complain about voltage fluctuations and in 62 percent of the households some appliances have broken due to voltage fluctuations. The most common broken devices are light bulbs, but also phone charger, radios and even TVs.

Table 12

Reason for non-connection

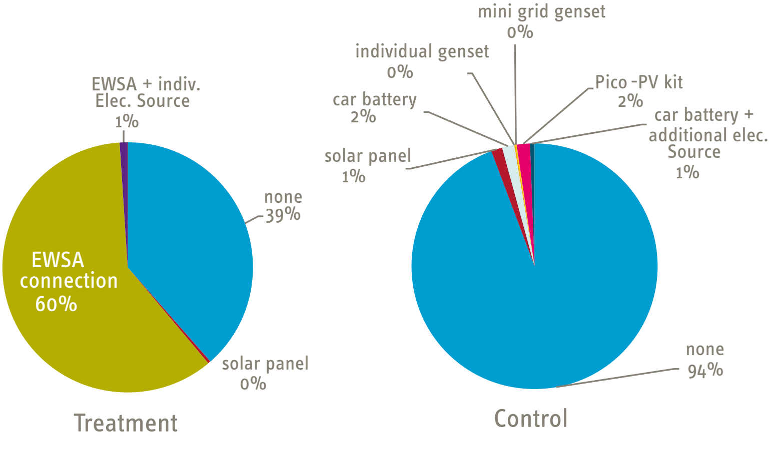
	Share of non-connected households
Not able to pay connection fee	0.78
Electricity consumption too expensive	0.38
Bad experiences with EWSA	0.00
Heard of bad experiences with EWSA	0.01

Source: EARP baseline dataset 2013.

Asking non-connected households in treatment communities for the reason why they do not connect, we see the following picture (see Table 12): the most important reason for non-connection is that households are not able to finance the connection fee. Only around 40 percent think they might not be able to pay for electricity consumption. Beyond these cost related reasons there is no sign that households might not want to connect to EWSA because they are not interested.

Figure 3

Electricity Sources (follow-up values)



Source: EARP follow-up dataset 2013.

In control communities, a small share of households (6 percent) also uses electricity. Most of them have car batteries, Pico-PV kits or solar panels (see Figure 3). The share is slightly higher in 2013 than in 2011 when 4 percent of households used an electricity source. Especially the share of Pico-PV kits has increased from 0 to 2 percent.

5.1.2 Traditional energy sources

Apart from electricity, the most commonly used energy source is firewood (see Table 13). Nearly 90 percent of all households use it. While the majority collects firewood, more than 20 percent of households buy firewood exclusively. Another 25 percent sometimes buys and sometimes collects firewood. Due to the high population density and resulting deforestation pressures, the collection of firewood in Rwanda is restricted (Ndayambaje 2005, 1). This is why the share of households that buy firewood is relatively high compared to other rural areas in low income countries. Among treatment communities, the share of households that buys firewood is substantially higher than among control communities at the follow-up stage. Estimating the DiD model at the community level, though, shows that this is not an effect of electrification. We do not find any significant changes, which means that already at the baseline stage the share of firewood buying households had been higher among treatment communities. When comparing connected and non-connected households within the treatment communities it turns out that a substantially higher share of connected households buys firewood. This is in line with expectations since wealthier households are both more inclined to purchase wood and to connect to the EWSA grid. The DiD for connected households again shows that buying firewood is not influenced by electrification.

Table 13

Percentage of households using energy sources (DiD and mean follow-up values)

Energy Source	DiD community	DiD household	Control	Treatment all	Treatment connected
Electricity	0.57***	0.94***	0.06	0.61	1
Firewood	0.04	0.01	0.86	0.89	0.88
- Only bought	-0.00	-0.03	0.20	0.26	0.33
- Only collected	0.004	-0.01	0.54	0.45	0.38
Batteries	-0.44***	-0.62***	0.83	0.40	0.24
Kerosene	-0.29***	-0.37***	0.35	0.19	0.08
Candles	0.13**	0.19**	0.32	0.52	0.63
Charcoal	0.03	0.09	0.12	0.22	0.31
Gas	-0.00	-0.00	0.002	0	-

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

Source: EARP dataset 2011/2013.

5.1.3 Non-productive appliances and lighting usage

All households that are connected to the EWSA grid use electricity for lighting. The most common electric lighting devices are energy savers (see Table 14)[18]. More than 85 percent of connected households use it. Normal electric bulbs and neon or fluorescent tubes are only used by few households. This does not come as a surprise since the Government of Rwanda promotes energy savers by offering energy savers at a reduced price to newly connected households. Electric lighting devices have mainly replaced wick and hurricane lamps. To a smaller extent also battery-run lamps and hand-crafted LED have been replaced. Ready-made torches are also substantially less used by connected households at the follow-up stage. We are not able to calculate the DiD, because we did not differentiate between battery driven and rechargeable torches in the baseline. Since torch usage in the baseline, though, is almost perfectly balanced between treatment and control communities it is probably right to assume that also ready-made torches have been replaced by electric lighting devices.

Electric lighting devices are generally used much longer outside than inside the household. The background of this is a requirement by the Rwandan government that asks people who have electricity to put at least one lighting device outside and switch it on the whole night. Traditional lighting sources are generally used more hours by control households.

18 *An illustration of all lamp types can be found in Annex 4.*

Table 14

Lighting Devices (in % of total households; DiD and mean follow-up values)

Lamps	% of HH using lamp					Hours lit per day (only HH using respective lamp)	
	DID community	DID household	Control	Treatment all	Treatment connected	Control	Treatment
Energy Savers	0.52***	0.84***	0.02	0.61	0.86	Outside 0 Inside 4	4.46 2.25
Electric Bulbs	0.06***	0.09***	0.00	0.05	0.08	Outside 1 Inside 3	3.17 1.6
Neon/ Fluorescent	0.04***	0.06***	0.00	0.05	0.07	Outside 2.7 Inside 3	7.14 2.95
Candles	0.07	0.07	0.29	0.44	0.52	2.32	2.14
Wick Lamps	-0.19***	-0.20***	0.30	0.17	0.06	2.47	2.11
Ready-made battery torch	n.a.	n.a.	0.34	0.11	0.06	2.49	2.35
Battery-Run Lamps	-0.07	-0.08	0.12	0.05	0.03	2.25	2.96
Hurricane Lamps	-0.16***	-0.22***	0.10	0.05	0.05	2.72	2.29
Hand-crafted LED	-0.08***	-0.09***	0.15	0.03	0.01	2.86	3
Recharge-able Torches	n.a.	n.a.	0.02	0.04	0.05	2	2.64
Recharge-able Lamps	-0.03*	-0.03	0.02	0.01	0.01	2.62	7
Solar Lamps	n.a.	n.a.	0.04	0.00	0.01	2.87	-
Gas Lamps	-0.00	0.00	0.00	0	-	2	
Mecha-nical Lamps	-0.03**	0.03**	0.03	0	-	2.8	

*Note: *, ** and *** indicate significance levels of 10%, 5% and 1%, respectively. n.a.= not applicable since baseline values have not been collected in a comparable way.*

Source: EARP dataset 2011/2013.

In total, the number of lighting devices is substantially higher in treatment communities than in control communities (see Table 15), especially among connected households. We furthermore observe a significantly higher amount of total lighting hours consumed per day summed up over all lamps among treatment communities. Through electrification, connected households consume on average 22 lighting hours more per day. If we only consider lighting inside, connected household consume on average 10 lighting hours more per day. Since most of the lamps used in treatment communities are electric lighting devices and light emitted by these lamps is substantially brighter, the amount of lumen consumed is also substantially and significantly higher among treatment communities. While traditional lighting sources like wick lamps or hurricane lamps only emit 11 and 32 lm respectively, an 18 W energy saver emits 1000 lm (O'Sullivan and Barnes 2006). Lumen levels emitted by hand-crafted LED lamps vary substantially depending on the number and quality of LEDs and batteries used. Based on a laboratory tests for two different LED hand-crafted lamps connected to two different battery packages we assume an average level of 10 lm emitted by hand-crafted LED lamps.[19]

Table 15

Lighting hours and lumen hours consumed per day (DiD and mean follow-up values)

	DiD community	DiD household	Control	Treatment all	Treatment connected
Number of lighting devices	2.38***	4.34***	1.9	4.7	6.4
Daily lighting hours per lamp	-0.70	0.67	3.88	3.35	4.1
Sum of lighting hours	10.68***	21.61***	8.1	19.4	28.2
Lumen hours	16,653***	28,314***	526	17,473	26,733

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

Source: EARP dataset 2011/2013.

19 No reliable lumen estimates existed for the hand-crafted LED lamps, since they have only recently emerged. We therefore sent two typical sample lamps from one of the survey communities to Hochschule Ulm in Germany, where the lumen emissions where tested using standard measurement instruments (integrating (Ulbricht) sphere).

5. Household and community level: Outcomes and Impacts

Apart from lighting, electricity is used above all for charging mobile phones, listen to the radio and watching TV (see Table 16). More than 70 percent of all households own at least one mobile phone. There is no significant difference between control and treatment communities. Mobile phones usage will be examined in more detail in Section 5.2.2.

A stark difference between treatment and control communities can be observed for radio ownership. Households in treatment communities have significantly less radios than households in control communities (57 percent vs. 71 percent). Interestingly, the share of radio owners among connected households in treatment communities is similarly low as among non-connected households. A possible reason for the decrease of radio usage among treatment communities is the increase of TV ownership. The share of TV owning households in communities with electricity access is significantly higher (20 percent vs. 2 percent). Details on radio and TV usage will be examined in Section 5.2.2.

Other widely used appliances are charcoal irons which are used by slightly more than 20 percent of the households both among treatment and control households. The share of households using these appliances has barely changed due to electrification. Only few connected households use electric irons (8 percent) – but they also continue to use the charcoal irons.

Table 16

Appliance usage (in % of total households; DiD and mean follow-up values)

Appliances	DiD community	DiD households	Control	Treatment all	Treatment connected
Mobile Phone	0.02	0.07*	0.71	0.75	0.89
Radio	-0.13***	-0.17***	0.73	0.57	0.58
(bivalent)	0.182***	0.292***	0.13	0.33	0.45
(battery only)	-0.321***	-0.485***	0.60	0.25	0.13
(line power)	0.146***	0.238***	0.01	0.15	0.25
Cassette Recorder	0.035**	0.058*	0.03	0.06	0.10
Charcoal Iron	0.000	0.000	0.21	0.23	0.30
Electric Iron	0.07***	0.11***	0	0.08	0.12
TV (colour)	0.140***	0.219***	0.01	0.18	0.29
TV (black and white)	0.022*	0.041**	0.01	0.02	0.03
DVDs	0.099***	0.164***	0.01	0.13	0.19
Computers	0.020*	0.033*	0.01	0.03	0.05
Mechanical Sewing Machine	0.007	0.025	0.02	0.03	0.05
Electric Sewing Machine	0.011*	0.017**	-	0.01	0.02
Video	0.015	0.018	0	0.02	0.04
CD-Player	0.025**	0.033**	0	0.02	0.03
Coffee Maker	0.019*	0.032*	0.00	0.02	0.03
Electric Refrigerator	0.002	0.003	0.01	0.01	0.01
Fuel Refrigerator	0.002	0.003	0.01	0.01	0.01
Electric Mills	0.003	0.005	0	0.01	0.01
Fuel Run Mills	-0.014	-0.022	0.02	0	-
Water Heater	0.002	0.003	0.01	0.02	0.01
Electric Stove	0.004	0.006	0	0.01	0.01
Landline Telephone	0.004	0.006	0.01	0.01	0.01

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

Source: EARP dataset 2011/2013.

5.1.4 Productive appliance usage

Although on a low level, access to electricity seems to unlock some low-key business activities among connected households. While in the control communities, only 5 percent of households use any appliance (electric or not) for productive purposes, the share is at more than 10 percent in treatment communities and even at 16 percent among connected treatment households. The DiD indicates that this increase is borderline significant with a p-value of 0.106. Most of the productively used appliances are electric appliances. Appliances for communication and entertainment prevail. Around half of the households that use an appliance productively employ mobile phones for some sort of business. For example, mobile phones are lent to make phone calls on a fee basis. Some other households use TVs and DVDs and operate small community cinemas in which they show films and, even more frequently, football matches. Only few devices are used for manufacturing purposes, mostly sewing machines and mills, whereof the majority are mechanical and not electric. Furthermore, two households have a grinding machine and one household a soldering equipment and an electric mortar that are driven by grid electricity.

Table 17

Productive appliance usage (DiD and mean follow-up values)

	DiD community	DiD household	Control	Treatment All	Treatment connected
Share of HH using appliances productively	0.051	0.08	0.05	0.11	0.16
Share of HH using electric appliances productively	0.044	0.07	0.04	0.11	0.16
Productive Usage of Mobile Phone	0.04	0.06	0.03	0.05	0.07
TV	0.010	0.011	0.00	0.04	0.05
DVD	0.014	0.017	0.00	0.02	0.03
Sewing machine (in parentheses electric sewing machines)	0.005 (0.01*)	0.012 (0.02**)	0.01 (0)	0.02 (0.01)	0.03 (0.02)
Mills (in parentheses electric mills)	0.003 (0.013*)	0.007 (0.021*)	0.01 (0)	0.01 (0.01)	0.01 (0.01)

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

Source: EARP dataset 2011/2013.

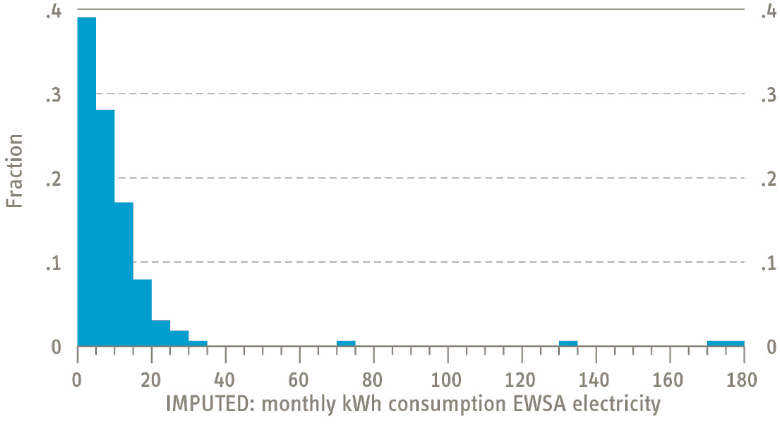
5.2 Impacts

5.2.1 Energy expenditures

The payment of electricity provided by EWSA works through a pre-paid metering system. Households can charge the system at EWSA selling points that are either the official EWSA branches or smaller shops that work for EWSA on a commission basis. It takes households on average 40 minutes to reach the place where they can buy electricity. Because of this pre-paid system, electricity consumption and expenditures have been more difficult to elicit than in other cases in which households receive invoices on a regular basis. Only in few cases households had receipts of how much electricity they bought and they often found it difficult to recall the amount of kWh bought or money spent. Only around half of the EWSA clients were able to provide accurate consumption data. This is why we infere consumption data based on appliance usage and lighting consumption habits.[20]

On average, the surveyed connected households consume 11 kWh per month which is equivalent to expenditures of 1,500 FRW. The median electricity consumption is only 6 kWh, 10 percent of the households do not even consume 1 kWh per month and three household have not consumed any electricity at all. The detailed distribution of electricity consumption can be observed in Figure 4. The average over all households in treatment communities is 900 FRW. The total energy expenditures including traditional energy sources are substantially higher, amounting to 5,600 FRW among treatment communities and 5,500 FRW among control communities. Since energy expenditure of treatment communities used to be substantially higher at the baseline level, the DiD shows a negative but not significant difference even though energy expenditures are almost the same in the follow-up.

Figure 4
Histogram of electricity consumption of EWSA clients



20 For electric lighting, we can calculate exact electricity consumption since we know the number of bulbs and usage hours for each household. For electric appliances we assume average usage times specified in Annex 5. For households who gave information on consumption and expenditure for EWSA we can assess the quality of our inferred values by comparing actual and inferred consumption values. The comparison shows that the two values deviate on average by 2 percent, which is fairly low. Hence, the inferred values appear to be quite accurate.

Looking at the different components of energy expenditures it can be seen that only energy sources potentially to be replaced by electricity have changed significantly. Most importantly kerosene, battery and mobile phone charging expenditures have decreased significantly. Looking at operational cost, electrification has no significant effect on the share spent on energy in total expenditures.

Apart from the monetary advantage for households that a reduction in dry-cell battery consumption brings, the decrease in dry-cell battery usage has further consequences: around 90 percent of the households throw used batteries into their pit latrines (unproteced 3-4 metre holes in the backyards of the compounds), the remaining households either throw them into their garbage (which is disposed of simply in the bush) or directly into nature. Environmental consequences have not yet been properly analysed, but it is clear that in non-electrified areas this problem will become even more dramatic in the coming years since dry-cell battery consumption is steadily increasing because of the increasing LED usage. While in 2011 household consumed on average 5.5 batteries per household and month, in 2013 households in control villages consume 9 batteries per month and household. This implies an annual increase of almost 30 percent. Among treatment villages the consumption of dry-cell batteries decreased from 5.5 in 2011 to 2.5 batteries per household in 2013.

Table 18

Energy expenditures (DiD and mean follow-up values)

Energy Expenditures	DiD community	DiD household	Control	Treatment all	Treatment connected
EWSA electricity	904***	1,512***	0	890	1,512
Firewood [E]	679	1036	1,882	2,611	2,998
Charcoal [E]	278	730	1,084	1,526	1928
Batteries	-1,045***	-1,457***	1,331	291	204
Kerosene	-1,068**	-1,163***	899	167	62
Mobile phone charging	-529***	-718***	583	93	25
Candles	-81	-148	307	267	296
Decentralized electricity sources	-371	-214	59	15	22
Gas	-0.38	-0.58	36	0	-
Monthly energy expenditures in FRW [E]	-812	-384	5,535	5,656	6957
Share of energy in total expenditures [E]	-0.002	0.017	0.10	0.11	0.14

*Note: Investment costs for electricity sources are not included in the energy expenditures. *, ** and *** indicate significance levels of 10%, 5% and 1%, respectively. [E] indicates that observations from one enumerator have been excluded, since – as became obvious during data cleaning - this enumerator had not understood properly how to elicit these variables.*

Source: EARP dataset 2011/2013.

5.2.2 Access to information

Access to electricity is often expected to facilitate the access to information. In order to test this hypothesis we look at the usage of radio, TV and mobile phones.

Mobile phones had already been used widely before electrification. At the baseline stage, 55 percent of households had at least one mobile phone. After electrification, the share is substantially higher both among treatment and control communities at around 72 percent. We do not observe any significant difference between treatment and control communities. Looking at connected households, the DiD indicates a significant increase in mobile phone usage.

As to be expected, the share of households who charge their mobile phone at home is substantially higher among treatment communities. Households in control communities who do not charge the mobile phone at home spent on average 23 minutes to reach the place where they can charge it. Obviously, both monetary and non-monetary costs of mobile phone usage decrease by electrification and, in consequence, especially connected households increase their usage intensity. At the community level, we do not see a significant difference.

Table 20 shows the purposes of mobile phone usage. All households use the mobile phone for calling people who live in the same community. The second most important purpose is to talk to people outside the province. Here, we observe that again virtually all households owning a mobile phone do this among treatment communities and still 95 percent among control communities. This difference is statistically significant. Unfortunately, we do not have baseline data to be able to estimate a DiD model. The third and fourth most common purposes are the usage of the mobile phone as a torch or as a radio. Still more than 50 percent of households use the mobile phone for money transfers. The share is significantly higher among treatment communities. If we look at connected households within treatment communities we see generally higher usage intensities for all usage purposes. While television hardly exists in control communities, 20 percent of households in the treatment communities own a TV (Table 21). The usage rates are even higher. 24 percent of head of households in treatment communities watch TV regularly, which means that some of them watch TV in bars, at neighbours or friends. Also spouses and small children exhibit high shares of TV usage. All differences are statistically significant. Unfortunately we are not able to calculate the DiD since TV watching has not been elicited on household member level during the baseline.

Table 19

Mobile Phone charging (DiD and mean follow-up values)

Mobile phone charging	DiD community	DiD household	Control	Treatment all	Treatment connected
HH has mobile phone	0.02	0.07*	0.71	0.75	0.86
Number of mobile phones	0.09	0.28***	1.2	1.4	1.8
Charge mobile phone at home	0.65***	0.87***	0.06	0.71	0.93
Average price paid per charge (in FRW)	-81***	-94***	87	15	4
Total monthly expenditure on charging (in FRW)	-529***	-718***	583	93	25
Times phone charged last week	0.24	0.15	2.2	2.1	2.1
Times phone used last week					
more than 6 times	-0.03	0.05	0.67	0.69	0.85
more than 21 times	0.10	0.15*	0.30	0.37	0.49

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

Source: EARP dataset 2011/2013.

Table 20

Mobile Phone usage

Mobile phone usage (follow-up values)	Control	Treatment all	Treatment connected
Talking to people outside the community	1.00	1.00	0.99
Talking to people outside the province	0.95	0.99**	0.99
Information on agricultural products	0.26	0.29	0.29
Money transfer	0.51	0.67***	0.72
Listen to radio	0.75	0.72	0.76
Lighting	0.91	0.94	0.96

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

Source: EARP dataset 2013.

Table 21

TV usage

TV usage (follow-up values)	Control	Treatment	
		all	connected
HH has TV at home	0.02	0.20***	0.30
[*HH member*] watches regularly TV			
Head of HH	0.08	0.24***	0.34
Spouse	0.01	0.19***	0.29
Children 6-11 years	0.01	0.22***	0.30
Children male 12-17 years	0.01	0.11***	0.16
Children female 12-17 years	0	0.13***	0.21

*Note: The asterisks refer to the significance level detected by t- and chi-squared tests on differences in means between the treatment and control group as a whole *, ** and *** indicate significance levels of 10%, 5% and 1%, respectively.*

Source: EARP dataset 2013.

While it is often claimed that people watch TV for entertainment reasons only, our data shows that news are very popular at least among head of households and their spouses (Table 22). We asked all household members that watch TV regularly about their preferred program. The question was posed in an open way and did not propose any answers.

Table 22

Preferred program (only TV owners)

Preferred program (follow-up values)	HoH	Spouse	Children 6-11	Male 12-17	Female 12-17
News	0.87	0.86	0.27	0.30	0.42
Sport	0.48	0.23	0.45	0.80	0.36
Soap Operas	0.45	0.53	0.22	0.17	0.49
Music	0.10	0.15	0.13	0.13	0.20
African movies	0.09	0.13	0.24	0.46	0.54
Other movies	0.17	0.24	0.42	0.51	0.68

Source: EARP dataset 2013.

The time head of households and their spouses watch TV is substantially higher among treatment communities than in control communities and especially high among connected households in treatment communities. The DiD estimation confirms that through electrification the time household members watch TV increased significantly.

Table 23

Time HH members watch TV (DiD and mean follow-up values)

Time watching TV	DiD community	DiD household	Control	Treatment all	Treatment connected
Time head of household watches TV per day	0h11***	0h20***	0h03	0h15	0h23
Time spouse watches TV per day	0h16***	0h27***	0h01	0h17	0h28

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

Source: EARP dataset 2011/2013.

The question for the respondent's main source of information shows that even though the role of TV as a source of information increased, radio still dominates the information service.

Table 24

Main source of information (multiple answers possible; DiD and mean follow-up values)

Main Source of information	DiD community	DiD household	Control	Treatment all	Treatment connected
Radio	-0.01	-0.03	0.64	0.57	0.59
TV	0.10***	0.16***	0.01	0.09	0.17
Neighbours and friends	-0.02	0.00	0.15	0.15	0.12
Community Gatherings	0.06	0.03	0.35	0.32	0.29

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

Source: EARP dataset 2011/2013.

5.2.3 Time Use

The availability of electricity in the communities clearly has a significant effect on the daily routine of all household members. The time people are awake is significantly higher in treatment communities and especially pronounced for connected households. While the magnitude of the effects varies between household members, all groups in treatment communities go to bed later than people in control communities and are thereby awake on average between 15 and 40 minutes longer (Table 25).

The type of income generating activity household members pursue is not influenced by electrification. The majority of household heads and their spouses are subsistence farmers both before and after electrification (see Table 26). Around 5 percent are public employees. Among head of households around 10 percent engage in independent activities, 10 percent in other dependent activities. These shares are substantially lower for spouses.

The significant increase in the share of spouses who engage in no income generating activities is driven by an unclear demarcation between subsistence farming vs. household duties. Many female household members are engaging in both and depending on the agricultural season the time shares of each activity may differ substantially.

Table 25

Daily routine of household members (DiD and mean follow-up values)

Daily routine	DiD community (in hours)	DiD household (in hours)	Control (day time or hours)	Treatment (day time or hours)	
				all	connected
Time head of household...					
...gets up	-0h03	-0h03	5h39	5h50	5h47
...goes to bed	0h14**	0h29***	20h29	20h50	21h11
...is awake	0h16**	0h31***	14h50	14h58	14h16
Time spouse...					
...gets up	-0h04	-0h06	5h40	5h49	5h47
...goes to bed	0h19**	0h38***	20h30	20h50	21h11
...is awake	0h21**	0h42***	14h50	15h55	15h23
Time male children 6-11...					
...gets up	-0h00	-0h05	6h04	6h05	6h04
...goes to bed	0h24***	0h36***	20h04	20h25	20h34

...are awake	0h24**	0h41***	14h01	14h19	14h28
Time female children 6-11...					
...gets up	-0h03	-0h02	6h00	5h59	6h05
...goes to bed	0h28***	0h36***	20h03	20h26	20h38
...are awake	0h31***	0h37***	13h59	14h19	14h30
Time male children 12-17...					
...gets up	0h01	0h04	5h56	5h57	5h58
...goes to bed	0h26**	0h42***	20h24	20h52	21h08
...are awake	0h26**	0h37**	14h23	14h52	15h07
Time female children 12-17...					
...gets up	-0h07	-0h10*	5h12	5h19	5h54
...goes to bed	0h22***	0h29***	20h25	20h44	20h57
...are awake	0h29***	0h42***	14h27	14h46	15h02

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

Source: EARP dataset 2011/2013.

Table 26

Income generating activity of household members, in percent (DiD and mean follow-up values)

Income generating activity	DiD community	DiD household	Control	Treatment all	Treatment connected
Head of household is					
Subsistence farmer	-0.05	-0.03	0.70	0.69	0.67
Public employee	0.01	0.02	0.05	0.06	0.08
	0.02	0.03	0.12	0.11	0.14
Other dependent activity	0.01	-0.01	0.07	0.07	0.07
No income generating activity	0.01	0.01	0.06	0.06	0.04
Spouse is					
Subsistence farmer	-0.05	-0.07*	85	84	0.83

Public employee	0.01	0.01	0.05	0.05	0.07
	0.01	0.002	0.03	0.04	0.05
Other dependent activity	0.000	-0.02	0.03	0.05	0.02
No income generating activity	0.051**	0.078**	0.03	0.04	0.04

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

Source: EARP dataset 2011/2013.

Looking at the time that the head of households and the spouses dedicate to productive activities we see no substantial changes. Productive activities comprise agricultural activities, income generation at home and income generation outside. At the follow-up we asked households to specifically distinguish between the three subcategories of productive activities. Comparing community averages we only see significant differences for the time spouses dedicate on income generation at home. In treatment communities spouses dedicate on average around 15 minutes more to income generating activities at home. Since we do not have baseline data for this indicator, we cannot assess whether this difference had already existed before electrification. Comparing the time use of connected and non-connected households in treatment communities we see that both for head of households and spouses the time spent on income generation at home is substantially lower for non-connected households. Furthermore, spouses in non-connected households dedicate more time on agricultural activities than their counterparts in connected households.

Table 27

Working Hours (DiD and mean follow-up values)

Time Use	DiD community	DiD household	Control	Treatment all	Treatment connected
Hours head of household spends per day on					
All productive activities	-0.06	-0.01	6.32	6.40	6.48
Agricultural activities	-		4.10	4.10	3.58
Income generation at home	-		1.11	1.24	1.50
Income generation outside	-		1.11	1.05	1.00
Hours spouse spends per day on					
All productive activities	-0.01	-0.08	6.17	6.06	6.11
Agricultural activities	-		4.57	4.44	4.28
Income generation at home	-		0.26	0.43	1.02
Income generation outside	-		0.55	0.40	0.41

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

Source: EARP dataset 2011/2013.

Significant effects can furthermore be detected for school enrolment and study time of children. The DiD for connected households shows that households with electricity are more inclined to send all their children between 6 and 11 years to school. At the follow-up, 75 percent of households send all their children to school while in control households only 61 percent of household send all their children to school. In the remaining households only some children go to school, but no household exists that does not send any of the children to school. The DiD indicates a difference of 0.17 accounting for baseline values and further HH characteristics.

Furthermore, we find significant effects on study time. Depending on their age, children study between 20 and 38 minutes longer after nightfall due to electrification. The total time children study does not increase, though. Apparently, children in households with electricity shift their study time from daytime to night-time. Effects are similar for male and female children.

Table 28

School enrolment and study time (DiD and mean follow-up values)

School enrolment	DiD community	DiD household	Control	Treatment	
				all	connected
Children between 6-11 years					
All children go to school	0.06	0.17**	0.61	0.65	0.75
Study hours total	0.06	0.29	0.16	0.32	1.16
Study hours after nightfall	0.13**	0.20**	0.19	0.35	0.40
Children between 12-17 years					
All children go to school	0.02	0.14	0.62	0.70	0.83
Study hours total	-0.06	0.14	0.31	0.31	1.20
Study hours after nightfall	0.26***	0.38***	0.33	0.60	1.11

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

Source: EARP dataset 2011/2013.

5.2.4 Gender

Table 29

Gender aspects (DiD and mean follow-up values)

Gender aspects	DiD community	DiD household	Control	Treatment all	Treatment connected
Husband would accept if wife executed an independent work outside home	0.04	-0.04	0.83	0.80	0.80
Husband would accept if wife executed dependent work outside home	-0.02	-0.02	0.80	0.75	0.74
Woman thinks it is justified that husband beats a woman if...					
...she neglects her children	-0.13*	-0.10	0.40	0.32	0.30
... she leaves home without telling him	-0.12**	-0.06	0.31	0.20	0.17
...she argues with the husband	-0.10**	-0.07	0.22	0.11	0.11
...the food is burnt	-0.05	-0.01	0.15	0.09	0.08
Age when a woman should marry (in years)	-0.30	-0.46	22	22	22
Age when a woman should have first baby (in years)	-0.10	-0.34	23	23	23

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

Source: EARP dataset 2011/2013.

The following section relies on information elicited through the women questionnaire. While we do not find any changes in the woman's assessment of what her husband would allow her to do, we find significant effects on the acceptability of violence against women. We asked the women whether she thinks it is justified that a husband beats a woman in certain circumstances. The most accepted reason for being beaten is neglecting the children. 40 percent of interviewed women in control communities agree on this. Among treatment communities only 32 percent agree and the DiD at the community level indicates a significant difference of 0.14. For connected households, the difference is not significant and smaller than for the community comparison. For these households the share of women accepting violence had already been comparably low before electrification. Accordingly, it is especially non-electrified households in communities with EWSA electricity that have changed their opinion. This seems plausible since also non-connected households in treatment villages have substantially better access to information than before (see Section 5.2.2 on access to information). We see a similar picture when asking women about other situations when a husband might beat a woman.

We do not find any significant effect on women's opinion on the age a woman should marry or have her first baby.

6. Electricity in micro-enterprises, health infrastructure and schools

6.1 Micro-enterprises

For analysing the effects of electrification on micro-enterprises, we asked community chiefs about the number and type of businesses both in connected and non-connected communities. Furthermore, we conducted semi-structured interviews with around 100 micro-enterprises during the follow-up. This section summarizes general findings from these interviews. An extended version of findings from semi-structured interviews with small enterprise portraits is provided in Annex 8.

Positive impacts of electrification on the business environment are expected to be either the emergence of new businesses or the improvement of existing ones. For an already existing business, impacts are expected to be money and/or time savings through better equipment, better quality or new products, higher productivity, longer operation hours and an increase in security leading possibly to higher owner income. The impacts on the community level could be employment creation, the availability of higher quality products or new products and price effects. Here it is of utmost importance to enquire at which markets products are sold and if other locally produced goods are crowded out in order to assess net benefits. Most positive net income effects on the community level can only materialise if products that used to be produced outside the community are now produced locally or if enterprises manage to serve markets outside the community.

The business environment differs in quantity and type of businesses in the surveyed communities. While some of the sites have a vivid centre, others have no or very little entrepreneurship. The most common enterprise type is a small shop, selling among others rice, flour, batteries, biscuits and soap. A similar business type is a bar, selling sodas, local or bottled beer and small snacks. Other very common businesses are tailor shops, mills, hairdressers and carpentries. Technicians, mechanics or bakers often work independently and wait for customers to ask for their services. In the more developed communities photocopy shops, welder shops, small cinemas and pharmacies can furthermore be found. In an exceptional case, a coffee washing station and a coffee producer performing all activities of the value chain are located in one of the surveyed communities. Furthermore producers of pineapple and banana vine and a big mining company are present in the visited communities.

While some businesses like mills, welder shops and carpentries are uniquely driven by or employ men, small shops, bars, tailor shops or the bigger exceptional companies are partly driven by or employ women. Table 30 displays the most frequent enterprises in control and treatment communities and whether enterprises in treatment communities are connected to the EWSA grid.

Table 30

Most frequent enterprises in sampled communities

	Control communities (N=29)	Treatment communities (N=15)	
	Share with [*enterprise*]	Share with [*enterprise*]	Share of [*enterprise*] connected to EWSA
...small shops	0.90	1.00	0.45
...bar	0.79	1.00	0.57
...hairdressers	0.65	0.87	0.96
...tailors	0.83	0.71	0.13
...carpenters	0.55	0.73	0.17
...mills	0.54	0.64	0.78
...welding shop	0	0.47	1.00
...restaurants	0.48	0.46	0.64
...copy shops	0	0.26	1.00

Source: EARP community data 2011/2013.

We generally observe a slight increase of business activities in connected communities. Some enterprises emerge and existing enterprises partly extend their operation hours, products and services. While in many cases electrification of enterprises only increases convenience and causes a redistribution of income within the community or region, some enterprises also increase net community income by serving demand from outside the community or offering products and services locally that formerly had been imported from urban areas. Impacts are disproportional for well-connected communities that already had a vivid business centre before electrification. The crucial factor for the development of all business activities is local demand and market access that is normally not affected by electrification. Enterprises that have the highest connection rates and are most positively affected by electrification are mills, hairdresser, copy shops, and welding shops.

Mills exist in around half of the communities and they normally want to connect to the grid immediately when electricity arrives in the community. In some communities mills cannot be connected to the grid because EWSA does not offer three phase connections that are necessary for operating a mill. If possible, all mills connect to the grid. In comparison to fuel-run mills, electric mills offer their services to substantially lower prices, offer finer grinded flour and increase the variety of offered milling services. Corn milling, for example, is only offered by electric mills since it is especially energy intensive. These productivity gains leading to better and cheaper milling services increase demand: first, more customers from the community but also neighbouring communities that used to mill their crops with fuel-run mills now come to electric mills. Furthermore, formerly unmet demand is now served: people that used to mill their crops by hand now start to use a mill and existing customers demand higher quantities than before. We observe higher owner income and/or creation of mills in connected communities. This is mainly due to a shift of demand from non-electrified mills and communities to electrified mills. However, we also see an absolute increase in demand since formerly unmet demand is served. Moreover, people who formerly had to bear either long distances (carrying a sack of flour) or long waiting periods can find a miller close to their houses.

We furthermore observe the emergence of copy and welding shops in the liveliest communities that do not exist in any non-connected community. All of them use EWSA electricity. These shops offer services and products that had not existed before in the communities and people had to travel to urban areas to get them. Even though demand is especially low for copy shops and also for welding shops, these shops generate income within the communities that formerly had been generated in urban areas. Especially for welders we see that people who had left the communities to work in urban areas in some cases came back to the rural areas to open welding shops there.

6. Electricity in micro-enterprises, health infrastructure and schools

Hairdressing saloons are very frequently visited places both in connected and non-connected communities and are often the first place in non-connected communities having a decentralized electricity source. This is why they frequently also offer phone charging services. Since also all hairdressers in non-connected communities have electricity mainly through car batteries, the arrival of EWSA electricity has mainly cost implications. Hairdressers save money and time to charge the car battery. The cost reduction and longer availability of electricity normally lead to higher owner income and an increase in services like phone charging, radio and TV entertainment and longer opening hours. In some communities also the number of hairdressers increased with electrification.

For small shops, bars and restaurants, impacts on their business operation are rather small and on a softer level. They mostly use electricity for lighting only; in a few cases also for radio, TV or refrigerator operation. Electricity mainly increases convenience and thereby often attracts more customers. This increases the turnover and often the income of the owner. However, since normally only the resident population is served, this business activity does not increase the net community income. Demand is shifted from non-electrified establishments to electrified ones or customers who formerly did not spend anything on restauration now spend less on other products and services. If these expenditures used to be spent locally, electrification only causes a redistribution of income. Only in communities that are located at connecting roads with people passing by from outside the region, especially bars have the potential to increase community income mostly by offering cold drinks to travellers and traders.

Carpenters and tailor shops connect to electricity only in few cases. The reason is twofold: first, demand is low and an increase of production wouldn't necessarily lead to higher sales. Second, electricity does not really affect the operational processes of their business. For example tailors often prefer to keep their mechanic sewing machine even though with an electric machine they could produce faster. However, they could not increase the amount of clothes and services sold since demand is too low. The only additional feature of an electric sewing machine is the possibility of sewing embroidery. However, customers in the surveyed communities in rural Rwanda apparently are not willing or able to pay more for this.

6.2 Health Infrastructure

One of EARP's major purposes has been to connect rural health stations. Electricity in health stations, in turn, is frequently considered a prerequisite for an improved health care provision. In order to assess the extent to which EARP has achieved its goal of pushing the connection rate of rural health centres we conducted a full census of all 442 health centres in the country via telephone. The subsequent question that arises is whether access to grid electricity in fact improves health care provision compared to the counterfactual of not having grid electricity. As an indicator for this we use take-up of basic health care appliances and electricity usage of such appliances in the telephone full census. Only if grid connection also leads to appliance usage an improved health care provision can be expected. Most appliances, though, can also be used without grid electricity, for example kerosene or LPG-fridges.

Table 31

Electricity connection and appliances usage in health centres

Share of HC with ...	
EWSA connection in 2013	0.68
EWSA connection in 2009	0.40
Share of EWSA connected HC in 2013 with...	
Examination lighting	0.99
Refrigerator	0.99
Microscope	0.99
Centrifuge	0.93
Sterilizer	0.89

Source: Health centre telephone survey 2013.

Table 31 shows the share of health centres connected to the grid in August 2013 and the share of health centres connected to the grid in 2009 (i.e. before EARP started). In fact, the share is substantially higher now than it used to be, although it is far from being at 100 percent. It is furthermore striking to see that appliance usage rates in grid connected health centres are close to 100 percent for at least some basic appliances like lighting, refrigerator, microscopes, centrifuges or sterilizer. For other machines like office equipment such as computers or printer usage rates are lower, but still considerably higher than among non-connected health centres.

In-depth interviews have been held with 26 Health Centres (HCs) in the northern, southern and eastern provinces during the follow-up. Half of them are located in the surveyed communities and the other half are HCs that are close to the surveyed communities and frequented by the surveyed households. The respondents were mainly the HC's directors or accountants and in a few cases nurses. All surveyed HCs have an electricity source. 14 HC are connected to the grid, of which 8 have been connected by EARP (i.e. 2009 or later) and the remaining 6 already before EARP started. Two connected HCs own an additional solar panel and three still have a functioning generator. 12 HCs do not have a connection to the electric grid. These facilities either possess a solar panel or an individual generator or both. In the treatment communities, all HCs immediately got connected as soon as the grid became available.

The surveyed HCs were founded between 1930 and 2013 and 64 percent are public facilities while the remaining 7 HCs are government-assisted and thus financed by the government but founded by (either the catholic or the protestant) church. They are all open 24 hours and 7 days a week.

The HCs provide a catchment population of 25,600 on average, but the variation is high ranging from 14,400 to 41,950 people. On average, 2,404 patients per month visit each HC to get treated. The catchment population lives in the surrounding hills and mainly approaches the HCs by foot or in a few cases by motorcycle-taxi or bike-taxi. They cope with a distance of at maximum 30 km or, where interviewees could not estimate the distance in kilometres, a maximum distance of "3 hours walk".

Health Centres do not have any doctors, patients are treated by nurses. Management tasks in the location are fulfilled by the director and the biggest share of the workforce are nurses. Furthermore, there are on average two laboratory assistants and up to 14 other employees such as social assistants, cleaners, cooks, guards, and nutritionists.

The three most frequent diseases in the surveyed communities treated in HCs are respiratory infections, malaria and parasitic worms. All three diseases vary strongly between regions with different climates and between seasons. An important service of HCs is delivery assistance. The 26 surveyed HCs have on average 46 deliveries in their facilities per month out of which 63 percent are at night.

In the following we will assess advantages and disadvantages of each electricity source given the needs of a HC by looking at running and reparation costs, power intensity, reliability, and comfort.

The most important effect of getting a grid connection is related to costs. The connected HCs unanimously paid 56,000 RWF for the connection, which they mostly paid from their own budget. Two HCs got a donation. On average the HCs pay 62,540 RWF per month for electricity consumption. 25 percent furthermore had moderate (3,000 to 16,200 RWF) maintenance costs for damaged cables or bulbs in the last year. For comparison, the HCs using a generator, a solar panel or both face on average diesel costs of 205,000 RWF, i.e. three times more than what grid connected HCs pay.

In terms of reliability, 50 percent of grid electricity users report no or rare outages. The other 50 percent suffer from two to four outages per week, which vary strongly between the different HCs. The cuts increase in the rainy seasons, especially during thunderstorms. Those who still have a generator or a solar panel use these (only) as backup against outages; others resort to candles, hurricane lanterns or torches.

Voltage fluctuations have damaged fridges or sterilizers among one fifth of the interviewed HCs. The rest have not experienced any voltage fluctuation problem. Some respondents state that a voltage regulator helps them to avoid such difficulties. In contrast, there are many complains about broken solar panels and generators: 20 percent of all interviewed HCs have a broken generator and 27 percent have a solar panel that is not working anymore.

HCs that are not connected to the grid and that use solar panels instead complain about the low power supply that is, for example, even not sufficient to operate a printer. They can use the panel only for lighting purposes, to charge phones, to connect laptops or minor machines. Generators are often used in addition to the solar panel. Because of high costs, they are only started for a short time in the evening to operate a sterilizer or a printer. 25 percent of the non-connected HCs have these devices – a sterilizer, a printer or computers – in their facilities, but do not use them either due the high costs of diesel consumption or because they do not work with their solar panels. Interviewees furthermore outline a significant increase in comfort and work improvements when switching from solar panels and generators to grid electricity, as electric appliances can be used continuously all day long and independently of their power requirements.

The interviewees were furthermore openly asked to name the three main purposes, they use electricity for. All HCs name lighting as one purpose, followed by the usage of medical machines (79 percent) and 28 percent explicitly name medicine storage and sterilizing. The next important main purpose is the use for administrative purposes (43 percent). It is furthermore often mentioned that electricity facilitates the attraction of (trained) staff from urban areas to the community, not only as it improves working conditions, but also because electricity in their home places increases their quality of life in the community. Problems to recruit qualified staff due to lack of electricity access is named as a major problem by all surveyed non-connected HCs in the control communities.

All recently connected HCs say that their work has improved since electrification. Some of the directors and accountants specify that their work has become easier and more comfortable, since lighting enables conducting treatments independent of day light and to continuously use appliances. Before electrification, they could only use the sterilizer for instance once in the evening, while today they can use it whenever needed. They also describe the atmosphere as improved, because patients are much more satisfied and they "behave well" as they can sit in the light and watch TV in the waiting hall. Furthermore, they say their service is better, because they get the results of examinations quicker, they can serve patients at night and they can monitor the patient's health with computers. Further new activities that have evolved only after connection are electric sterilization, the writing of reports, doing biochemical analysis and hematology tests. In addition, nurses stress the difficulties of giving birth assistance in the weak light of a candle. In some cases, phone charging, water filtering and baby respirators are named as new activities since the connection to the electric grid.

6.3 Schools

In our survey, 38 schools were interviewed about the schools' characteristics and challenges, their energy sources and usage. 66 percent of interviewed schools are located on the survey sites and the remaining 34 percent are the closest available schools in neighbouring communities. Half of them are located in treatment communities, the other half in control communities. Respondents were, with very few exceptions, school directors, with around four fifths being male. 39 percent of these schools are connected to the grid, 5 percent have a generator, and 3 percent each have a solar panel or a generator and a solar panel.

The Rwandan school system is divided into 6 years of primary school, 3 years junior secondary school (tronc commun) and 3 years senior secondary school (S3-S6). Afterwards, technical schools or one of the 8 public or 17 private Rwandan universities can be visited. In this survey, most of the schools are primary schools (63 percent), 32 percent are integrated primary and secondary schools (groupe scolaire) offering either 9 or 12 years of education, and few (5 percent) are pure secondary schools. Most surveyed schools are public (60 percent), 5 percent are private and the remaining facilities are managed by (mainly catholic) churches.

In the connected schools, a higher availability of appliances and more diverse devices can be observed in comparison with the non-connected schools. Connected schools use computers, printers and televisions. Furthermore, there is some evidence for a broadening of the curriculum, as a few schools have purchased microscopes, a fridge or a DVD player. Computers are rated as very important by all directors. Today, 100 percent of the connected surveyed schools possess a computer, 64 percent of them did not have one before electrification. Those who did have a computer already before electrification, used it either with a generator, a solar panel or charged it outside the school.

Table 32

Appliance usage in schools

Appliance	Share of connected schools with [*appliances*]	Share of [*appliances*] purchased since electrification	Energy source used before electrification
Microscope	0.27	0.25	manually
Computer	1.00	0.64	solar panel, generator, charged elsewhere
Radio	0.40	0.40	solar panel, batteries
Radio Cassette	0.47	0.57	solar panel, batteries
TV	0.47	0.71	generator, solar panel
Printer	0.60	0.60	generator, solar panel

Sonne: EARP enterprise survey 2013.

Schools that used to operate a generator before EWSA electrification highlight the cost savings they experience due to electrification. One respondent gave a clear example: “Before we used 40 litres of diesel for our generator and paid about 42,000 RWF monthly; for EWSA electricity we paid 56,000 RWF once and 15,000 RWF monthly; and we use the machines much more”. For schools that used to have a solar panel, most schools report problems due to the limited capacity of the solar panel and high maintenance costs.

Being asked for the three main purposes of electricity the directors unanimously report to have improved their work since electrification. Particularly often they mention the possibility of lighting (73 percent) and the usage of computers and other electric devices for administrational purposes (73 percent) as opportunities for the school. One director explains: “I am now able to write my reports much quicker; also I can print in the office, while before I had to travel for one hour to the closest copy shop and spent a lot of money for the transport”. 33 percent furthermore mention informatics classes, which “open students’ minds and shows them modern communication” as one out of three main purposes of electricity use. With the same frequency, the directors of schools mention that the preparation of exams and classes and homework revision has become easier and has improved thanks to electric lighting, computer usage and printers. Some directors name a greater security since the guards use lighting at night. Some underline the usage of electronic teaching materials and some are relieved to be able to charge phones and radios at the schools (each 20 percent).

The directors’ perceptions of work improvements are reflected similarly in the evolution of new school activities: 40 percent offer computer classes for students and 13 percent for teachers since electrification. Furthermore, we encounter one unexpected new activity: 13 percent of connected schools offer free hair cutting at school for their students. While none of the unconnected schools (independently of whether they have a generator or a solar panel) offer classes after 6.00 pm, 33 percent of the connected surveyed schools give revision classes and computer classes at dusk or after sunset.

7. Sustainability of the Intervention

In spite of its huge magnitude, EARP activities are by and large business-as-usual for EWSA on both headquarters and local branches level. Unlike decentralized electrification approaches like solar home dissemination or mini-grids that in most cases rely on demanding operation models with billing and maintenance as typical breaking points, EARP builds on an established approach. The sheer dimension of the programme, though, might induce problems in two areas: generation capacities and staff requirements to conduct maintenance.

In terms of generation capacities, various projects are ongoing, planned or have recently been terminated. According to the country's energy sector strategic plan 2012/2017, the country had around 110.44 MW of installed capacity in 2012 and it is foreseen to increase electricity generation to 563 MW in 2017 (GoR 2012). If all the current pipeline projects are implemented, the installed capacity would be around

610 MW by 2017/18, which is slightly higher than required (563 MW). The details of the generation roadmap to achieve 610 MW of installed capacity can be found in MININFRA (2011).

While most other African countries suffer from severe supply shortages that would preclude a comparable endeavour like EARP in most cases, Rwanda does not seem to have such severe problems on the supply side. Installed generation capacities have increased by 24 percent between 2009 and 2012 from 84.4 MW to 110.44 MW. Further projects are in the pipeline and even though commissioning targets for 2013 have not been achieved on time, several projects are under construction and capacity will increase in the coming years. In addition, interconnections with neighbouring countries are currently enforced, which contributes further to a stable supply. Nonetheless, some problems in the energy sector exist, not least the heavy subsidies that are required for the diesel generators, which are currently used to meet the increasing demand. While this imposes an obvious burden on the governmental budget, it does not endanger EARP's sustainability as long as the political support of the sector prevails.

In order to assess the capacity of EWSA staff to conduct maintenance measures we first talked to the branch representatives and technical staff and second examined the effective maintenance policy on the ground. While all branch managers and technical staff said that the strong increase in connections also induced a substantial increase in maintenance requirements, all stated that their resources have been increased as well. According to their statements, it does not take longer than a few days until the technical staff on the ground passes by a connected community so that emerging problems can be solved. This could in fact be confirmed by looking into our household and community data: 23 percent of connected households report technical problems with the connection. Most of them had problems with short-circuits that burned cables or even the electricity meter. The second most reported problems are technical issues with the meters. In 58 percent of the cases, EWSA came to the households to resolve the problem. In the remaining cases mostly private technicians resolved the problem. In order to find out whether households generally know who to contact in case of technical or payment problems, we asked those households that had not yet experienced problems directly about their knowledge. Around half of them indicate that they know who to contact in case of technical problems (47 percent). 90 percent indicate they would inform EWSA and ten percent would call a private technician. As for problems with the payment, more than half of all households indicate that they know who to contact (57 percent). Again the majority sees EWSA as their primary contact point and one third indicate that they would try to solve the problem with the person who is running the shop that sells the pre-paid credit.

8. Register of Research Questions

8.1 Input and policy relevance

What attempts have been made to target and include women at all stages in the programme/project cycle?

• EARP is a top-down project with no particular gender policy in its implementation. At the beneficiary level, households, schools and in particular health stations are targeted. Obviously, women benefit from the intervention, but there is no particular policy to target women.

What are the financing mechanisms for the programme/project and does this include measures to ensure equity in access to energy (e.g. access to credit for women)?

• The Government of Rwanda finances large parts of the programme (also based on donor contributions). Households pay around one tenth of the real initial connection costs (see Section 2.3 'Description of the EARP intervention'). All households that live close to the extended grid have access and can get a connection. No particular equity rules are applied.

8.2 Output and results

How has the grid roll-out evolved over the period taken into consideration? How many villages and households have been connected that prior to the intervention were not connected to the grid?

• During its first phase from 2009 to 2013, EARP has outperformed its target and by May 2013, the total number of electricity connections amounted to 360,000 - 10,000 connections more than expected. As for social infrastructure, the goals of connecting all health stations, all administrative offices and 50 percent of schools by 2012, though, have not been met. By May 2013, only 36 percent of schools, 56 percent of health facilities and 58 percent of administrative offices had been connected. Furthermore, transmission and distribution lines were constructed or rehabilitated, which results in an increase from 180,000 km in April 2009 to 350,000 km in May 2013, thereby achieving the corresponding project targets. For more details see Section 2.3.

• Additionally to the 360,000 household connections, we found during the field work that in some communities many households are physically connected without having paid the first instalment of the connection fee. Consequently, these households cannot consume electricity in spite of their connection. We probed deeper into this and in fact, apart from the official connection policy, in some communities EWSA also connected households that had not paid the initial instalment of 15.000 FRW (and in some cases they have even not applied for a connection). The underlying expectation of EWSA is that households will afterwards bring up the connection costs and start using electricity.

• Furthermore, we interviewed branch managers. Five out of twelve report that households have been connected without paying anything. The subsequent experiences have been very different. While in some branches only a small fraction of these households afterwards paid the connection fee and started to consume electricity (like branch Rwamagana or Ngororero), in other branches like Huye and Ruhango around 50 percent paid afterwards, in Ngororero even 90 percent.

What have been the total (development and recurrent) costs and the costs per main output and beneficiary? To what extent are costs covered by contributions of the users/consumers?

• See Section 2.3 'Description of the EARP intervention'. According to planning documents, it was planned at the outset that one tenth of the overall investment costs should be covered by the beneficiaries via connection fees. In fact, households pay around 80 EUR as a connection fee. A simple cost-per connection ratio shows that each connection cost around 1,100 EUR. Accordingly the beneficiary pays around 7 percent.

How cost-effective is the intervention, taking into consideration the financial inputs in terms of equipment, personnel and technical assistance as compared to the access to energy provided expressed by the number of households or beneficiaries ("value-for-money")? What benchmark can be used?

• EARP is implemented by the Government of Rwanda, i.e. no international implementing agency or NGO is involved. The cost effectiveness of processes within the Rwandan ministry or the energy agency EWSA cannot be assessed. A simple cost-per-connection ratio shows that around 1,100 EUR (1,500 USD) were required. The costs do not include investments required for additional generation capacities, though. This seems to be in line with cost-per-beneficiary ratios in other large on-grid electrification programmes (note that EARP does not pursue a picking-the-low-hanging-fruit policy). Individual electricity solutions like solar home systems or Pico-PV systems are obviously cheaper, but not comparable in quality.

• While it can be stated that for a wide strata in the target population solar solutions would probably allow for the same service level that effectively is consumed at a significantly lower price, consumer satisfaction is extremely high. Also, sustainability can be expected to be higher in an on-grid programme, since no innovative business model or sophisticated maintenance is needed. In a nutshell, a value-for-money comparison is difficult, but the EARP cost-per-beneficiary is in line with experiences in other countries.

Have specific measures been undertaken to enhance efficiency? If so, how and what have been the results?

• Compared to the before situation – people are using kerosene, candles, or dry-cell batteries to meet their energy demands – electrification is efficiency enhancing in the sense that the same amount of energy can be produced at lower costs. In addition, EARP also improves the transmission quality in the existing grid and promotes energy saving appliances thereby contributing to a higher efficiency in Rwanda's energy sector.

8.3 Outcomes

What is the connectivity rate of households, enterprises and social infrastructure institutions in the project area?

The connectivity rates in our surveys are as follows:

• Households: 61 percent

• Micro-enterprises: 50 percent

• All health centres and schools in the access area normally connect to the grid. For Rwanda as a whole, official statistics indicate that by May 2013, 36 percent of schools, 56 percent of health facilities and 58 percent of administrative offices had been connected.

- How reliable is electricity supply (frequency of outages)?

  • Generally households are satisfied with their electricity connection, in spite of some outages that 93 percent of all connected households have experienced during the last month. 28 percent of these households say such outages only occur rarely and are not able to specify how often they experience an outage per month. The average number of outages per month reported by the remaining households amounts to 3.8. Furthermore, many households complain about voltage fluctuations and in 62 percent of the households some appliances have broken due to voltage fluctuations. The most common broken devices are light bulbs, but also phone charger, radios and even TVs.

- Which socio-economic groups (incl. poor/non-poor) benefit from availability of electricity?

  • The vast majority of (direct and indirect) EARP beneficiaries are rural households. Virtually all of them qualify as poor.

- Who (gender-specific) in the household has made the decision to connect to the electricity grid?

  • In 80 percent of the connected households the head of household decided to get connected. These are mainly men. In 11 percent the head of household decided together with the spouse and in 3 percent the spouse decided alone. In some few remaining households also the children, the owner of the house or community authorities had a say in the decision to connect.

- How many hours per day or week is electricity being used?

  • Electricity is used every day and households consume on average 11 kWh per month. Exact usage pattern for lighting and other electric appliance can be found in Section 5.1.3 and 5.1.4 and 5.2.2.

- What are the main electricity using appliances, used by households, enterprises and social infrastructure institutions?

- Household appliance usage is reported in Table 16.

- Micro-enterprise appliance usage is reported in Section 6.1.

- Health centre appliance usage is reported in Section 6.2.

- School appliance usage is reported in Section 6.3.

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

- Energy usage patterns are part of Section 5.1.3 and Section 5.1.4. Lighting is, of course, used by all household members. The questionnaire addresses TV usage patterns disaggregated by household members, see Section 5.2.2.

8.4 Impacts

What is the change in expenditure (per time interval) between the energy sources used prior to the arrival of electricity (candles, kerosene, batteries) and current expenditures?

- See Section 5.2.1.

To what extent has (the perception of) safety changed?

- Given a substantial amount of electric lamps installed at the outside of the houses, an increase in safety could be expected (for more details, see Section 5.1.3 on lighting).

- However, we do not find any impacts on perception of safety:

- We find significant impacts on acceptability of violence against women. For more details, see Section 5.2.4 on gender.

Table 33

Security aspects (DiD and mean follow-up values)

Security aspects	DiD community	DiD household	Control	Treatment all	Treatment connected
Interviewee is afraid when					
...being outdoors after nightfall	-0.08	-0.14	0.42	0.32	0.28
...children are outside after nightfall	-0.08	-0.15	0.52	0.43	0.40
....being at home at night	-0.07	-0.03	0.34	0.27	0.27
Interviewee thinks that darkness is dangerous	-0.01	-0.01	0.99	1.00	0.99

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

Source: EARP dataset 2011/2013.

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

• In order to gauge the value people assign to the connection we asked connected households for their willingness to accept that someone cut their electricity connection. Around 80 percent respond that they would not accept it no matter how much one would pay. The remaining households report and average of 11.308 FRW (14 EUR) per month. The initially offered starting price was 5,000 FRW.

• The following table displays the willingness to pay for electricity in the hypothetical situation that so far non-connected households got a connection. Each respondent was confronted with a certain service level and asked whether s/he was willing to spend 2,000 FRW per month. Depending on the answer, the offered price was decreased or increased. The results indicate that households are willing to spend more if they can consume more electricity.

Table 34

Willingness to pay for electricity consumption (in FRW per month)

Electricity connection allows following type of electricity services	non-connected
Electric lighting inside	1,908
Electric lighting inside and outside	2,014
Electric lighting, radio, tv and mobile phone charging	2,341
Electric lighting, radio, tv, mobile phone charging, fridge and electric stove	2,496

Sonne: EARP dataset 2011/2012

To what extent have the household's activities during evening hours changed? Have study hours/reading time of children changed? Do women (and children) enjoy more or less rest?

- The activity profiles of household members are discussed in Section 5.2.3 on time use.

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

- According to the perception of dwellers, indoor air pollution has been reduced significantly.

Tabelle 35

Indoor air pollution (mean follow-up values)

	Control	Treatment		
		all	connected	non-connected
Indoor air had improved	0.10	0.27***	0.40	0.07***

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

Source: EARP dataset 2011/2013.

Has the availability of electricity triggered new economic activities or displaced old ones?

- Section 5.1.4 'Productive appliance usage' addresses energy related economic activities of households. Section 6.1 addresses electricity usage in micro-enterprises.

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

  • Effects on gender aspects are reported in Section 5.2.4. Section 5.2.3 analyses children's school enrolment.

- Has the enrolment and school attendance changed as a result of use of electricity in the school?

  • Section 5.2.3 analyses children's school enrolment. Section 6.3 addresses electricity usage in schools.

- How are benefits distributed across different income groups? Has the activity had an effect on gender equity in access to, use of and benefits from energy sources?

  • Usage intensities of electricity increase substantially with income. If we look at electricity consumption distinguished by baseline expenditure quintiles we see substantially higher consumption with higher expenditures:

Table 36

Electricity consumption across expenditure quintiles

Expenditure Quintile (baseline)	Electricity consumption (in kWh per month)
1	3.7
2	6.0
3	9.2
4	13.9
5	19.0

Sonne: EARP dataset 2011/2012

  • In the women questionnaire we ask who is responsible for buying and deciding on energy sources. We do not find any effects.

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

  • We do not find any un-intended negative impacts.

8.5 Sustainability

- To what extent is the Rwandese government capable of continuing the roll-out and maintaining the stock of a nation-wide electricity network?

  • A second phase of EARP is already in the pipeline. The government together with World Bank and the Dutch Embassy are working on a scaling-up programme until 2017. See Section 2 for more details.

- To what extent have national strategies taken into account possible exit strategies for donor intervention in EARP?

  • On-grid electrification and in particular grid extension interventions require heavy investments and will rely on public financing in Africa for the next decades. Donor contributions, in turn, are the most probable source of funding. Hence, it appears to be unrealistic to expect an exit strategy. In fact, the main donors involved in EARP already plan to scale-up the programme, which also includes further donor contributions.

- To which extent has the government a sustainable (financial) capacity to provide incentives (tax benefits or direct subsidies) to both private sector suppliers and customers alike in the energy sector?

  • Private activities in the Rwandan electricity sector are limited to investments into generation capacities of smaller scale (e.g. micro-hydro). Transmission and distribution of electricity is operated by the public energy agency EWSA.

9. Concluding Remarks

This report presented the results of an impact evaluation of Rwanda's Electricity Access Roll-Out Programme (EARP) that is financed – among other donors – by the Embassy of the Kingdom of the Netherlands as part of its Promoting Renewable Energy Programme (PREP). EARP is implemented by the Government of Rwanda via the Energy, Water and Sanitation Authority (EWSA) and its major activities are grid extension and densification projects. EARP is one of the most ambitious and largest electrification programmes in the world and conceptually constitutes an antipode to the private sector oriented and decentralized electrification efforts that can mostly be found in PREP. Furthermore, EARP has to be considered as part of the United Nations initiative Sustainable Energy for All (SE4All), which envisages providing modern energy – including electricity – to everybody by 2030.

The first result of this evaluation is the fact that EARP is not only ambitious, but also effective as can be seen in the number of households, health stations, and schools connected in the last four years. Also the communities surveyed for this evaluation that were foreseen for connection in 2011 have widely in fact been connected, which is far from being the case in other comparable evaluations.

At the same time, the effective roll out comes at a price: the per-connection-investment of the programme at around 1500 USD is considerably higher than for decentralized alternatives like solar home systems or Pico-PV kits that do not provide the same quality of electricity in terms of power, but that would nonetheless meet the electricity consumption patterns of most rural households, also in the EARP target group. An in-depth analysis of EARP's impacts is therefore warranted and pursued by the present evaluation.

The evaluation has examined effects on all beneficiary levels, households, micro-enterprises, health centres and schools with the focus being clearly on the household level. The main identification strategy is a difference-in-differences approach, for which we conducted two waves of data collection in 2011 and 2013. The broad data sets enabled us to examine take-up of electricity and impacts on various dimensions of households' living conditions. We found that take-up of electricity is strong with around 60 percent of households in newly connected areas connecting to the grid. Connected households increase their lighting usage tremendously and obtain new appliances, mostly for consumptive purposes. While total energy expenditures are not reduced, those components that are potentially replaced by electricity like kerosene, battery and mobile phone charging expenditures go down significantly. Another important effect we observe is a clear reduction of dry-cell battery consumption after grid connection. While among control households in our study, battery consumption has increased by almost 30 percent annually over the last two years, treatment households consume considerably less dry-cell batteries than before (> 50 percent) indicating a net reduction of more than 70 percent. Nonetheless, dry-cell battery consumption deserves special attention for the near future, as the majority of rural Rwandan dwellers remain unconnected for the years to come. Battery consumption will therefore further increase in the country with the vast majority of batteries not being disposed of properly. Households throw used batteries into their pit latrines, into their garbage or directly into nature. In all cases, the toxic content will end up in uprotected repositories. Environmental consequences have not yet been properly analysed. Some future researech in this area is recommendable as well as the establishement of a disposal system. Batteries could be collected, for example, in Cell or Regional Offices.

The availability of electricity in the communities clearly has a significant effect on the daily routine of rural dwellers. All household members in treatment communities are on average longer awake than household members in control communities. Children shift their study time from daytime to hours after nightfall and even school-enrolment is positively affected. We furthermore observe a significant increase in TV as the main source of information. Better access to information leads to significant effects on gender aspects. We find a significant decrease in women who think that it is justified that a husband beats a women in different situations.

In terms of productive take-up we find two things: first, households increase their home business activities quite considerably. Most new productive activities are low key in this area, though. Take-up in (non-home business) micro-enterprises is rather humble. We generally observe a slight increase of business activities in connected communities. Some enterprises emerge and existing enterprises partly extend their operation hours, products and services. While in many cases electrification of enterprises only increases convenience and causes a redistribution of income within the community or region, some enterprises also increase net community income by serving demand from outside the community or offering products and services locally that formerly had been imported from urban areas. Impacts are disproportional for well-connected communities that already had a vivid business centre before electrification. The crucial factor for the development of all business activities is local demand and market access that is normally not affected by electrification. Enterprises that have the highest connection rates and are most positively affected by electrification are mills, hairdresser, copy shops, and welding shops.

EARP's goals in connecting health centres have not fully been realized, but nonetheless the share of grid connected health centres has increased from 40 to 68 percent since the kick-off of EARP. This has proven to also push appliance usage in health centres which can subsequently be assumed to improve the quality of health care provision in rural areas. On a more anecdotal level, our research has shown that the main purposes electricity is used for is lighting, the operation of medical machines and administrative purposes. It is furthermore often mentioned that electricity facilitates the attraction of (trained) staff from urban areas to the community, not only as it improves working conditions, but also because electricity in their home places increases their quality of life in the community.

In line with this, also schools have broadly been connected to the grid. While it is less urgently needed for their service than it is for health centres, it is still used for improving administrative processes in the school and also sporadically for improving the schools' schedule.

Altogether, this evaluation endeavour has shown that EARP has reached its goals of substantially increasing the electrification rate in the country. It has furthermore provided new evidence for whether impact hopes associated with electrification are justified. In fact, we have found strong indication for broad socio-economic impacts on the household level, whereas micro-enterprises seem to face other (or additional) bottlenecks than (only) a lack of access to electricity. Putting the findings into the perspective of SE4All's global tracking framework, two aspects stand out. First, as in many other grid extension projects we found that a considerable share of the target population that in principle has access to the grid now does not connect (here: 40 percent), virtually all of them for cost reasons. While some of these households might still obtain a connection in the years to come, this shows that in order to achieve access *for all,* additional measures need to be contemplated since the poorer strata in rural Africa will not be able to bring up the connection fees (even if already pretty low as in the EARP case). Further specifically targeted subsidies might be required. Another option could be low-cost solar kits of a good quality, although it is questionable if this is accepted by households with grid-connected neighbours.

Second, as for SE4All's multi-tier access definition, EARP allows for Tier 4 access in terms of electricity supply. However, large parts of the target group reveal demand patterns that only qualify for Tier 1 or 2. This categorization is more than a technical question. It rather leads to the political question of whether the high investment costs are justified compared to lower cost (and of course lower quality) off-grid solutions. A debate among energy access experts is required to put the SE4All-movement on the right trajectory, which encompasses a consideration of trade-offs between different electricity access technologies. More precisely, translating the required investment costs of 1500 USD per connections into off-grid solutions, one could provide at least five households with a 50 Watt solar home system that would already satisfy the electricity demand of many of the surveyed households.

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Annex 1: List of surveyed communities

Pro-vince	District	Sector	Cell	Umugudugu(s)	Treatment or Control in 2011	Effectively 2013	Commu-nity Code
East	Bugesera	Juru	Kabukuba	Kamatongo, Kabukuba	T	C	35
		Mayange	Kagenge	Kiruhura, Ruhorobero, Rukindo	C	C	51
		Ngeruka	Ngeruka	Ngeruka, Kamajeri, Binyanzwe	C	Out	10
		Ntarama	Kibungo	Rusekera, Nyarunazi	T	T	13
		Nyamata	Murama	Kivugiza, Kiyogoma, Rutukura	C	C	38
		Rilima	Kimaranzara	Byimana, Buhoro	T	T	34
		Rweru	Nemba	Nemba, Rutete, Muyoboro, Rwiminazi	T	C	9
	Rwamagana	Fumbwe	Sasabirago	Byimana, Birembo	T	C	46
		Karenge	Byimana	Rukori, Karamba	T	C	18
		Karenge	Bicaca	Bicaca	T	C	23
		Muhazi	Karambi	Gahengeri, Kinunga, Kayenzi, Ragwe	T	C	44
		Rubona	Nawe	Gaseke, Cyili, Rudashya, Murudashyi	C	C	43

Pro-vince	District	Sector	Cell	Umugudugu(s)	Treatment or Control in 2011	Effectively 2013	Commu-nity Code
North	Burera	Bungwe	Tumba	Mubuga	T	C	33
		Gatebe	Gabiro	Kajeijeri, Nyakabungo	T	C	6
		Kivuye	Nyiratabа	Kabasha, Shanja, Bukumbi	C	Out	31
	Gankenke	Nemba	Gisozi	Kamateke	T	Out	20
		Nemba	Mucaca	Kiruhura	C	C	19
	Gicumbi	Byumba	Ngondore	Bukamba	T	C	7
		Manyagiro	Ryaruyumba	Bugasa, Gasyata, Taba, Russabira	T	C	8
		Manyagiro	Kabuga	Mugera	C	Out	32
	Musanze	Busogo	Kauumu	Karema, Karuriza, Rugeshi, (M) rutaboneka	T	C	21
		Busogo	Kauumu	Gatovu	C	C	22
		Gataraga/ Shingiro	Rubindi/ Gakingo	Gacondo, Butakanyundo/ Gasura	T	T	48
		Kinigi	Kampanga	Rutindo, Rugi, Rurembo	T	C	45
		Kinigi	Bisoke	Kumazi,Kinazi	C	Out	47
South	Gisagara	Gisagara	Ndora	Kabuga, Nyarunazi	T	C	14
		Kansi	Akaboti	Agacyamu, Akayenzi, Ruhuha, Kimana	C	C	5

Pro-vince	District	Sector	Cell	Umugudugu(s)	Treatment or Control in 2011	Effectively 2013	Commu-nity Code
		Mamba	Ramba	Kayenzi, Gakoma	T	T	26
		Mugombwa	Kibaye	Rinda, Kabuga, Udokoni, Agakanka	C	C	15
		Musha	Bukinanyana	Agatega, Bukinanyana, Ghinga, Rwatano	T	T	1
	Huye	Huye, Mbazi	Sovu	Gako, Chahafi, Kagarama	T	T	40
	Nyamagabe	Cyanika	Karama	Nyanza, Kibingo	C	C	29
		Kibirizi	Gashina	Muganza	T	T	2
		Kibirizi	Bugarura	Muyange, Uwinya	T	T	27
		Kibirizi	Karambo	Nyirakiraro, Gitwa, Nyamirama	C	C	30
		Musebeya	Gatovu	Gatovu, Ryanyakayaga	T	T	28
	Nyaruguru	Busanze	Nkanda	Bitare, Nkanda	T	T	3
		Rusenge	Raranzige	Karimba, Ntanda, Nyamagari	C	C	4
	Ruhango	Kinazi	Burima	Nyaruteja, Nymiyaga	T	T	16
		Kinazi	Rubona	Gashike	C	C	17
		Ntongwe	Kebero	Cyeru, Gasuna, Rwintama, Kaburanjwiri, Kanyete	T	T	41

Province	District	Sector	Cell	Umugudugu(s)	Treatment or Control in 2011	Effectively 2013	Community Code
		Ntongwe	Nyarurama	Rwintama, Gahunga, Nyabitare	C	C	42
		Ruhango	Nyamagana	Mabera	C	T	39
West	Karongi	Bwishyura	Gasura	Ruganda	T	T	24
		Bwishyura	Gasura	Nyabishanga, Nyarusange	C	C	25
		Rwamkuba	Nyakamiro	Musango, Gasenyi, Kigarama	T	C	36
	Ngororero	Nyange	Nsibo	Cyambogo, Vugu, Nyarugenge, Kanyinya	C	C	12
		Nyange	Gaseke	Birambo, Gaseke, Giko	T	C	37
	Rubavu	Kanama	Nkomane	Rwanzuki	C	Out	50
	Rutsiro	Kivumu	Kabujenje	Kabuye, Buhongo	T	T	49

Annex 2: Study timeline

Baseline

Pre-Departure Preparation of the Studies	until April 1, 2011

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 IB&C

In-Country Preparation of the Studies (RWI/ISS Mission)	between April 11 and 22, 2011

- Coordination with local partner IB&C, project staff and national partners of the EARP project.
- Field trips to project regions;
- Choice on survey sites and planning of survey organisation and logistics, with the assistance of the local partner IB&C and EARP project staff;
- Design details of the study;
- Revision of the questionnaire;
- Training in Kigali of the enumerators on the questionnaire and data entry;
- Final review of questionnaire and survey organisation and logistics.

Realization of the EARP Survey	between April 25 and May 30, 2011

Survey implementation by RWI research assistant and enumerators.

Data Compilation	until July 1, 2011

Data entry by enumerators

Follow-Up

Pre-Departure Preparation of the Studies	until May 1, 2013
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 IB&C	

In-Country Preparation of the Studies (RWI/ISS Mission)	between May 15 and 24, 2013

- Coordination with local partner IB&C, project staff and national partners of the EARP project.
- Field trips to project regions;
- Decision on survey organisation and logistics, with the assistance of the local partner IB&C and EARP project staff;
- Design details of the study;
- Revision of the questionnaire;
- Training in Kigali of the enumerators on the questionnaire and data entry;
- Final review of questionnaire and survey organisation and logistics.

Realization of the EARP Survey	between May 30 and August 9, 2013
Survey implementation by RWI research assistant and enumerators.	

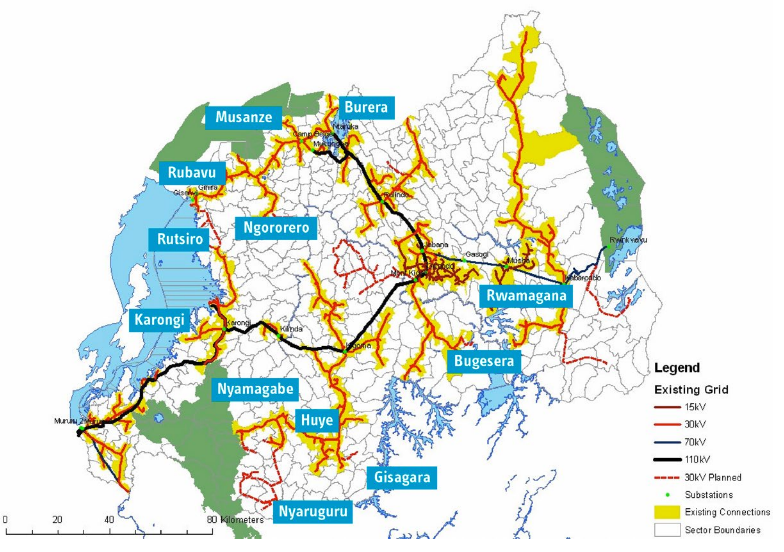
Data Compilation	until end of August, 2013
Data entry by enumerators	

Source: Own illustration

Annex 3

Figure 35

Map of Rwanda (with survey region)

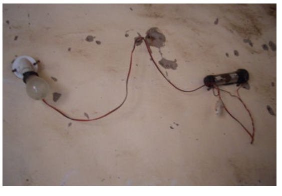


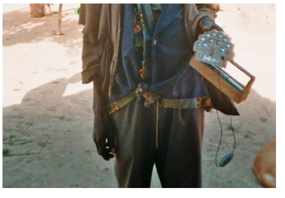
Source: own illustration based on information provided by EWSA

Annex 4: off-grid lightningt device

a. Mobile LED lamp

b. Fixed Torch





c. Hurricane Latern and Traditional Tin Lamp

Source: Own illustration

Annex 5: Electricity consumption of different appliances used for inference of electricity consumption

	wattage	source	usage hours per day	kWh/month
iron_electric	1100	1	0.05	1.54
fridge_electric	230	2	8	51.52
stove_electric	1200	1	0.5	16.8
ventilator	100	1	1	2.8
phone_mobile	3	1		depending on charging behaviour
radio_bivalent	6	2	1	0.168
radio_line	6	2	1	0.168
tape_recorder	18	2	0.5	0.252
stereo_system	20	1	0.5	0.28
cd_vcd	10	2	0.5	0.14
tv_bw	20	1	1	0.56
tv_colour	70	1	1	1.96
video	35	2	0.5	0.49
dvd	14	2	0.5	0.196
computer	70	1	1	1.96
mill_electric	2000		1	56
sewing_electric	100		1	2.8

1 = http://www.wholesalesolar.com/StartHere/HowtoSaveEnergy/PowerTable.html

2 = http://mybroadband.co.za/vb/archive/index.php/t-102117.html

Annex 6: Propensity Score Matching

Probit Model used for propensity score matching

Probit regression	Number of obs = 286
	LR chi2(8) = 68.72
	Prob > chi2 = 0.0000
Log likelihood = -155.22389	Pseudo R2 = 0.1812

EWSA connection	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]	
BAS_Has Bankaccout	0.2798583	0.1818907	1.54	0.124	-0.0766409	0.6363576
BAS_HoH Subsist_ Farmer	-0.2956979	0.2249886	-1.31	0.189	-0.7366675	0.1452717
BAS_HoH_Sex	0.350773	0.2272277	1.54	0.123	-0.0945852	0.7961311
Distance_ Mainroad	-0.0167079	0.0070708	-2.36	0.018	-0.0305665	-0.0028494
BAS_ Lightinghours	0.1409333	0.0387123	3.64	0.000	0.0650586	0.216808
BAS_HHsize	0.1324225	0.0446387	2.97	0.003	0.0449322	0.2199128
BAS_ livConImpr	-0.5671603	0.4479063	-1.27	0.205	-1.445041	0.3107199
BAS_hoh_ higherEdu	0.0306964	0.2260382	0.14	0.892	-0.4123302	0.4737231
_cons	-0.7286087	0.3321849	-2.19	0.028	-1.379679	-0.0775383

Covariates

BAS_Has Bankaccout	Dummy: HH has bank account at baseline
BAS_HoH Subsist_Farmer	Dummy: Head of HH is Subsistence Farmer at baseline
BAS_HoH_Sex	Dummy: Head of HH is Female at baseline
Distance_Mainroad	Distance of HH to mainroad
BAS_Lightinghours	HH's consumed lighting hours at baseline
BAS_HHsize	HH size at baseline
BAS_ livConImpr	Subjective assessment of the dynamics of the last three years
BAS_Hoh_higherEdu	Dummy: Head of HH has finished higher education

Propensity Score Distribution among control communities.

We use all observations for matching that have a propensity score >0.5

	Percentiles	Smallest		
1%	.026936	.0000924		
5%	.243104	.0012801		
10%	.2987384	.0032687	**Obs**	663
25%	.4335763	.0034575	**Sum of Wgt.**	663
50%	.5997925		**Mean**	.597418
		Largest	**Std. Dev.**	**.227875**
75%	.7716495	.9991503		
90%	.9254049	.999912	**Variance**	.051927
95%	.9654431	.9999995	**Skewness**	-.1329352
99%	.9970245	.9999998	**Kurtosis**	2.397848

Balancing of covariates between treatment and control group

Covariates		Connected households	Control households
BAS_Has Bankaccout	Before	0.65	0.54
	After	0.67	0.72
BAS_HoH Subsist_Farmer	Before	0.73	0.73
	After	0.72	0.67
BAS_HoH_Sex	Before	0.19	0.17
	After	0.18	0.16
Distance_Mainroad	Before	7.31	13.27***
	After	7.05	9.39*
BAS_Lightinghours	Before	5.38	4.48***
	After	5.48	5.82
BAS_HHsize	Before	5.57	4.97***
	After	5.68	5.45
BAS_ livConImpr	Before	0.02	0.03
	After	0.02	0.01
BAS_Hoh_higherEdu	Before	0.26	0.18**
	After	0.26	0.26

*Note: The asterisks refer to the significance level detected by t- and chi-squared tests on differences in means between the connected households and the whole control group in the before situation and between connected households and the matched control households in the after situation. *, ** and *** indicate significance levels of 10%, 5% and 1%, respectively.*

Source: EARP dataset 2011/2013.

Annex 7: Micro-Enterprises: Summary of findings from semi-structured interviews

The business environment differs in quantity and type of businesses in the surveyed communities. While some of the sites have a vivid centre, others have no or very little entrepreneurship. The most common type of business is a small shop, selling among others rice, flour, batteries, biscuits and soap. A similar business type is a bar, selling sodas, local or bottled beer and small snacks. Other very common businesses are tailor shops, mills, hairdressers and carpentries. Technicians, mechanics or bakers often work independently and wait for customers to ask for their service. In the more developed communities photocopy shops, welder shops, small cinemas and pharmacies can furthermore be found. In an exceptional case, a coffee washing station and a coffee producer performing all activities of the value chain are located in the surveyed communities. Furthermore, producers of pineapple and banana vine and a big mining company are present in the visited communities.

In many of the communities independent producers organize themselves in cooperatives. These cooperatives have very different focuses, depending on the economic activities the organized enterprises pursue. Among them are a dairy cooperative, where cow owners share a guard and stall, an artisan cooperative and a cassava production cooperative. While some businesses are uniquely driven by men like mills, welder shops and carpentries, small shops, bars, tailor shops or the bigger exceptional companies are partly driven by or employ woman.

Positive impacts of electrification on the business environment are expected to be either the emergence of new businesses or the improvement of existing ones. For an already existing business, impacts are expected to be money and/or time savings through better equipment, new or better quality better quality or new products, higher productivity, longer operation hours and an increase in security leading possibly to higher owner income. The impacts on the community level could be employment creation, the availability of higher quality products or new products and price effects. Here it is of utmost importance to enquire at which markets products are sold and if other locally produced goods are crowded out in order to assess net benefits. Positive net impacts at the community level can only materialize if products that used to be produced outside the community are now produced locally or enterprises manage to serve markets outside the community.

In the following, we will present in detail those businesses that are most affected by electrification, i.e. mills, copy shops, welding shops and hairdresser. Carpentries, bars, tailors and small shops will be portrayed in less detail only.

Mill

Millers usually possess one room or a mostly wooden outside-stall, which they use for milling. Customers bring a sack of a base product to the miller, where it is being milled and weighted with a hanging scale. Most important base products are corn, sorghum, manioc, soya, cassava and wheat.

Mills are omnipresent both in non-connected and connected communities. While among non-connected communities 64 percent of the communities count with at least one mill, among connected communities 55 percent have a mill. In some of the connected communities new mills have been opened that run on electricity. The majority, though, still runs on fuel. One reason for this is that EWSA does not offer (yet) three phase connection in all communities which are required to run a mill. Inhabitants of the surveyed communities without mills have to overcome distances of between three and seven kilometres to reach the nearest mill.

Impact within the business

The millers are among the most positively affected businesses by electrification in the surveyed communities. While mills in non-connected communities normally run on diesel, all millers in communities with three phase grid connections use an electric motor. Some of the connected millers furthermore use electric lighting.

The most central difference between electric and fuel-run mills are operation costs. The surveyed non-connected millers have expenditures of between 15,600 and 84,000 RWF monthly. The connected millers by contrast spend between 4,000 and 75,000 RWF per month. One connected miller illustrates the relevant differences in production costs as following: He uses grid electricity 26 days per month and uses his generator around six times per month for between 30 and 120 minutes as a back-up during outages. Per month he has approximately the same expenditures (4,000 RWF) on electricity as on diesel. Given the more powerful electricity supply, millers furthermore unanimously report a higher productivity of electric mills, i.e. more output per operation time. Furthermore, an electric mill produces more finely grinded flour. These productivity improvements normally lead both to lower prices for the clients and an increase of the owner's income. The finely grinded flour and lower prices attract more clients and millers report an increase of demand. According to the millers the increase of demand can be traced back to two factors: first, more customers from the community but also neighbouring communities that used to mill their crops with fuel-run mills now come to electric mills- Furthermore, formerly unmet demand is now served: people that used to mill their crops by hand now start to use a mill and existing customers mill higher quantities than before.

This increased demand translates into longer operating hours: the main operation hours of millers are during the morning and afternoon hours after fieldwork. Connected millers increase their operation hours by at maximum two hours per day. Electric light furthermore gives them more flexibility as they can serve customers "whenever needed". However, given the normal working hours during daylight, no miller actively names increased safety as an impact of electrification.

Impact within the community

First of all, electrification of mills has price effects. The direct comparison of milling prices before and after electrification in the same community nevertheless shows a clear price reduction for all base products. The milling price per kilogram of corn, for instance, declined on average from 48 to 33 RWF and sorghum milling prices decreased from 22 to 15 RWF. Concerning quality effects or the emergence of new products, millers and interviewed authorities observe an increase in flour quality, as it is more finely grinded when milled with an electric engine. Moreover, given that especially corn milling is power intensive, in two communities, electrification resulted in the emergence of corn-milling, which before was not being practiced.

These price and quality effects lead to an increase in demand since it attracts customers from non-electrified communities and because customers increase the quantity of crops they mill. However, no export creation or expansion of business to other regions can be found: all millers state that their customers are coming from their own or neighbouring communities and none serves traders, urban population or companies. This means that all mills (existent fuel-run and newly created electric mills) within one region compete for the same clients. The electrification of one community might attract customers from neighbouring non-electrified communities, but on the regional level the net-effect is zero. Accordingly we observe above all a shift of demand from non-electrified mills and communities to electrified mills. Furthermore, there seems to be an absolute increase in demand since formerly unmet demand is served.

This leads to creation of mills and thereby employment creation; the millers are in all cases small businesses, which consist out of an owner and usually one worker. Usually the always male miller hires a male worker to operate the mill, while the owner himself weights the milled sacks and settles up with customers. Due to the limited need for further employees in a mill, no existing miller hired additional employees after electrification. The grid connection on the other hand led in most of the communities with access to a three phase grid to an increase in mills. Since also formerly unmet demand is now served, net employment effects are positive.

Furthermore, people who formerly had to bear either long distances (carrying a sack of flour) or long waiting periods can find a miller closed to their houses.

Miller Portraits

Innocent Nzarubara

Innocent Nzarubara is one out of three millers in the centre of his community. His house is connected to the grid but his wooden mill stall is standing some metres apart without connection. After his community got electrified, he bought a dynamo for his mill to connect it to the grid. Shortly after, he was told by EWSA technicians not to do so as there is only a single phase grid in the community. He is also not using electric lighting inside his stall, as he "lacks the authorization to connect". He and the other millers are the only businesses suffering from this problems in this community due to the high power consumption of mills. He is therefore still working with a diesel engine. He starts working at 3 pm when the farmers bring their harvest from the fields. As starting the diesel engine requires a lot of energy, he refuses the customers the service until various clients are available to assure profitability. From 6.30 pm to 8 pm he uses two candles per day for lighting. He furthermore uses 40 litres of diesel per month and serves around 20 customers per day. He expects his work efforts and his working time per customer to decrease with electricity and his productivity and profitability to increase. Therefore Innocent is looking for support to be authorized to connect and is waiting for EWSA to provide a three phase connection.

Jean Bosco Uwimana

The community Jean Bosco is living in has been connected a year ago and he immediately bought a dynamo for his so far fuel-run mill. In spite of the fact that six more mills have been created in his community since electrification, he still serves a few more customers and makes higher profits than before. His prices decreased by between 20 to 33 percent, depending on the product. He increased his operating time by two hours per day and uses two energy-saving bulbs in his mill. He thinks that there is still unsatisfied demand in his community and he would like to buy a stronger electric engine, but lacks the capital to do so. Generally, the miller is very satisfied with how his life changed since electrification. With the higher profits from milling he bought some land for his family, which he works together with one employee. He proudly explains that he now pays taxes and a health insurance for his children.

Copy shop

Copy shops can only be found in the most lively communities, where a small centre developed and movement can be seen on the main road. They are remarkably well equipped despite the remoteness and scarce infrastructure in the communities. Since only few communities with copy shops exist, the few existing ones serve a wide clientele from the surrounding communities or even cells. Especially schools, health centres or state offices appreciate the existence of such copy shops and use their services. The shops usually offer copying, scanning, typing and printing of (official) documents. Furthermore, they take and print (passport) photographs or sometimes prepare colourful wedding or birthday cards. Sometimes they add further services, such as selling school materials or repairing computers. The owners receive between two and 30 customers per day and all, except one, feel that the demand is low, but still high enough to make a profit. They take relatively similar prices for their services: 30 RWF for a copy, 500 RWF for typing and printing documents and 250 RWF for taking a picture and printing it. They are open usually from 7 or 8 am until 6 or 7.30 pm.

Grid electricity represents a necessary condition for the establishment of copy shops. While in non-connected communities no copy shops or similar businesses exist, in 26 percent of connected communities such businesses evolved. In some of these communities, not just one but two or three copy shops have been opened.

Impacts within the business and community

In non-electrified communities, no copy shops exist. Hence, the pure existence of such businesses is an outcome of electrification. The interviewed copy shop owners had been students, technicians, fishermen or unemployed beforehand.

Copy shops are usually run by one owner and at maximum one part time employee or a family member. Employment creation is therefore existent but rather small and limited. Concerning price effects from electricity, no price comparison can be made, given the small number of copy shops. Customers however definitely benefit financially by saving formerly invested time and possibly costs for transportation for reaching the closest copy shop. The distance to the nearest shop before electrification had been between 15 and 50 km. For people who did not or could not use copy shops services beforehand, a new service is now available. Some of the newly offered services are fun activities such as printing birthday cards and making small designs, for which nobody would have travelled before. Accordingly, new demand is created and furthermore existing demand formerly served by copy shops in neighbouring towns is now served locally. Demand creation often contains fun activities, while substituted services are usually the printing and typing of official documents or school exams and reports. This results in an increase in community income. Private people and schools, additionally to the so far discussed impacts, might furthermore benefit from the contact with modern office machines (computers, printers, scanners, binding machines, plastification machines and cameras) and can see and use possibilities of how to use them in business or daily life.

Welding shop

The communities' welders are often visible from far, as they work outside in front of their welding shops with doors and windows leaning against the wall. They usually work with a sander and a soldering-iron and produce doors, windows, gates, sometimes roofs or make reparations of metal objects, such as bikes. In non-connected communities, no welders at all exist. While in 47 percent of the connected communities, at least one welder shop emerged, in half of these cases, even two or three shops developed after electrification. The welders all use electricity for the usage of their sander and soldering-iron. Many of them report to need better equipment for producing various designs, better quality and being quicker, and they report to suffer from high transport costs and long distances to material suppliers. The welders feel that they cannot compete with product prices and quality from the cities.

Welders mostly produce only if a customer asks for it, but sometimes they have a few products in stock. Welders sell their new products for between 5,000 RWF for small boxes and 250,000 RWF for a big gate. Repair services are much cheaper. All surveyed welders report that between 40 and 60 percent of their demand comes from their own community and the remaining orders are from neighbouring communities or even other cells or sectors. All this demand had been met in the next bigger towns or cities in a distance of at maximum 35 km beforehand. Some of the welders experience that some wealthier people from the community still go to big cities to buy their doors and windows, as they seek a better quality or different designs. The average number of customers that want to buy a product manufactured by the welder varies strongly from welder to welder and amount to at least one customer up to a maximum of 25 per week. Demand is generally higher on market days and in dry season when most people are constructing houses. Smaller reparations are being done to a much larger extent. Many welders complain about insufficient demand and one welder explains that due to poverty, many people do not have the means nor see the need for spending their money on his services.

Impacts within the business and community

Grid electricity is a necessary condition for the emergence of welder shops due to the high costs of alternative energy sources. Therefore, no before and after comparison within one business can be made. Almost half of the welders formerly were employed at welding shops in Kigali and came back to their home communities to work independently when these communities got electricity. The rest of the welders had not worked as welders before.

Almost half of the interviewed welders learned their skills in the capital and brought the knowledge back to their communities, when electricity arrived. The welding shops have between zero and four employees and on average hire 1.6 workers. Concerning price effects, no general tendency can be given. Customers benefit from the availability of the service and save time and transport costs but pay higher prices than they would in towns. Whether customers benefit seems to depend on the individual preferences of quality and prices and transport costs. Welder in the communities produce rather lower quality than in the cities due to less equipment and skills. All welders report to partly substitute imports from towns. Especially lower income groups in the communities seem to benefit from the availability of the basic metal products.

Welder Portraits

Jean Claude Narambe

Jean Claude Narambe is 20 years old and learned welding and machinery skills in the capital at a welding shop. A former colleague called him and told him that there might be working opportunities in a community, which recently got connected to the electric grid. He followed this advice and is now working the whole year from 6.00 am to 5.30 pm for the community chief, who invested in a welding shop after electrification. They mainly produce metal gates, doors, windows and do reparations of metal objects. Jean Claude receives around three new product orders and 20 reparation tasks per week. He estimates that 60 percent of his clients are coming from the community and the surrounding hills, while 40 percent come from other cells. He feels that the demand is currently very low, as no new houses are being constructed, but he is waiting for January to come as constructions will start again in that season. Jean Claude says that the lack of electricity is the main problem for his colleagues and their work.

Hairdressers

Hairdressing saloons are very frequently visited places and often the first places in non-connected communities that have a decentralized electricity source. This is why they frequently also offer phone charging services. Young people come together, charge their phones and listen to a radio. In rural areas in Rwanda, men and women usually get the same shorthair cut and men are being shaved. The saloons are usually one big room with mirrors and posters on the walls and the owners are usually young men. The hairdressers have between five and 30 customers per day and demand is especially high on market days, when people living further away in the hills come to the community.

While in non-connected communities, there is an average of two hairdressers per community, there are on average 3.5 hairdressers in the connected communities. The hairdressers in non-connected communities use a car battery for running their electric cutting machines and their colleagues in connected communities immediately switch to grid electricity after electrification. In non-connected communities all use electric cutting machines, about half offer phone charging, over half have a radio and only one out of 46 has a TV in his saloon. The devices usage increases with electrification: in connected communities, most hairdresser offer phone charging, over 60 percent have a radio and a bit less than 30 percent possess a TV. The hairdressers are among the businesses that are the most affected by electrification. Many saloons either opened after electrification or added new services (phone charging) or entertainment (radio and TV) to their business.

Hairdresser Portraits

Evaliste Gasana

Evaliste Gasana is representative for the surveyed hairdressers, as many of them have same characteristics and experience similar developments. Evaliste was employed in another saloon, using a car battery as electricity source. When the community got electrified, Evaliste opened his own saloon and bought two cutting machines and a radio. He never thought about buying a generator or a car battery beforehand, as it is expensive and he did not have the capital. Today he pays 5,000 RWF on electricity per month. He opens his shop from 7.00 am to 9.00 pm and hires one worker. He has around ten customers per day, especially many of them are students as his saloon is located near the school. His main problem now is the high competition and he would therefore like to distinguish from other shops for example by sterilizing his machines.

Théoneste Nyandwi

Théoneste has his saloon since six months and runs his machines with a car battery. He has around 20 customers per day and offers haircuts, phone charging and they can listen to the radio. He charges his battery 50 km away from his community and pays 8,000 RWF a month. He starts working together with his one employee at 6.00 am and finishes at 9.00 pm. When thinking about grid electricity he is very excited and plans to keep his saloon open two more hours per day and hire four more workers. He also dreams about buying a TV and a ventilator as soon as electricity arrives. Currently he cannot use these devices as his battery is too weak and a generator would be too expensive. In his community there are two other saloons, but he anyways thinks that demand is unsatisfied as customers are sometimes being sent home when the batteries are not charged. Being at his shop confirms this: customers are frequently walking in and wait for him to start his electric hair cutter.

Carpenter

The communities' carpenters produce gates, doors, beds, banks and other types of furniture. They all produce for the local population only and have usually around two customers per week. In 60 percent of the surveyed communities there is at least one carpenter and the number of carpenters is slightly higher among connected communities. One of the non-connected interviewed carpenters has a diesel-driven cutting machine, some few carry wood to workshops in a nearby town to use electric machines, but in general most work the wood manually. The non-connected carpenters all say that using a generator for running the electric machines would be much too expensive. Only few of the carpenters in connected communities connect to the grid and purchase an electric wood cutting machine and an electric sander, but most continue working with their manual machines, as they lack financial resources for the purchase. Some use electric lighting. Generally they complain about the lack of capital, machinery and the competition from towns. These competitors seem to offer nicer designs, as they have better machinery.

Carpenter Portraits

Isaac Baziramwabo

Isaac Baziramwabo is working as a carpenter since ten years and got connected to the electric grid one year ago. He produces all kind of furniture and sells for instant his cupboards for 100,000 RWF and his chairs and banks for 6,000 RWF. He used to work his wood manually beforehand and after electrification he purchased an electric cutting machine and a sander. Before, he tried to connect a sander to a generator but says that his generator did not produce sufficient power to run the machine. Isaac names a lack of financial resources as his main bottleneck, as he would like to buy further machinery and build a depot to store his wood and furniture. Since electrification he produces quicker and his quality is better. For these reasons, and also as customers seem to trust him more since he uses electric machinery, he has a higher demand. He estimates to have 30 percent more customers than before, some even coming from another sector. His prices went up a little bit since electrification and he will keep increasing them slowly, as he now has to pay income taxes. He furthermore has to pay back a loan. Even though he only suffers from few and short interruptions of electricity supply, he did experience problems with voltage fluctuations. For example, his cutting machine broke due to fluctuations and the reparation was more expensive than buying a new machine. He therefor took a loan. There are six workers at his carpentry and two of them were hired after electrification. He trains the workers himself and some of them stay with him, while others look for work elsewhere. Isaac is very happy with how electricity supply changed his working life, as he sells more, works longer (on average two hours per day) and produces better products.

Jean de Dieu Habineza

Jean de Dieu is working as a carpenter since 13 years and since two years he is connected to the grid. Electrification did not have the expected impact in his case. He only uses electric lighting and a radio but does not use any electric machinery. He used to have an electric sander which enabled him to do the work of three days in one day. Furthermore, more customer were coming to his shop as his products where of higher quality. The sander, however, was of bad quality and broke after a month. Now he cannot afford new machinery and many of his former clients go to town, where they find different designs. The electric lighting does not affect his working hours on a regular basis (only in cases of emergency he works in the evening hours). Jean de Dieu has four workers, as he always had. He says that nothing changed for his business since electrification, neither did it for the other two carpenters in his community.

Bar

The bars differ in their size and their range of goods. The basic goods are local beer, some sweets and water or some sodas. More developed or bigger bars furthermore offer grilled brochettes and bananas, beignets and are often very proud about offering bottled beer. Most of the non-connected bars do not have any electricity source but only use candles and torches and very few use a car battery, a generator, or biogas for lighting. No one uses electric devices. In connected communities, around half connect to the EWSA grid. Almost all connected bar owners use electricity for lighting, most have a radio, some offer phone charging services and very few have a TV or a fridge.

Of the here surveyed businesses, the bars are the ones which are most connected to customers from outside, such as travellers and traders. This only applies to communities with a connection road. All of the connected bars experienced an increase in customers since electrification, mostly when they offer cold drinks or because people feel more comfortable and safer in bright light than in the light of a candle.

Bar Portraits

Liberée Mutabaruka

Liberée opened her bar six years ago and is connected to the electricity grid for over one year. Since electrification she estimates to have 60 percent more clients, and now welcomes around 50 people per day. She thinks that some of the people are attracted by her bar as she offers cold drinks and as she allows them to charge their mobile phones. She uses electricity for lighting, her fridge and a TV, but stills grills her brochettes and bananas with charcoal. Before electrification she used petrol lamps for lighting and customers left at latest at 8.00 pm, while nowadays they stay until around 9.00 pm and sometimes even until 1.00 am. Her prices did not change, as the tariffs for beers are given by the producers and local beer prices depend on the season (harvest or seedtime). Liberée is very happy about the electricity access and now dreams about painting her bar and installing more tables.

Tailor

Tailor's shops are very frequent in the communities but usually very small scale businesses. The sewing machines are located in a room in the tailor's house together with a sewing machine, threads, scraps of material and some cloth. The tailors mostly fix cloth and rarely produce new pieces. The number of sewers per community varies strongly: in the surveyed communities there is an average of five sewers with a maximum of 25 and a minimum of no shop per community. The number of sewers seems not to increase with electrification. In the non-connected communities, all sewers use a mechanical machine while in the connected communities only nine percent acquired electric machines.

The surveyed tailors are all very different from each other: mostly they work on a small scale and with low demand at home; in some cases the sewers cooperate and share orders and machines and one sewer has been interviewed, who expanded his business and does his own designs. The largest share of tailors in connected communities do not acquire an electric machine due to a lack of financial resources, a lack of skills for running it, or very little demand.

Tailor Portraits

Soleil Hirwa

Soleil is working as a tailor and is around her house (and tailoring room) for either five hours in the morning or five hours in the afternoon. She has very few customers, on many days there are none and on a good day there can be up to five. In her community there are two other tailors. Soleil does not have any energy source or electric device, but only uses her manual sewing machine. She does not consider buying an electric machine as it is too expensive. Also she does not know how to operate it.

Emmanuel Nsabimana

Emmanuel Nsabimana is the only surveyed tailor who was able to record productive use of electricity and has extraordinary success. He is working as a tailor since 2001, owns a solar panel and got connected to the electricity grid in April 2012. For a while he also tried working with a generator but diesel prices were too high. He therefore opened a tailor shop in Butare, one of Rwanda's biggest cities, and started to commute each day from his community to Butare. When electricity came to his community he moved his business back, as transport costs were high (5,000 RWF per day) and commuting very tiring. Today, 75 percent of his customers are coming from the sector he lives in and 25 percent are from further away. Many of these customers are his old clientele from Butare, who order by phone and get their dresses either by courier or directly from Emmanuel. He now uses one manual machine for regular sewing tasks and two electric machines, which have different functions and do different designs. He says since electrification he sells much more, as his prices decreased and also poorer customers can afford his products. Given the high demand, he works from 6.30 am until 9.00 pm and employs one tailor and gets support from his wife. When working with a generator he could not work longer than until 6.00 pm as the generator was too noisy for the neighbours. Emmanuel Nsabimana says he was the first one to bring new designs to his community and created new desires in the people. One problem he still faces are bad quality bulbs; he underlines this by showing a basket full of old bulbs, which do not work anymore. Also he complains about the lack of qualified tailors in his community and the fact that most of them leave to Kigali after having learned from him.

Small shop

The most frequent type of business is a small shop, which sells a range of basic goods. In the surveyed communities there are between two and 50 small shops per community. Usually they offer rice, soap, biscuits, batteries, flour and drinks (soda and liquor). Often the shops consist out of one room which is part of the owner's house. Given that small shops can be found in almost all communities, the shop owners only serve (around 25) customers who come from their own communities per day.

In the survey non-connected communities, few small shop owners possess a car battery or very rarely a solar panel for lighting and a radio, while the remaining ones do not use any electricity source. Among small shops in connected communities around half connect to the grid and the main purpose is electric lighting. Generally there is very little usage of electric machinery. Some few small shops have a radio in their shop and even less have a TV or offer phone charging to their customers. The fact that there are only few small shop owners who actually buy a fridge or a TV, is due to a lack of financial resources and the limited need for such in this business type. By contrast, they tend to leave shops open for longer and feel safer.

Small shop owner Portraits

Charles Nshimiyimana

Charles Nshimiyimana owns a relatively big shop since 2004 and has grid electricity since one year. He has above-average success compared to the other surveyed small shop owners. He has around 150 customers per day and the majority are travellers, who pass by his community. Since electrification he estimates his number of customers to have increased by 30 percent as he now offers cold drinks and milk products. Especially travellers ask for cold water. He tells that before electrification, the only way to get cold drinks was from a man selling cold sodas with a small container full of ice. Charles pays 15,000 RWF on electricity per month and uses the EWSA service for lighting, a TV, a radio, a fridge and car battery charging.

For boiling his eggs he uses firewood and in the case of interruptions of electricity supply (long-term interruptions around three times per month) he uses candles. Charles tells that the centre of his community changed a lot since electrification, that there is more movement and people are outside until late. For this reason he increased his working hours by around two hours per day and hired four new employees since electrification. Charles says he is still in the progress of changing and is waiting to get a loan for buying an electric dough kneading machine.

Annex

Annex 8 (electronic): Household Questionnaire

Annex 9 (electronic): Women questionnaire

Annex 10 (electronic): Community questionnaire

Annex 11 (electronic): Health Centre Questionnaire (semi-structured)

Annex 12 (electronic): Health Centre Questionnaire (calling)

Annex 13 (electronic): School Questionnaire

Annex 14 (electronic): Micro-Enterprise Questionnaire